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PHYSICS FOR THE LIFE SCIENCES

A Student's Question Manual

Created by WebStraw

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Open Access Physics For The Life Sciences

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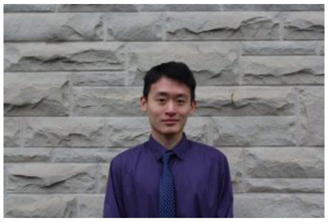

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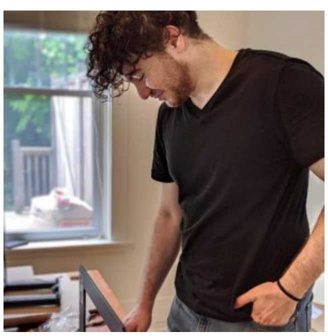

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Preface

Dear Student,

We at WebStraw are delighted to present the first product of our open-access project series!

You are looking at the first open-access physics for the life sciences student question manual. In this resource, our team has created one of the largest question-banks with a series of highly-relevant, authentic questions for science students taking introductory physics. Our selected topics are Kinematics, Forces, Momentum, Rotation, Torque, Fluids, Magnetism, Electricity, Optics, Oscillations, and Waves.

We wanted to create this textbook due to the current difficulty in finding a legally accessible, high-quality question manual anywhere for life sciences physics, instead of randomly interspersed questions throughout the internet. Similar resources at the moment are unfortunately limited by copyright, which limits accessibility and creates socioeconomic barriers to learning. We wanted to change that and this is why we created this resource.

At WebStraw, we believe all students should have equal and free access to educational resources. We want to advocate for a system that puts the interest of the students at an ultimate priority uncoupled with a business oriented mentality. We hope that you enjoy this resource and find it helpful.

Please feel free to redirect yourself to our website to see more of what we are doing and explore the many various projects we are working on.

We wish you the best of luck on your learning journey!

The WebStraw OER Lead Team

PART I

PRACTICE PROBLEMS

1. Kinematics

Numerical Questions

Units and Measurement

A1. You want to swim across Lake Ontario (51.6 km long route!) How fast should you swim if you want to finish your swim in 24 hours? Put in units of m/s and km/h. Note, the fastest time at the moment is around 15 hours!

A2. Dimensional analysis is a critical skill when it comes to solving physics problems. To get you started, here are a couple of variables,

$a = XY^{-1}$

$b = X^{-2}$

$c = Y^{2}$

$D = Y/a$

$E = bY^{3}$

Using the variables above, solve the right-hand side of the following expressions in their simplest form

WebStraw = Ea

Straw = Y/a

Webby = Dba

StrawWeb = A/[DE]

A3. The density of aluminum is 2.7 g/cm^3. Convert the density into kg/m^3.

Position and Displacement

A4. You are walking through a park. After covering a distance of 180 m, you drop your phone, but are not paying attention and don't realize it is gone until walking another 300 m. You walk back 200 m and still can't find your phone so you decide to give up. What are your two displacements from the starting point of your walk and from the point where you dropped your phone? What do both these numbers mean with respect to this situation?

A5. Displacement is essentially the final change in the position of an object after it undergoes a trajectory. If an object goes 2 m to the left, then 3 m to the right, the object would have a displacement of 1 meter to the right, as that is its final position. Practicing your generalization skills, figure out an expression for the displacement of an object that travels 2X to the left, then NX to the right diagonally, with an angle theta to the horizontal (note, theta less than 90 degrees). Say N = 1 and theta = 45° , figure out the total displacement in terms of units X.

A6. On vacation, a tourist decides to go snorkelling (the term comes from the shaped breathing tube called a snorkel) to explore life in the water. After getting into the water, she initially swims 180 m South. After not seeing anything, she faces the west and continues to swim for 450 m. Lastly, she notices a beautiful fish swimming in the direction 30° North of East and decides to follow it for 165 m. How far and in what direction should the diver swim to get back to the starting point in the shortest distance possible?

Velocity

A7. You are a wild life researcher and notice two rare rainbow parrots flying freely in the air. You notice that Parrot 1 is travelling at a speed x m/s, and is Nx m ahead of Parrot 2. However, parrot 2 is travelling at a speed of 2x m/s.

(a) How long will it take Parrot 2 to catch up to Parrot 1?

(b) Suppose that the distance between Parrots 1 and 2 was suddenly doubled, but so did the speed of Parrot 2. Would this affect the time it takes for Parrot 2 to catch up to Parrot 1?

A8. The Autobahn, one of the world's most famous highways, has no speed limits. However, it is recommended you move at 130km/h.

(a) How fast are you moving in m/s?

(b) Suppose it takes you 30 minutes to get to work at this speed. How much time would you save if you drove at 160 km/h?

A9. A projectile is aimed horizontally at a target at a speed of 25 m/s. It reaches the target 0.8 s later at some height, d, below the intended bulls-eye. What is the difference in height between the desired target and the spot where the projectile actually lands?

A10. Drake and Future are riding at 60 mph chasing after the robber of the ASTROWORLD City bank, who has a head start of 6 minutes, but whose vehicle can only go 45 mph. How long does it take for them to catch up to this robber, and how far would they be from ASTROWORLD City when this occurs?

A11. Continental Australia is drifting away from Asia at a rate of 200 mm/year. Assuming the drift rate remains constant, how many years will it take for the two continents to be 50 km further apart than they are now?

A12. At a throwing axe range, you decide to try your luck throwing a couple of axes at the bullseye 5 m from where you stand. You wind up, and release the axe, which travels down the length of the lane in approximately 1.5 seconds. Unfortunately, it seems that your release point was slightly off, and the axe actually bounces off the target, flying backwards towards you for 1 second before hitting the ground 3 m in front of you.

(a) What is the total displacement of the axe?

(b) What is the average velocity of the axe?

(c) What is the total distance the axe travels?

(d) What is the average speed of the axe?

A13. A ship sets sail from the Port of Port Stanley at 8 m/s. Determine the velocity of the ship relative to Earth, taking into account an ocean current of 2.00 m/s in a direction 40° South of West.

A14. You are in a ferris wheel that spins at exactly 1.7 rotations per minute. Passengers are found sitting 20.0 m from the centre of the wheel.

(a) What is the average speed of passengers with reference to the centre of the wheel?

(b) What is the average velocity of passengers over the course of 5 revolutions?

A15. You are in a motorboat that is headed across lake Ontario at 18 m/s. The lake has a current of 4.3 m/s. If you want to get across the lake in the shortest amount of time, what is the direction that you should angle your boat?

A16. Congratulations, you are the first Human to walk on Mars! Melon Tusk is speaking to you all the way from the earth. Calculate the distance from Earth to Mars given that the travel time is 835.2 s and that the message travels at 3.00×10^8 m/s (the speed of light).

A17. A toy car is moving around a circular race-car track of radius meters and completes one lap in $\pi^2/4$ s. What constant speed is the toy car moving at?

A18. The following function describes an object's position with respect to time: $x(t) = -5t^2$ m.

(a) Describe the object's velocity as a function of time.

(b) Is the velocity of this object ever positive?

(c) Determine the velocity of the object at t = 2.0 s.

Acceleration

A19. A car travels 3.0 km as it comes to a stop over a period of 100s.

(a) What is the acceleration of the car?

(b) What is the car's initial and final velocity?

A20. Indiana Jones and Henry Jones Sr. are extremely stressed because they have to cross a river that is 280 m wide and there is a lake full of hungry crocodiles 80 m down the river. They both start swimming at a speed of 5 m/s, but the current pushes them towards the crocodiles at a speed of 4 m/s. How much should they accelerate in the direction directly across the river in order to successfully make it across without running into the crocodiles?

A21. Instead of using your lottery winnings appropriately and saving them, you decide you want to replicate a scene from Batman. Using your custom bat jet, you begin accelerating vertically at 2g (let g = 10 m/s^2 for simplicity here). You forget that you actually get dizzy really easily, so you decide to jump off your jet and test your bat suit landing system. Assume that there is no terminal velocity, calculate the following:

(a) The time it would take you to hit the ground (safely of course) assuming that you jump off horizontally off the jet, and that the jet has been in motion for 40 seconds.

(b) Your final speed as you safely hit the bottom.

(c) The distance between you and the jet at the precise time you hit the ground.

A22. Cheetahs are the fastest land animals in the world. Cheetahs can reach top speeds of 96.6 km/h in three seconds or less of acceleration. However, most cheetahs can only maintain this top speed for approximately 4 seconds before needing to rest.

(a) Calculate the average acceleration for the cheetah, assuming that it needs exactly three seconds to reach its top speed.

(b) Based on this information, would a cheetah be able to run 150 m in 7 seconds from rest? Assume that the cheetah needs exactly 3 seconds to reach its maximum speed.

A23. As a very strong, young alien adult, you get mad and launch your toy truck with a speed of 100,000 m/s into space. Your angry space mom yells at you saying you broke the 1 million km/hr speed limit. With your IQ of 289, you begin your physics calculations. Is your mom right here?

A24. During your driver's licensing test, you're driving peacefully along the road at a speed of 40 km/h and spot a stop sign in the distance. You'd like to come to a stop smoothly to impress your instructor.

(a) If your braking produces an average deceleration of 2.5 m/s, how far from the stop sign should you begin braking?

(b) Suppose that a careless jaywalker starts crossing the street 10 meters away from you. What is the minimum deceleration required to come to a full stop 2 meters away from the jaywalker?

A25. A train can reach a speed of 350km/h in approximately 2 minutes. What is the average acceleration of this train? State your answer in m/s.

A26. As a curling stone travels along the ice, it decelerates at a rate of 1.2 m/s^2 due to friction. After release, the stone stops in 13 seconds. What is the release velocity of this curling stone? Suppose that the surface of the ice is incredibly rough and inconsistent, causing the stone's deceleration to change constantly as the surface of this ice changes, could you still use the equations you resorted to solve the first part of this question?

Challenge question: Come up with a method to estimate the release velocity if the initial deceleration rate was 5 m/s^2 and it gradually, but constantly, slowed down over the period of 13 seconds to 1 m/s^2 . For more information, follow this link: Jerk(physics, Wikipedia)

A27. A motorcycle goes from 25.5 m/s to 45 m/s in the span of X seconds over a distance of 40 meters.

(a) Calculate the average acceleration of this motorcycle (communicate your answer in terms of variable X.

(b) If you need any, what variables do you need to solve for X?

A28. Minor changes in acceleration are needed to ensure that car rides are as comfortable as possible for the passengers inside. Suppose that an Uber driver, interested in getting that 5-star rating, wants to maintain a deceleration of 2.5 m/s or less for their passengers. In this scenario, what is the minimum distance that the driver should start braking at in front of a red light if the car was moving at 40 km//h? How long does it take for the car to stop?

A29. On a nice, sunny day, you find yourself jogging outside along the beach. As you move from sidewalk to the sand, you notice that your speed drops from a smooth 8 km/h down to 5 km/h. If this change occurs over 5.0 seconds, what is the deceleration caused by the sand? How far did you travel as you decelerated?

A30. Flight Sergeant Nicholas Stephen Alkemade once survived a 5500 meter fall without a parachute. During his fall, Alkemade used various tree branches along his path to slow himself down. If Alkemade falls through a 20 meter patch of trees and has an impact velocity (when he hits the ground) of 40 m/s, what is the deceleration caused by the branches?

A31. Two trucks are moving at 40 m/s in opposite directions towards one another. When they are 1 km apart, the brakes are applied. Calculate the acceleration of the trucks assuming they have the same acceleration and just barely avoid a collision.

A32. At a carnival, you are attempting to throw a ball horizontally at a target 11 m away that would result in your friend dropping into a cold water tank. Accounting for the force of gravity, you aim the ball 4.8 m above the target and are able to successfully dunk your friend. How fast was the ball moving towards the dunk tank?

5 Kinematics Equations

A33. You drop a ball from the top of the building. Your cousin is a physicist, and instead of being annoyed, shows you the powers of a physicist. She calculates the time, t, it took the ball to go from the top of the window to the bottom of the window. She then measures the height of the window, h.

(a) How did she calculate how fast the ball was falling when it came to the window?

(b) When you see your cousin again, she tells you that she actually knows exactly how high you were in the building you dropped the ball. How did she find out?

A34. The speed limit in a school zone is typically around 40 km/h. An unsafe driver gets pulled over by you, a police officer, but claims that he had not done anything wrong. The driver admits to accelerating at 1.50 m/s^2 from his initial speed of 20 km/h, down a 500m section of the school zone. Using your expert understanding of physics, did this driver violate the school zone limit at any point of the section?

A35. In the streets of New York, a street racer manages to accelerate his car to his top speed after 5 seconds of acceleration at the start of the race. This speed is maintained for the duration of the 2 km race. Suppose that the racer finishes in 36 seconds. What is the racer's top speed, and what is the racer's acceleration at the start of the race?

A36. A bank robber is escaping from the crime scene, running on foot at a speed of 4.8 m/s to his escape car 200m away. A police officer who just arrived on the scene starts their pursuit 40m behind running at a speed of 6.9 m/s. Will the robber escape, or will the police officer catch up in time?

A37. A baby bird falls out of its nest in a tree. Suppose that an impact velocity of 15 m/s is lethal for this bird.

(a) If the nest is 5 meters above the ground, will the bird survive?

(b) What if the nest is 15 meters above the ground?

(c) Suppose the bird suddenly learns how to flap its wings during the descent, managing to decelerate at 0.5 m/s^2. If the bird starts decelerating when it is 2.5 m above the ground, will it survive the situations in (a) or (b)?

A38. A subway GO train travels at a velocity of 30 m/s, and slows down at a rate of 4 m/s^2 when it enters a subway station, until it reaches a complete stop.

(a) How long will it take for the train to decelerate?

(b) What is the minimum length of the train station? Hint: how far will the train travel in the time it needs to decelerate?

(c) Suppose that the train also accelerates at a rate of 4 m/s^2 when it leaves subway stations. What is the speed of the back-most section of the train when it leaves the station?

A39. As a physics student, you observe a 100 meter dash. Surprisingly, the legendary Usain Bolt shows up and races against the other participants. After finishing the race, Bolt begins slowing down, his velocity 11.5 m/s when he does so.

(a) Assuming no air resistance, create a function for how far Bolt will go if he slows down 1 m/s for X seconds. Create another function calculating his speed after X seconds!

(b) Suppose Bolt wants to run another race. Assuming he slows down at his pace for X seconds (but his speed doesn't reach 0), and he begins accelerating at a rate of 2 m/s^2 up to a maximum speed of 12 m/s, how long would it take him to finish a 100 m dash now? How would that compare to if he had started at 0?

(c) Calculate his final speed.

(d) Are the numbers you got realistic?

A40. To run faster than Oosain Volt, the world record holder for the 100m dash, you must accelerate faster than 3.09 m/s^2.

(a) Assuming you are able to match Mr. Volt's acceleration, how fast are you running 25 m into the race?

(b) Maintaining that constant acceleration throughout the race, what is your 100m sprint time?

A41. A flamingo accelerates from rest to a speed of 15 km/h in a distance of 0.15 km. How quickly did she reach this speed?

A42. A Toronto Am flight headed to Boston takes off at a velocity of 77 km/h at an angle of 42° above the horizon, while accelerating at 12.5 m/s^2 in the same direction. After 14.9 seconds, the plane stops accelerating, and the crazy co-pilot, Frank Abagnale Jr., decides to drop his wedding ring off the plane. How long would it take for the ring to land on the ground, given that the altitude at the moment the ring was dropped was 780 m? (assume no air resistance impacts the direction of the falling wedding ring)

A43. Cruising along the highway, you and the car in front of you are travelling at 30 m/s with 125 m between the two of you. In an attempt to catch up to the car in front of you, you slam the gas pedal. You accelerate forward at a constant rate for 30 seconds, at which point you have caught up.

(a) Convert 30 m/s to km/hr?

(b) Find your acceleration during the 30 seconds you use to catch up to the car ahead of you.

(c) Find your speed when you are caught up with the other car.

A44. An object is thrown into the air and caught 3 s later, at the same initial height.

(a) Determine the maximum height reached by object compared to its initial height?

(b) What is the final speed just before the ball is caught? What is the initial speed the ball was thrown at?

A45. A child thinking she has the same capabilities as Captain Marvel, throws a rock vertically into the air trying to hit the moon. She releases the rock at a velocity of 120 m/s above her head. How long does the child have to get out of the way of the rock before it collides with her if she is 1.3 meters tall?

A46. A police officer identifies a speeding car travelling at a constant 150 km/h on the 407. Once the suspect passes, the police suddenly turn on their engines and accelerate at a rate of 5.0 m/s^2. Seeing that the police are right behind them, the suspect begins accelerating at a measly 1 m/s^2, as they forgot to change their oil before driving recklessly! How long will it take the police car to catch up to the speeding car?

A47. After finishing a rigorous leg day, you begin trying to clean your room. You find an old gameboy that you want to recycle – however, you don't have the energy to go downstairs. You drop your gameboy through the window and it lands right in the recycle bin (assume final velocity of zero). Your brother, a physics major, uses his magical physicist senses to tell you that in its last 2 seconds of travel, the gameboy traversed 1/3rd of the house. Tired of his snarky comments, you immediately calculate the height of your house, h, so that you can have a strong counter to his own useless facts. What is the height of the house?

A48. You are trying to overtake a slow truck on the highway. It is going at 70 km/h (unbelievable!) and you are going at a speed of 100 km/h. You accelerate to 110 km/h over a period of 4 seconds. The truck is 12 m long and your car is 3 meters long.

(a) Find how long it will take you to pass the truck.

(b) Find how far you have traveled in that time.

A49. You must cross a river in your canoe to reach your campsite. You are able to row at a speedy 2.5 miles per hour in still water. Unfortunately there is a current moving at 1.5 miles per hour. The river itself is 15 m from bank to bank.

(a) Heading perpendicular to the river bank where you begin canoeing, how far downstream do you complete your trip?

(b) You realize that in order to avoid arriving downstream of your campsite, you must row at an angle. What is the magnitude of your velocity upstream?

(c) At your maximum rowing speed of 2.5 miles per hour, how time does it take for you to reach the other side?

A50. You are using a water gun that shoots out water through a long nozzle.

a) If the chamber can accelerate the water at a rate of 3 m/s^2 for a time period of 1.5 s, calculate the velocity that the water will exit with if the end part of the nozzle was to also slow down the water for 10 ms with a deceleration of 1.5 m/s^2.

A51. At the top of a slope, a cart on a water roller coaster begins to descend.

(a) If the track it descends at accelerates it downwards at a constant rate of 6.6 m/s^2, how long would it take to reach the coaster's peak velocity of 65 km/h?

(b) After this descent, the cart travels 30 m in a section of water before coming to a full stop. What is the deceleration of this water section?

(c) How long does it take to stop?

(d) Conceptual: Is the deceleration of the water zone related to the mass of the cart? Would the deceleration be the same if the mass of the cart (including the passengers) doubled?

A52. As you enter the highway, you decide to accelerate your car from rest by a rate of 4.5 m/s^2 for 9 seconds. Are these parameters appropriate if the track you are merging from is 30 meters long to get you up to speed to the 100kmh limit?

A53. Calculate the time that a sequence of motions a puck takes as follows: Position = 0, V_I = 2 m/s and V_F= 4 m/s. The distance over which the hockey player accelerated/decelerated is a total of 5 m. In the first 2 m the player brings the ball to stop (from 2 m/s) at a rate of 1 m/s^2 to avoid the player in front of him. As he approaches the goal, over a distance of 3 m he brings the ball back up to the final speed V_F = 4 m/s.

A54. On July 1st (Canada Day), a group of friends light up some fireworks to celebrate in a nearby park.

(a) If these fireworks manage to accelerate at 8.8 m/s^2 until they reach a height of 50 m and detonate, how long do the fireworks accelerate for?

(b) Right before the firework detonates, what is its velocity?

(c) Suppose that one of these fireworks fails to detonate, and falls back down instead. What is the total amount of time it spends in the air?

A55. A duck is chilling peacefully when it suddenly notices a hungry crocodile and starts running away. The duck accelerates (in the opposite direction) at 0.5 m/s^2 until it reaches the minimum takeoff velocity of 5.0 m/s.

(a) Calculate the distance the duck travels before taking off. Assume it starts from rest.

(b) Suppose that the crocodile can travel at a constant speed of 2 m/s. Will the crocodile catch the duck?

A56. Suppose that you are a flag football player with the ball in your hands, and you're almost at the end zone. You decide to speed up to secure the touchdown. If your initial velocity is 7.8 m/s, and accelerate at 0.2 m/s^2 over 4 seconds before reaching your limit.

(a) What is your final velocity?

(b) If you maintain this top speed, how much time would you save (compared to if you chose not to accelerate) if you were initially 70 m from the endzone?

(c) Suppose that a defensive player on the other team accelerates at 0.3 m/s^2 over 5 seconds from an initial speed of 7.0 m/s. If this player is 10 m behind you initially, will they catch you?

Projectile Motion

A57. A bouncy ball is hit at an angle of 20° at some initial velocity. The ball follows a parabolic path and returns to the ground after it has covered a horizontal distance of 640 m. What was the initial velocity of the golf ball?

A58. A person is launched from the ground at some angle by a catapult. The person reaches a maximum height of 45 m and travels 250 m horizontally. Find the initial velocity of this person.

A59. A ball is released 30° above the horizontal at 102 m/s. What is its acceleration the moment after it is released?

A60. When Croatian track and field athlete Sara Kolak decides to practice her javelin-tossing skills, she realizes that there is an 8.7 m high wall 13.2 m away from her. If she throws the javelin at a speed of 80 m/s directed at the wall, what is the angle that the javelin should be thrown at, so that it barely clears the wall? Note: There is a wind blowing directly against the trajectory of the javelin with an acceleration of 9 m/s^2.

A61. A basketball player that is 1.75 m tall shoots a basketball at an angle of 60° above the horizontal above his head. With what initial speed must the basketball have to be shot if it is to go through the basket located 6.5 m away and 3.5m above the ground.

A62. A boy can throw a football at a maximum horizontal distance of 30 m when launched at an angle of 45°. How high up will the ball go if thrown vertically at the same initial speed.

A63. A baseball player hits a difficult speedball at an angle of 45° causing it to travel at a constant 40 m/s. Suppose the “out of the park” target is 150 m away, and has a fence 15 m tall. Does she make the shot? Where exactly will the ball land?

A64. A skier is sent into the air at an angle of 50° above the horizontal. Determine the skier's initial speed, if he lands 24 m below and 40 m away from his initial takeoff point.

A65. A soccer player kicks a soccer ball at a speed of 10 m/s and the ball just misses the net, flying right above it. It is 2.5 m high and located 50 m from the kicker. Find the angle at which the ball is kicked.

A66. You throw a water balloon horizontally with initial, constant speed of 15m/s. Assume no air resistance or any special lift effects.

(a) How long will it take the water balloon to drench your water balloon opponents, who are X meters away? [Note, this is a special type of futuristic balloon, so it releases the water once it is it is above its target]

(b) If you are 5 meters above your opponent when you launch your balloon, calculate the height of the balloon as it activates its futuristic release mechanism.

(c) Assume x = 20 m, find the horizontal and vertical components of the balloon's velocity when it activates its mechanism.

A67. A child is preparing for a water gun fight and is wondering how quickly their newly-purchased water gun can fire. They decide to shoot the gun upwards at a point 1.2 m above the ground. Holding a timer, the child notices that it takes about 4 s before the water splashes on the ground. The child asks you, with this information, if you could calculate how the speed of the water as it leaves the water gun.

A68. Suppose that you're interested in calculating the launch angle for a projectile that would produce the highest projectile height/range. For initial angles between 0 and 90 degrees, which angle(s) produce the maximum height? Which angle produces the maximum horizontal range? Which angle would produce the highest average of both height and range?

A69. You throw a projectile in a parabolic trajectory. Assuming no air resistance, is there any point at which acceleration is parallel to velocity? Is the acceleration ever perpendicular to velocity?

A70. A ball is fired horizontally at 5 m/s from a tower. What is its speed 1 second after being thrown? Assume no air resistance.

A71. A basketball player throws a chest pass horizontally at some speed. Unfortunately, none of his teammates were there to receive the pass and the ball drops to the ground in t seconds. What is the direction of acceleration of the ball at ½ t?

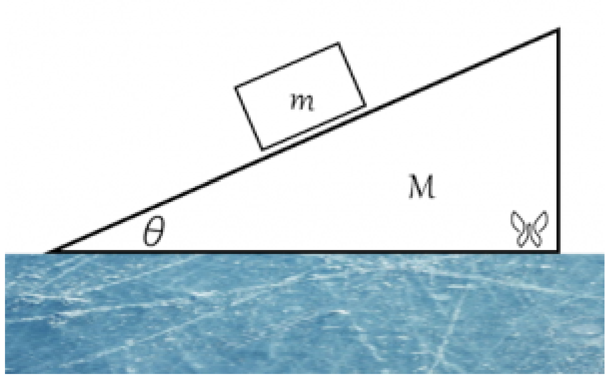
A72. A rock is thrown horizontally from the top of a cliff that is 80 m tall. The rock strikes the ground at a speed of 80 m/s. What angle does it strike the ground at?

A73. Draw a sketch of a graph that shows the vertical component of velocity, v, versus time, t, for an object fired out of a cannon at an angle of 45° above the horizontal. Only include the velocity up until the object reaches its maximum height.

2. Forces

Conceptual Questions

B1. When m slides down the surface of M (with friction), does M on the ice (frictionless) slide to the right or the left? Which force is driving the movement of M?



B2. A Canadian rock climber is suspended by a rope as they climb the wall of an indoor course. What are the forces acting on the rock climber? (Hint: What force acts on the rock climber's shoe as they scale the wall?

B3. Your annoying cousin from Milton, who is just turning 5, refuses your gift of a toy cart to her. "No matter what happens, if I pull on it, it will pull back on me with the same force, so it won't move. I hate you!" Her mother is baffled, but as a physicist, you explain to her the following about what actually happens:

B4. From **B3**, what would happen if you were in space? How would the interaction be different?

B5. A high-jump athlete is able to apply a force X on the ground right before their take-off. If this athlete was able to apply a force of 2X on the ground before the take-off, would they be a more, or less successful athlete? Why?

B6. A bullet is fired from a gun with an initial force of 5000 N, and is now flying through the air horizontally at 333 m/s. What are the forces acting on the bullet in the middle of its trajectory? Assume air resistance is not negligible.

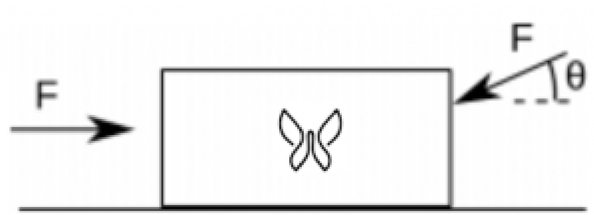
B7. A green ball swings back and forth on a string dangling from the roof. F_g is the magnitude of the force of gravity on the ball. T is the magnitude of the tension force on the ball (through the string). At the instant the ball and the string are vertically aligned:

(a) $F_g > T$

(b) $F_g < T$

(c) $F_g = T$

B8. In the diagram below, calculate the minimum force (F_2) needed to be applied to a box with mass M at an angle 30°, and coefficient of kinetic friction μk in order for it to resist a force pushing to the right of 10 N. Give the answer in terms of mass and F_2.



Drawing Free Body Diagrams

B9. Identify and draw a free-body diagram for a paper airplane gliding through the air. Consider the force of air-resistance in your diagram.

B10. Identify and draw a free-body diagram for a bowling ball rolling down a hill.

B11. Draw a free-body diagram for the following scenarios:

(a) A baseball at the exact moment it's hit by a bat.

(b) A child sliding across a non-frictionless rink of ice.

(c) A car driving uphill a steep slope.

(d) A rock climber suspended in the air by a rope.

(e) A teenager leaning against a wall.

B12. You gently push a child on a sled across a frictionless rink of ice. The child, on top of the sled, accelerate across the ice at 2.0 m/s^2. Consider what would happen to the acceleration if...

(a) The rink was non-frictionless?

(b) Your initial push was six times stronger?

(c) The mass of the child and sled was tripled?

(d) The mass of the child and sled was tripled, and your initial push was six times stronger?

B13. Suppose that you're playing baseball, and you hit the ball, causing it to accelerate at 30 m/s^2. Consider what would happen if…

(a) You hit the ball twice as hard?

(b) You hit the ball half as hard?

(c) You hit the ball twice as hard, but the mass of the ball is halved?

(d) You hit the ball twice as hard, but the mass of the ball is also doubled?

Numerical Questions:

GRAVITY, NORMAL FORCE, FRICTION AND TENSION

Elevator Questions

B14. Imagine two situations: the first, where you're in an elevator moving upwards, and the second, where you're in an elevator moving downwards. Draw a freebody diagram for the elevator in these two situations. What is different about the forces acting on the elevator in the two situations?

B15. You are heading back from your 8 AM class which is on the 12th floor of the engineering building. Rather than wasting your energy by taking the stairs you decide to take the elevator, which happens to have a body scale. At the moment that the elevator is at the 3rd floor, you step on the scale and notice that it only reads 70% of your original weight. Determine the elevator's acceleration when you reach the 3rd floor.

B16. Two children, with mass M kg and M+2 kg, respectively, stand in an elevator.

(a) Draw a free-body diagram for this scenario.

(b) Write an equation to describe the combined normal force exerted on these children, when the elevator is at rest.

(c) Describe another scenario which the equation you made in b) would apply.

(d) Now suppose that the elevator accelerates upwards at 5 $m/s^{2.}$ Would you expect the normal force to be greater or lesser than the normal force in c)? If it is different, write an expression for the normal force.

(e) What is the normal force exerted on the children if the elevator instead, moves upwards, at a speed of 2 m/s^2?

B17. Zeyad carries a 60 kg rock in an elevator as a spiteful gift for his boss. He weighs 112 kg. Draw the free body diagram of both Zeyad and the rock if:

(a) The elevator is stationary

(b) The elevator is falling down at 2 m/s^2.

(c) The elevator is moving up at 2 m/s^2.

(d) For each case, calculate the magnitude of the normal force exerted on the Zeyad by the floor.

B18. A physics-themed hotel has installed electronic scales in their elevators. One guest, a 60 kg man, decides to stand on it during his elevator ride. As he passes the second floor, the elevator is uniformly accelerating upwards at 3 m/s^2. Once he reaches the fifth floor, he collects a 20 kg package and takes the elevator back down, holding the package while standing on the scale. When he reaches the second floor, the elevator is uniformly accelerating downwards at 3 $m/s^{2.}$ In which case is the apparent weight read by the scale greater?

B19. The maximum occupancy of a given elevator is 20 persons. Suppose, 16 people are in an elevator whose mass is 440 kg and can hold a maximum force of 25,500 N. If the average mass of each passenger 60 kg, how fast can the elevator successfully accelerate to the 8th floor of a building?

NEWTON'S FIRST LAW OF MOTION (F_{NET} = 0)

B20. If a 0.2 kg puck slides across a frictionless surface at a constant speed, how much net force would it be experiencing in the horizontal direction?

(a) 0 N

(b) 1.96 N

(c) 3.92 N

(d) 5.88 N

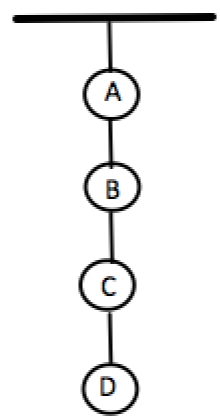
(e) 7.84 N

B21. Four spheres are connected by thin threads to make a Christmas ornament to go on a tree. Sphere A weighs 4 kg, sphere B weighs 3.5 kg, sphere C weighs 5 kg and sphered D weighs 6.5 kg.

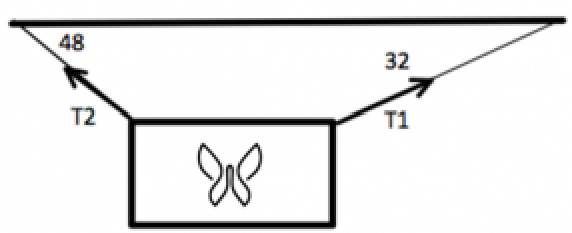
(a) Which thread will have the greatest tension? Which thread will have the least tension?

(b) Draw a FBD for sphere D and determine the tension in the lowest thread.

(c) Determine the tension in the highest thread (above sphere A).



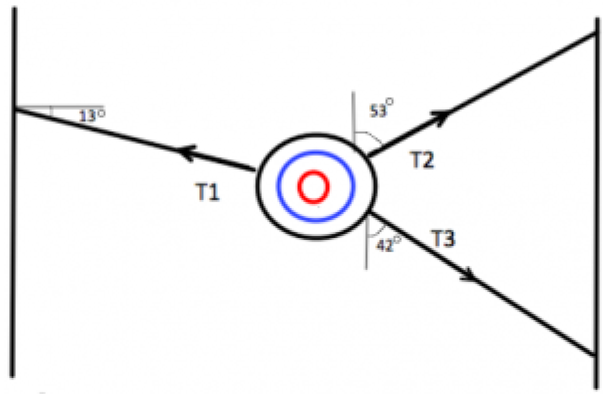
B22. A rectangular sign weighing 13 kg is suspended by 2 wires at either corner. One string makes an angle of 32° with the ceiling and the other makes an angle of 48° with the ceiling. Determine the magnitude of the tension in both of the wires.



B23. A 20.3 kg archery target is suspended by 3 ropes (T1, T2, T3 represent the respective forces of tension in each rope). The force of tension in rope 3 is 46 N as shown below

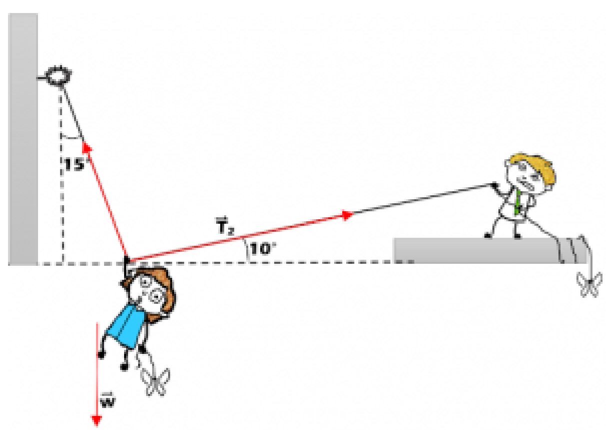
(a) Calculate the force of tension in rope 1.

(a) Calculate the force of tension in rope 2



B24. Three forces act on an object, which is in equilibrium. Suppose that forces F_1, and F_2, act downwards at 50 N, and rightwards at 35 N, respectively. What is the magnitude and direction of the third force, F_3?

B25. A woman (59 kg) holds on to a rope that is being held by her friend off to the side so that she remains motionless. Given the angles shown in the diagram below, what is the tension in each section of the rope.



B26. A toddler is playing with some toys at her preschool. One of the toys is a series of two blocks that are attached to either ends of a rope of negligible mass. The first block has a mass of 3 kg and the second block has a mass of 5 kg. When the child pulls the toy with a force of 15 N, the toy moves at a constant velocity.

(a) What is the coefficient of kinetic friction between the blocks and the surface?

(b) What is the tension in the rope attaching the two blocks?

B27. In an act of sheer brilliance, you try to lower a 50 kg piano using a pulley system you made on your balcony. How hard must you pull on the horizontal end of the rope to keep the piano moving at a constant rate?

NEWTON'S SECOND LAW OF MOTION (F = ma)

B28. At the start of the race, a Formula One driver accelerates her car from 0 to 100 km/h in 2.20 seconds. In order to accelerate at this pace, what is the force exerted by the car's tire on the raceway?

B29. A reckless driver brakes his car (m = 1400 kg) at the last second to avoid running a red light. If the car is initially moving at 70 km/h and stops in 3.00 seconds, what is the force of friction experienced by the car?

B30. Which object has the greatest inertia?

(a) 1000 kg elephant travelling at 10 m/s.

(b) 100 kg drone accelerating at 10 m/s^2.

(c) 10 kg dog travelling at 15 m/s.

(d) 1 kg hamster accelerating at 20 m/s^2.

(e) 0.1 kg fly travelling at 25 m/s.

B31. Imagine an acceleration-versus-force graph for two different objects being pulled upwards by a rope. Suppose that on the acceleration-versus-force graph, one of these objects produces a much steeper slope than the other. From this observation, can you tell which object is heavier than the other?

B32. A sprinter begins accelerating by exerting a force of 590N on the track. If the sprinter has a mass of 68.0 kg and is pushing on the ground for 0.600 s, what is her initial push-off speed and the distance she travels?

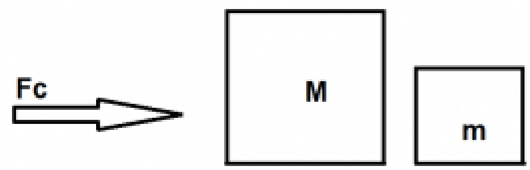
B33. A bullet (15 g) strikes a large block at a speed of 185 m/s. The bullet moves a distance of 16.0 cm in the block. Determine the force (magnitude and direction) that is responsible for stopping the bullet

B34. Two boxes are sitting on a surface that has a coefficient of kinetic friction that is equal to 0.001. As depicted in the figure below, a force F_C is applied to the larger box M that then comes in contact with the smaller mass m. If you know that M's acceleration is 2.5x less than small m's:

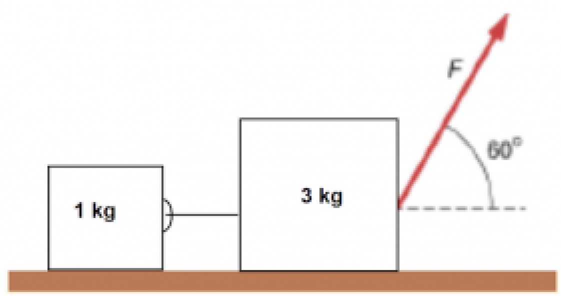
(a) Calculate the acceleration of both m and M.

(b) Calculate the forces exerted by M on m and m on M.

(c) Draw a free body diagram of mass m.



B35. A small block (m = 2.0 kg) is attached to a larger block twice its size. At an angle of 50 degrees from the horizontal, a force is applied to the larger block resulting in an acceleration of the system of 1.8 m/s^2. If the coefficient of kinetic friction between the ground and blocks is 0.30, what is the magnitude of the force applied?



B36. Two forces acting on a box produce a **net** acceleration of 8 m/s^2. Calculate the mass of the object if you know that force A is 20N in magnitude and acts horizontally and force B is 45N but 35° below horizontal in the opposite direction of force A.

B37. You are out on the lake tubing with your family. The boat starts to accelerate and as you hit a wave, the tube and passengers fly into the air, making an angle of θ with the horizontal. If the mass of the passengers and the tube combined is 150 kg, and the tension in the string connecting you to the boat is 2800 N, find θ and the boat's acceleration.

B38. As a super glue fanatic, you stick two objects together, one with a mass of 5 kg and one with a mass of 15 kg, using a glue that is supposed to be able to provide up to 25 N of force before it fails. Suppose you then pull on the 15 kg block with a 50 N force.

(a) Calculate the acceleration of the system.

(b) What is the force exerted on the 5 kg block, and where does it come from? Does the glue hold?

(c) Now suppose you pull on the 5 kg block instead with the same force. Does the glue hold this time?

B39. A 10 kg wagon carrying a 5 kg mass is being dragged along a frictionless surface.

(a) Calculate the force of the mass on the wagon.

(b) At what speed should you pull the sled, if you want the mass to remain stationary and the coefficient of static friction between the wagon and mass is 0.45?

(c) If the wagon is being pulled with a force of 50 N, what would the acceleration of the wagon and mass be, if the coefficient of kinetic friction is 0.35?

B40. A force of 18.0 N is applied parallel to a box of mass 6.0 kg. A second force is applied in addition, resulting in an acceleration in the positive x-direction of 3.0 m/s^2. What is the direction and magnitude of the additional force?

B41. Two objects are stuck to one another with glue. One object has a mass of 15 kg and the other with a mass of 6 kg. The glue can provide up to 20N of support.

(a) What is the maximum force with which you can pull the 15 kg mass before the two objects become unstuck to one another?

(b) At the maximum force found in (a), what is the acceleration of the whole system?

(c) What is the maximum force with which you can pull the 6 kg mass before the two objects become unstuck to one another?

(d) At the maximum force found in (b), what is the acceleration of the whole system?

B42. A bullet of mass 8.0 g travelling at some initial speed hits a target and moves 12 cm through the target in 0.90 s before coming to a stop. Find the initial speed of the bullet and the force that stops the bullet.

B43. An object, initially at rest, begins to move when a constant force is applied. In the first 5 seconds, this object moved 10 m. Assuming negligible air resistance and friction, predict how far this object will move from 0 to 10 seconds.

B44. Suppose that you threw a tennis-ball with mass **m** at a basketball with a mass **M**. You notice that this caused the basketball to accelerate with an acceleration **a**. Suppose you threw two tennis balls at the same time at a bowling ball (mass = **2M).** Would the bowling ball accelerate? By how much? State your answer in terms of **a** (the original basketball's acceleration).

B45. A large buoy sits in an ocean and is pulled by 2 boats. Both boats pull at the buoy with the same force of 2000 N, but boat 1 pulls at the buoy at an angle of 13° from the horizontal while boat 2 pulls at the buoy at an angle of 10° from the horizontal. What is the force of the resultant pull? If the large buoy weighs 50 kg, what is its acceleration?

Inclined Plane

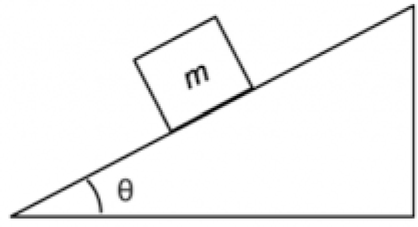
B46. As shown, a block of mass m is sliding down a plane that is inclined at an angle θ. The plane's coefficient of kinetic friction is μk.

(a) Draw a simple free body diagram demonstrating all the forces acting on the block.

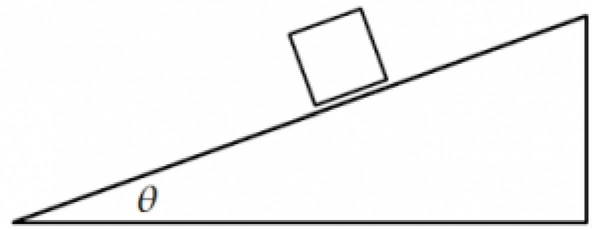
(b) Write an expression representing the net force acting on the block as it slides down the ramp.

(c) An individual walks into the room containing the system shown. They are mortified by the thought of a block sliding down a ramp, and decide to stop it from doing so. However, they need to quickly formulate an equation in their head to determine how much force needs to be exerted to achieve their objective. What is this equation?

(d) Suppose the individual in part c) fails to stop the box from reaching the bottom. Resentfully, he places another box on the inclined plane, with mass 2.7 m. Show how this change will affect how the new box will move compared to the old one, in the form of a mathematical equation and a written statement.



B47. A 10 kg block starts travelling down a 25 m ramp at a speed of 7 m/s. If the ramp's incline angle is 30°, and the coefficient of friction between the block and the surface is 0.15, how long does the block travel before coming to a rest?



B48. A force, F_1, can be used to move a block up and inclined plane at a constant velocity. Another force, F_2, can be used to move the block down the same incline. Find the coefficient of kinetic friction between the box and the inclined plane given that you know $F_1 = 10F_2$ and the forces are applied as shown in the figure. The angle, alpha, between the incline and the plane is 15 degrees.

B49. Given the information above in **B48**, can you find the coefficient of static friction? If so, do the math. If not, what other variables are needed to find it?

B50. A frictionless ramp makes a 40-degree angle with the horizontal and a 3.5 kg block is placed on the ramp. If the block is to move down the ramp with constant velocity, what force is applied parallel to the ramp?

B51. A 777 g box slides up a 20-degree incline. If the coefficient of static friction between the box and the ramp is 0.25 and the coefficient of kinetic friction is 0.20, how far up the ramp will the box slide if it has an initial velocity of 18 m/s?

B52. A 22 kg box is sitting on a ramp inclined at 36 degrees. The coefficients of static and kinetic friction between the box and ramp are 0.78 and 0.65 respectively.

(a) Determine the smallest force that can be applied perpendicularly (on top of the crate) so that the crate remains at rest.

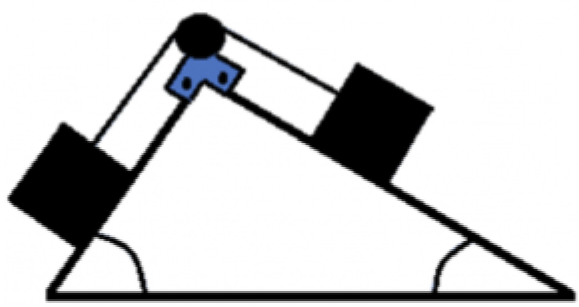
(b) Determine the largest force that can be applied upward (parallel to the ramp) if the crate must remain at rest.

B53. A block is sitting stationary on a 40-degree inclined plane. The coefficient of static friction is 0.35. What is the mass of the block?

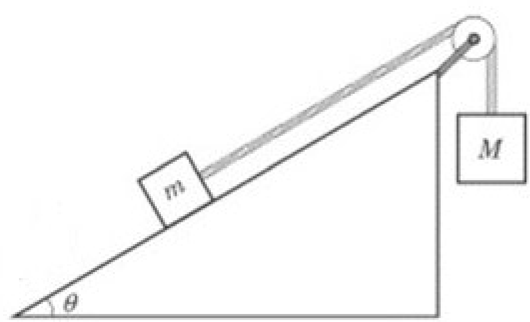
B54. A frictionless ramp with an angle of 35 to the horizontal has a spring resting at the top. A box of mass 15.0 kg is resting on the ramp and stretches the spring 5.0 cm when attached. Determine the spring constant of this stretched spring.

Pulley Questions

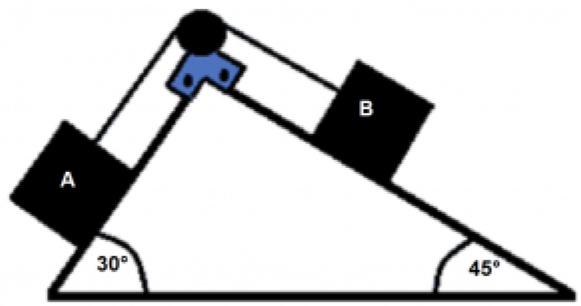
B55. The two blocks shown below have equal masses. Assume that the coefficients of static friction is 0.35, and the coefficient of kinetic friction 0.30 for both blocks. If the system is given an initial speed of v, to the left, how far will it move before coming to rest? Express your answer in terms of v.



B56. If m = 20 kg, M = 13 kg, θ= 25°, μs=0.25, μk = 0.20, find the acceleration of the blocks when they are released.



B57. Block A (15kg) and Block B (10kg) are held stationary on opposite sides of an inclined plane, as shown below. What is the acceleration of the blocks when they are released from rest? Assume no friction.

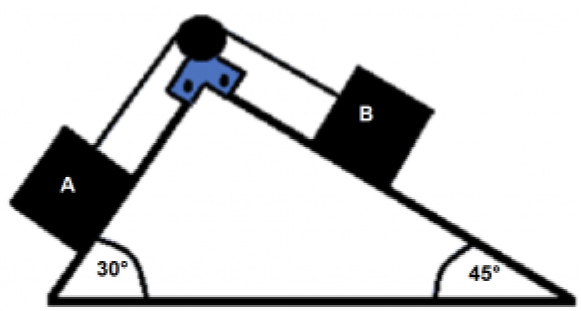


B58. Refer to **B57** for this question. Suppose that the angle below block B can be changed

(a) What angle must it be such that the blocks remain stationary when they are released?

(b) Find the tension in the string in the above situation.

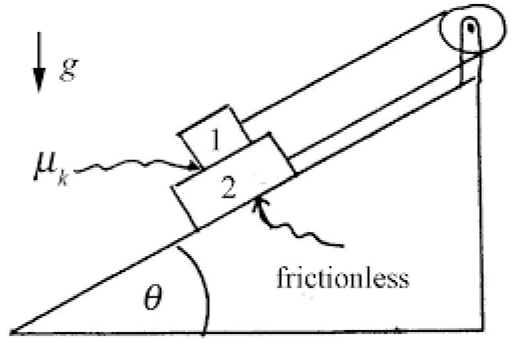
B59. Masses A and B are connected as shown in a ramp/pulley system. Block A has a mass of 10 kg, while block B has a mass of 15 kg. If the coefficient of static friction is 0.6 and kinetic friction is 0.42, what is the acceleration of mass A?



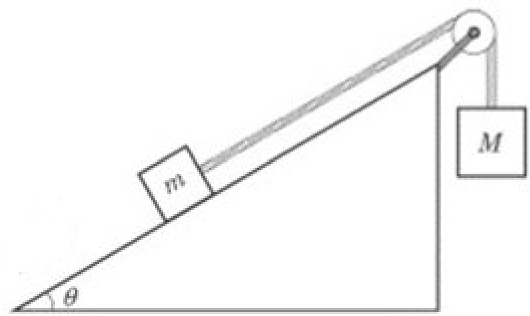
B60. Mass 1 and Mass 2 are connected, as shown in the diagram below. When the blocks are released from rest, mass 2 slides down a frictionless ramp, while mass 1 slides up on mass 2.

(a) Draw a FBD for each block.

(b) Assume the following: m_1 = 5 kg, m_2 = 20 kg and block 2 has μk = 0.15 and μs=0.25. Assume the angle between the ramp and the horizontal is 20°. Find the acceleration of the blocks when they are released.



B61. Masses 1 and 2 are connected as shown in a ramp/pulley system on planet 3TTE (g = 8.3). The left block (m_1) has a weight of 249 N, while the right block (m_2) has a weight of 166 N. Angle theta is 60 degrees. If the coefficient of static friction is 0.55 and kinetic friction is 0.45, what is the acceleration of the system?

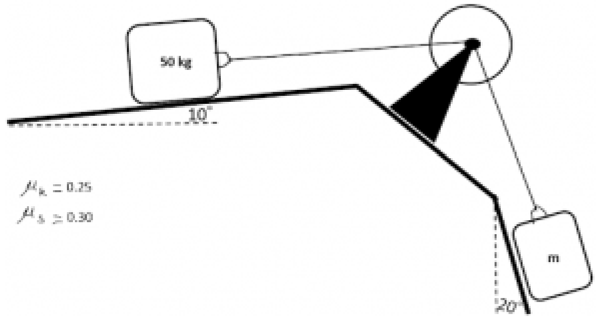


B62. A mass of 3 kg sits on an inclined plane, making an angle of 20° with the horizontal. A rope is attached to mass and placed over a pulley at the top of the incline, with a 1 kg mass attached to the other end of the rope. If μk = 0.33, what is the acceleration of the system?

B63. A 6 kg box moves down a 30° inclined plane at an acceleration of 1.75 m/s^2. The box is attached to another box by a pulley, with the second box hanging off the pulley vertically. Determine the mass of the second block if the coefficient of kinetic friction is 0.22.

B64. Two hanging masses (m1 = 2 kg, and m2= 6 kg) are held at the opposite ends of a rope attached to a pulley. What is the acceleration of each of the boxes? What is the tension in the rope holding the masses together?

B65. What range of mass m, will keep the 50 kg block in the system in equilibrium? Assume negligible friction in the pulleys.



B66. A 2 kg mass is sitting on a stationary table. From both sides of the mass, ropes are hung over pulleys at each end of the table. A 3 kg mass is attached to the rope on the left and a 5 kg mass is attached to the rope on the right. What is the acceleration of the system?

Forces of Circular Motion

B67. After a rainy day, cars travelling along a banked curve travel at a maximum speed of 55 km/h to avoid veering off the road. If the angle of the curve is 9 degrees with respect to the horizontal and the turn has a diameter of 600 m, determine the minimum coefficient of friction between the road and the rubber tires.

B68. A curve has a radius of 40 m and a banking angle of 10°. What speed is required for there to be no friction between the tires of the car and the road?

B69. One of the most famous demonstrations of centripetal force is the swinging bucket or glass of water. In this demonstration, a glass or bucket of water, sometimes held on a tray, is swung in vertical circles, but no water is spilt.

(a) What is centripetal force?

(b)If the vertical circle has a radius of 1 m, calculate the minimum speed required to prevent any water from spilling.

(c) Based on your answer in b), calculate the rotational frequency.

B70. A turn with a radius of 75 m is being designed for a highway with a speed limit of 50 km/h, what should be the angle of the banked curve?

B71. You are driving on a highway with a radius of 75 m and 18° bank angle, and a coefficient of kinetic friction of 0.30. What is the maximum speed that you can drive without slipping?

Additional Challenge Problems

B72. A truck is travelling on the highway at 110 km/h when a large package of mass 45.0 kg falls off of the back. The package slides 90 m once it is on the road before coming to a stop. What is the coefficient of kinetic friction between the package and the road?

B73. Suppose that an important object is hanging off a cliff attached to a rope. Using your current strength, you are able to pull up the object by pulling the rope horizontally, causing it to accelerate upwards (towards you) at an acceleration of a.

(a) Suppose that another friend, with similar strength as you, helped you pull on the rope. What is the acceleration of the object in terms of a?

(b) Suppose that this object doubles in mass. If you're the only one pulling on it, what is the acceleration of the object in terms of a?

B74. A rope of length L and mass M is held from the ceiling. Find an expression for the tension in the rope at position Y. Hint: think of linear density.

B75. Assume you are in a car going down a hill inclined at an angle θ with respect to horizontal. Because you suddenly wanted to test your physics skills, you slam down the breaks, causing your wife to get very mad. She says she will only forgive you if you can solve the following question. Calculate the car's maximum possible deceleration in terms of g, θ, and the coefficient of friction.

B76. You have a wheel that you are trying to get onto the side of a curb. The wheel has height R above the ground, and an overall radius r. The curb, which is a flat surface, has a height h above the ground.

(a) What force would you need to apply to the center to get the wheel on top of the curb?

(b) What force would you need to apply at the top to get the wheel on top of the curb?

(c) Explain the difference in forces between a and b.

B77. Two blocks below are connected using a string, and sit on a plane with an incline θ. Assume θ is large enough such that they will slide. Each block has a different kinetic friction between that block and the plane. Let μk_1 be the kinetic friction for block 1, and μk_2 the kinetic friction for block 2. Calculate the acceleration of the system when

(a) $\mu k_1 > \mu k_2$

(b) $\mu k_2 > \mu k_1$

(c) $\mu k_2 = \mu k_1$

B78. Suppose a rope is tied rather tightly between two trees that are 30 m apart. You grab the middle of the rope and pull on it perpendicular to the line between the trees with as much force as you can. Assume this force is 1000 N, and the point where you are pulling on the rope is h =1 m from the line joining the trees. What is the magnitude of the force tending to pull the trees together?

B79. Two girls with masses of 45 kg and 55 kg, respectively, are holding on to opposite ends of a 25 m tug-of-war rope and standing on a frictionless horizontal surface. They pull themselves along the rope towards each other. What distance will the girl of mass 45 kg have travelled when they meet?

3. Momentum

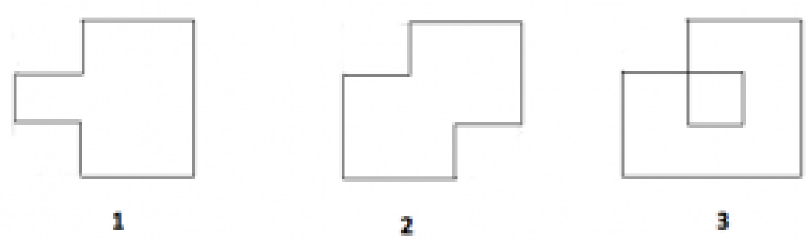
Conceptual questions

M1. A moving body makes a completely inelastic collision with a stationary body of equal mass at rest. What percentage of the kinetic energy is lost?

M2. A Canadian roller-skater of mass M, pushes off against a stationary block of mass m, horizontally. Assuming the floor is virtually frictionless and the skater moves with a velocity v, what is the velocity of the block relative to the ground?

M3. Two babies are coming closer to each other and bump into one another. They both are sent off travelling as one unit at a velocity of v/4. What is the ratio of their masses?

M4. Rank the 3 shapes in the figure below based on how far to the right their centre of mass is from largest to smallest in terms of the x-coordinate of their centre of mass.



M5. A marble with mass M is rolling with velocity V when it collides head on with a second marble of mass 3 m initially at rest. If the collision is elastic, what are the speeds of the marbles after the collision?

M6. You are really bored, so out of curiosity, you shoot a bullet mass m into the center of a brick from below (the brick is on your house roof). Assume you shot the bullet vertically upwards. When your bullet hits the brick, it is embedded in it, and the brick rises to a height H above the roof.

(a) What was the speed of the bullet just as it hit the brick?

(b) Was any kinetic energy lost? Why or why not? Describe it in words.

(c) If kinetic energy was lost, calculate the ratio of kinetic energy of the bullet before collision, and the bullet brick system after collision.

M7. Two objects with mass m are moving in opposite directions with the same speed. In this system, kinetic energy (K) and momentum (p) are described by

(a) $K = 0, p = 0$

(b) $K > 0, p = 0$

(c) $K > 0, p > 0$

(d) $K < 0, p = 0$

(e) $K > 0, p < 0$

M8. A very heavy bowling ball is travelling at 8 m/s and collides elastically with a very light marble which is initially at rest. If the lighter object begins travelling in the same direction as the heavy object, what is the speed of the lighter object after the collision?

M9. Assume that you are witnessing a car crash. A massive bulldozer with mass M collides with a small Fiat 500L (a small car with mass m). The bulldozer seems to be fine,/ but the Fiat is completely destroyed. Discuss whether

(a) This collision was elastic or inelastic. Why? What would the opposite collision look like?

(b) Did the car give the same impulse as the truck gave it, more impulse, or less impulse? Explain your reasoning.

Calculation Questions (sorted by difficulty)

Easy

M10. A 96 kg super heavy-weight wrestler decides to charge in (5 m/s to the right) at another super heavy-weight wrestler (m = 102 kg) who is moving at 2.5 m/s in the opposite direction. As they jostle, you notice that for a short duration of time they are joint together and travel in one direction.

(a) Calculate their joint velocity when they are stuck together.

(b) The 102 kg wrestler does not like to get defeated so he manages to push the 96 kg wrestler in such a way that he travels at 3 m/s to the left. Calculate their final velocities.

M11. A 20 kg curling stone collides with a 4.5 kg bowling ball initially at rest. This causes the two objects to move away apart at a rate of 5 m/s. If the initial speed of the curling stone was 2 m/s, what is the final velocity of the two objects?

M12. A distracted speedboat driver crashes his boat (m = 3630 kg) with a stationary fishing boat (m = 1040 kg). Suppose that the speedboat was initially moving at 130 km/h. If the two boats glide across the water together after this collision, what is the speed of the two boats (stuck together) after the crash?

M13. An ultimate frisbee player (m = 67 kg) leaps vertically for a 0.2 kg frisbee with a horizontal speed of 11 m/s. After a spectacular catch, the player starts to tumble horizontally. What is this player's horizontal speed after grabbing the frisbee?

M14. A curling stone is thrown with an initial speed of 4 m/s and collides with another curling stone at rest. After the collision, the initial curling stone thrown changes direction, at a 40-degree angle with respect to its initially thrown trajectory. What is the velocity of the curling stone originally at rest post-collision? Assume the stones have equal weight.

M15. A paper airplane (m = 5 g) is thrown into a wind tunnel with an initial speed of 2 m/s. If the wind tunnel accelerates the plane by 3.00 m/s^2 for 5 seconds, what is the plane's momentum as it exits the tunnel?

M16. A bowling ball (m = 5 kg) and a basketball (m = 0.625 kg) are dropped from a height of 3 m. What is the difference in momentum of the two balls as they hit the ground?

M17. After suffering a close defeat, an angry AAU Basketball player slams a basketball into the ground, and it bounces up vertically. If the ball reaches a peak height of 2.5 m, what is its momentum as it returns to the ground?

M18. A hockey player applies a force of 150 N to a puck with a radius of 3.6 cm for 0.5 seconds. What is the impulse experienced by the puck?

M19. "Chair Girl" throws a chair off of a balcony 195 m high in the air. If this chair weighs 9 kg, calculate how much impulse it experiences as it hits the ground.

M20. Suppose that another chair (m = 7.50 kg) is thrown from the fourth story and hits the ground, reaching a stop in 0.5 seconds. If one story is approximately 4.3m, what is the force of the ground acting on the chair?

M21. One night, a drunk driver is driving his car (m = 1440 kg) on a highway at 144 km/h on the wrong side of the road. In a tragic collision, the car collides with a second car (m = 1350 kg) driving on the right side of the road moving at 100 km/h. Assuming an elastic collision, how fast are the cars moving post-collision?

M22. Suppose that two cyclists (m_1 = 60 kg, m_2 = 67 kg) collide with each other moving in opposite directions at speeds of 4.2 m/s and 3.6 m/s. If these cyclists get twisted together post-collision, what is the velocity of the cyclists right after they collide?

M23. A 45.0 kg boy standing on a slippery hockey rink tries to kick a hockey puck and ends up moving backwards with a velocity of 0.0024 m/s. What is the direction and magnitude of the velocity of the hockey puck?

M24. A 0.46 kg soccer ball is rolling towards a kid (at 10 m/s). The kid decides to kick the ball, changing its trajectory to be at a 45-degree angle with a speed of 45 m/s.

(a) Calculate the impulse of net force assuming a collision time of 0.01s.

(b) Calculate the average net force.

Medium

M25. A NERF gun (m = 2.62 kg) fires a dart (m = 1.1 g) at a red plastic cup (m = 12 g). Upon impact, the dart is stuck on the surface of the cup and they move at a speed of 1.6 m/s away from the gun.

(a) Calculate the velocity of the dart prior to impact with the plastic cup.

(b) Calculate the recoil speed of the NERF gun to generate the velocity found in part (a).

M26. On frictionless ice, a child (m = 29 kg) pushes a crate (m = 4 kg) away from them at a speed of 8 m/s.

(a) After pushing the crate away, does the speed of the child change?

(b) Suppose that the child drifts 3 m away from their initial position. How far has the crate moved (relative to the child)?.

M27. You are playing a game of bocce ball on the grass. You throw your bocce ball in the direction of the pallino (the small ball that acts as the target). Unfortunately, you overshoot your throw and your bocce ball and that pallino collide elastically and move at the same speed in opposite directions. Find an equation to express the mass of the bocce ball.

M28. A professional shot-putter (m = 116 kg) can throw a heavy metal ball (m = 4 kg) away from them at a speed of 13 m/s. Suppose that they decide to try this on skates at a skating rink one day (do not try at home), but only manages to throw the ball at a speed of 8 m/s relative to themselves. After the throw, the shot-putter begins sliding away across the ice.

(a) What is the velocity of the shot-putter relative to the ground?

(b) What is the velocity of the heavy metal ball relative to the ground?

(c) What is the total kinetic energy of this system?

M29. A truck driver cannot brake in time and rear-ends another truck on the highway.

(a) If the rear-ended truck (m = 2700 kg) was moving at 44 km/h and the braking truck (m = 3400 kg) was moving at 70 km/h at the time of collision, how fast do the trucks move post-collision?

(b) Suppose that the vehicles separate instead of sticking together post-crash. If the braking truck now moves at 50 km/h in the forwards direction, how fast does the other truck move, and in what direction?

M30. A golf ball (m = 45 g) is hit at an angle of 45 degrees and travels at a speed of 24 m/s. Suppose that winds blowing against the golf ball reduces its horizontal speed by 1.5 m/s as it travels through the air. What is the momentum of the golf ball as it strikes the ground?

M31. A talented volleyball player hits a volleyball (m = 260 g) initially travelling directly towards them at 15.0 m/s. After the hit, the volleyball travels at 19.5 m/s in the opposite direction. If the duration of contact between the volleyball and the player's first was 0.3 s, what was the force applied?

M32. After catching a short pass, a running back (m = 100 kg) runs down the field at 9.5 m/s. The running back then collides with a defensive safety (m = 110 kg) running up the field at 7.5 m/s. Suppose that the running back maintains a speed of 3.0 m/s after the collision. What is the speed and direction of the defensive safety post-collision?

M33. At a red light intersection, a car (m = 1200kg) which just finished making a left turn from the southbound lane (v = 33 km/h East) collides with another car (m = 2000kg) moving south (v = 24 km/h South). If this is an inelastic collision, calculate the (a) combined momentum and (b) combined velocity.

M34. A bowling ball (m = 5 kg) moving at 4.5 m/s North strikes a pin (m = 2 kg) initially at rest. After they collide, the bowling ball now moves at a velocity of 3.7 m/s [77.0° N of W]. What is the speed and direction of the pin after it gets hit?

M35. Suppose that instead, the bowling ball (m = 5 kg, v = 4.5 m/s N) strikes another bowling ball of equal mass moving at a velocity of 3.9 m/s [15.0° N of W]. After they collide, the first bowling ball initially moving north now moves at a speed of 4.1 m/s [22.0° N of W]. What is the speed and velocity of the second bowling ball after they collide?

M36. A ten-year old child (m = 30 kg) standing still on frictionless ice is playing catch with a parent. If the child (initially at rest) catches a 55 g tennis ball moving at 12 m/s, what will the velocity of the child be (after the catch)?

M37. A NERF gun (m = 2.62 kg) fires a dart (m = 1.1 g) on a train moving 34 km/h North. If this dart ends up flying at 5 m/s (relative to the train) in the direction of the caboose, what is the NERF gun's ground speed?

M38. You are riding a slide and going down a hill in the snow. You find your cousin at the end of the track and signal him so he hops on when you pass by. As you are travelling, he manages to get on. If your speed was 5m/s before he hops on, what is your speed when you both are on? (Assume the mass of the sled is negligible and that the mass of your cousin is twice as much as you.)

Challenging

M39. A bouncy ball of mass 40 g is dropped onto the floor from a height of 3 m and returns to a height of 2 m after reaching the ground. If the force on the ball by the floor is 15 N, how long did the ball contact the floor for?

M40. A C4 explosive (m = 0.8 kg) suddenly detonates into three pieces. One piece, weighing 0.2 kg, moves North at a speed of 66 m/s. Another piece, with a mass of 0.34 kg, moves [45.0° S of W] at a speed of 50 m/s. What is the speed and direction of the last part of the detonated explosive?

M41. A firework is launched from the ground at 8 m/s and reaches a speed of 6 m/s. The rocket was attached to a box that then was let go. The box weighs 1 kg which also was travelling at 12 m/s when it was let go. What is the initial mass of the system?

M42. Two objects are held at either ends of a compressed spring on a frictionless horizontal surface. The ratio of the masses between the objects is 3:1. Immediately after the spring is released, the larger object has a kinetic energy of 43 kJ. What is the kinetic energy of the smaller object?

M43. A 2700 kg truck is moving at 120m/s on a highway when an 80kg deer sprints at a 15m/s across the highway. The truck and deer collide inelastically; what is their final velocity and in which direction?

M44. A 15.0 kg wedge-shaped block sits on a frictionless horizontal surface. A much smaller 4.0 kg rectangular-shape block is sliding down the rough inclined surface of the wedge.

What is the velocity of the wedge at the moment when the block has a horizontal velocity component of 4.0 m/s and a vertical velocity component of 3.5 m/s?

M45. A 170kg four-wheeler, including the passenger's weight, drives along an ATV trail at 19km/hr. When the driver is not paying attention, she accidentally hits a massive hare sleeping in the middle of the trail head on. The hare gets knocked forward at a speed of 12km/hr and weighs 10kg. Does the four-wheeler move, if so, at what speed?

4. Energy

C1. James Bamford (a Canadian stunt performer) shoots himself out of a cannon with the muzzle located 5 m off the ground. Suppose there is a rope hanging 7 m above the cannon opening and Evel is shot out of the cannon at 10 m/s. Is it possible for him to reach the rope? Assume air resistance is negligible.

C2. A man is pulling on a rope in order to close a large curtain. If he pulls downwards at an angle of 30 degrees below the horizontal and with a force of 20 N, how much work does he do after moving 6 m?

C3. What is the power needed for a 2000 kg object to climb a hill that is slanted at 3.00° slope while moving at a constant speed of 10.0 m/s. Assume wind resistance and friction total to 500 N.

C4. A 2 kg object is moving at a speed of 1 m/s and collides with an object of the same mass that is initially at rest. Assume that this is an isolated system.

(a) What is the initial kinetic energy of the system?

(b) What is the maximum amount of kinetic energy that can be "lost" (converted to other forms of energy) in this collision?

(c) If 50% of the answer you calculated in (b) is converted into other forms of energy in the collision, what are the final velocities of the two objects?

C5. A cowboy fires a 0.01 kg bullet into a barrel of wine (m=5 kg) in a battle. The bullet pierced through the barrel and continued travelling, now at a speed of 785 m/s. Before hitting yet another one of the barrels (after piercing the one before it), the shop owner, who had a background in physics, yells at the cowboy :

"You will pay me, in dollars, the same amount of energy that my first barrel has taken out of your bullet."

The cowboy stands confused. One of the villagers gets up and tells the shop owner that this is an impossible problem to solve because the cowboy does not know one of the essential parameters.

(a) What is one parameter/measurement you would want to make to allow you to solve this problem?

(b) Assume a realistic number for this parameter and calculate how much the cowboy owes the owner of the barrel.

(c) If the first 5 kg barrel hit began moving and sliding across the frictionless floor, and assuming 100% efficient energy transfer, what is the speed of the barrel? Assume the mass of the barrel decreases by 10% due to impact!

C6. A 60 kg passenger falls from a plane that is 3500 m above sea level. After falling 450 m, he reaches a terminal speed of 55 m/s.

(a) After falling 420 m, what is the gravitational potential energy of the system?

(b) What is the kinetic energy of the passenger at the time in part (a)?

(c) If the initial kinetic energy of the passenger is zero, then is $\Delta K = -\Delta U$ true for this system? If not, explain what happened to the "missing" energy.

(d) After the passenger reaches terminal speed, he falls for a while at constant speed. Describe the kind of energy conversion taking place during this time? (Assume that the Earth, the passenger, and the air around him make up the system).

C7. You are operating a machine that is lifting a 310 kg object vertically into the air at a speed of 0.25 m/s. What is the machine's power output?

C8. Your baby brother was running on the balcony and threw a ball straight downward with a force of 2 N. The 2.5 kg ball then drops from the 5 m high balcony. Your cousin is observing the ball as it drops and bounces, and swiftly marks the ball to have bounced a height of 3 m after hitting the ground.

a) You want to challenge your cousin in physics so you start calculating the kinetic energy of the bouncy ball before it contacts the floor. What is the kinetic energy?

b) Right after the collision, what is the kinetic energy of the ball? Assume a perfectly elastic collision.

c) Your other cousin with a PhD decides to test you and asks you what would have happened in a perfectly inelastic, and partially inelastic collisions. What do you tell your cousin?

C9. Your professor goes on along with a long sample problem. He presents on the board a system consisting of a block on ice with a few unknown forces on them. The professor then asks his class "look at the system shown here : which one of the forces that I drew on the board can change the mechanical energy of this system?"

You raise your hand and give out the correct answer.

What did you say? (Feel free to recreate the professor's diagram)

C10. A woman pushes horizontally to move a chair 30 m across a dining hall with a force of 90 N. What magnitude of work is done by the woman during this time?

C11. You work at a garden centre and try to lift up a large 98 kg boulder to move it to a new location, close by, in the yard. Quickly realizing that the boulder is much too heavy, you decide to use a rope and pulley system. By applying a constant force of 380 N on the pulley, you are successfully able to lift the boulder 4 m in the air and place it in the correct location.

(a) What was the speed of the boulder as you were lifting it up?

(b) How long would it take for you to lift the boulder up 4 m and are there any factors that would influence this rate?

C12. A rock with mass M is thrown on a trampoline on Pluto. Assume Pluto has a gravity value of 0.4 g.

(a) What kinetic energy of the rock is required to compress the trampoline springs 0.25 cm? Assume a spring constant 500 N/m.

(b) How much work does the trampoline do on the rock?

C13. A machine has a power output of 2450 W and is lifting an 800 kg object at a constant speed. What speed is the object being lifted at?

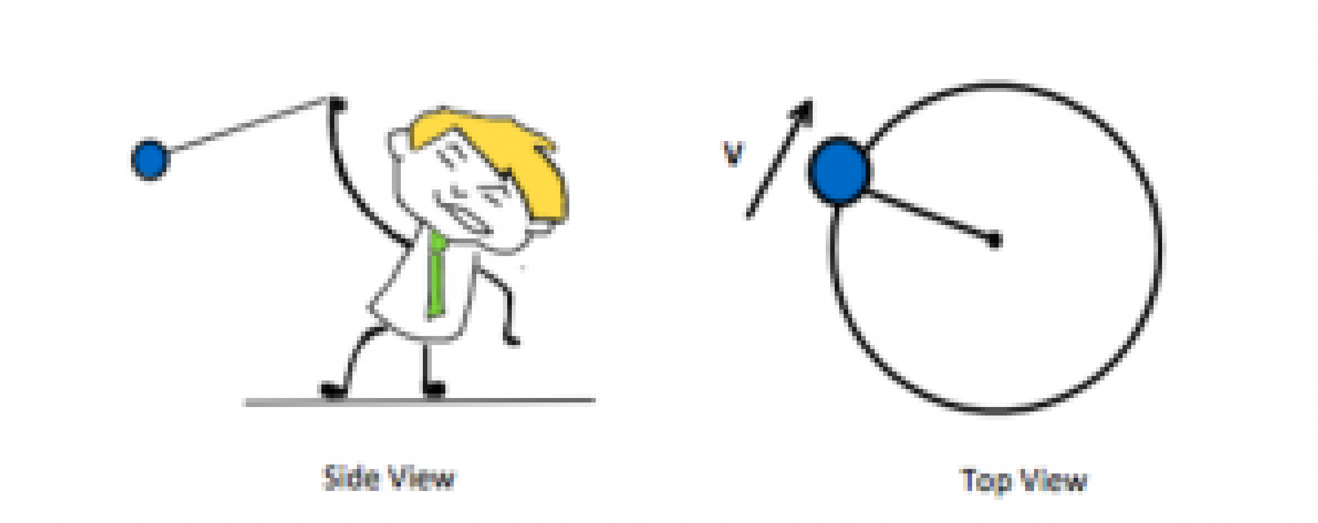
C14. A car moving at 38 m/s runs into a barricade and comes to a stop, crushing its front end in the process. During this time, the car's centre of mass shifts 0.6 m forward.

(a) If the car has a mass of 1,800 kg, determine the magnitude of the average force acting on it while it stops?

(b) Determine the change in kinetic energy for the car by the time is fully comes to a stop. Where is all this kinetic energy distributed?

C15. Imagine that you are sliding a 2.8 kg disk with a speed of 10 m/s on a bumpy horizontal surface in the direction of a spring with k = 600 N/m. The coefficient of kinetic friction between the surface and the disk is $\mu k = 0.6$. If the disks speed is ⅓ of its initial speed when it first comes in contact with the spring, what is the spring's maximum compression?

C16. A man is swinging a tennis ball of mass 0.5 kg, attached to a string, in a circle above his head (see the sketches below). Note that the string in the "side view" diagram is not sketched as horizontal due to artistic error.



(a) Draw a free-body diagram for the object.

(b) Provide an explanation for why the spring is not sketched as horizontal.

(c) Determine the horizontal and vertical components of the tension in the string.

(d) What is the centripetal acceleration of the object if it completes a circular rotation of radius 0.7 m in 2.8 s?

(e) What is the angle the string makes with the horizontal?

C17. A golf ball is hit into the air at an angle of 45° and travels a distance of 240 m horizontally before landing on the grass 8s later, 2 m below its original height. Determine the initial velocity of the golf ball (horizontal and vertical components)?

C18. A 3 kg book is placed at the top of a 30-degree incline and slides down the incline towards the bottom. Assume that the coefficient of kinetic friction between the book and the incline is $\mu k = 0.23$.

(a) Draw a free-body diagram for the book on the incline.

(b) What are the normal force and the force of kinetic friction?

(c) What is the book's final speed after sliding 0.75m down the incline?

(d) If the coefficient of static friction is $\mu s = 0.4$, what is the maximum angle θ that would allow the book to remain stationary on the incline?

C19. To motivate your physics roommates to see the sun, you all decide to play frisbee outside. You throw a frisbee to Andres, a "specialist" in string theory, who still struggles with kinematics. You throw it at a speed of X m/s at an angle of 30-degree above the horizontal.

The Y kg frisbee is caught by Andres; however, it dropped 1.5 m in its journey through the air. As always, assume no air resistance, and solve in terms of X and Y.

(a) What is the frisbee's kinetic energy just as you throw it? Does the fact that it is angled actually matter? Why or why not?

(b) Calculate the kinetic energy of the frisbee as it is caught by Andres.

(c) Calculate the horizontal distance the frisbee travelled.

C20. A spring has a force constant of 20 J/cm. How much force must be applied to compress it by 8 cm?

C21. Object 1 has a mass of x and 3 times the kinetic energy of a mass of 3/2 x. Determine an expression for the ratio of the speeds of these objects.

C22. A massless spring ($k = 5.5 \times 10^3$ N/m) is compressed 4.4 cm when a box of mass 5.0 kg is pushed against it. When the box is released, it slides 4.4 cm before coming to a complete stop. Determine the coefficient of friction between the surface and the block.

C23. You and your family go on a sled at a hill where the coefficient of kinetic friction nears zero. Your science-y little brother looks at the sled and comments:

"The sled looks like it's about 50 degrees below the horizontal, I should ride it!"

You proceed to tell him that if he uses conservation of energy, he could see how he will not reach a speed higher than 36.8 m/s going down the 90 m slope assuming zero work is done by friction. He then looks at you and says, "how did you find that?" You explain how you found the answer!

C24. A WebStraw particle (consistent of one electron and two protons) is to reach a speed of 5.5×10^6 m/s in 0.002s from rest. What is the power given to this particle for it to accelerate if it was over a displacement of 5 mm.

C25. Issa got a new smartwatch gift from his best friend Olayyan on his birthday. Olayyan claims that Issa's jogging speed is around 12 km/h in the gym. The new smartwatch has this cool power display and the meter is at 750 W when Issa runs in the gym. If Issa is 70 kg and he is 25% efficient, use the power meter to calculate the rate he uses energy when jogging up a 9 m high slope that is angled upwards at 15°.

C26. In the midst of the corona pandemic, a man is refilling on his supply of food and necessities. As he is travelling home with his new purchases, he pulls his 5.0 kg trolley with a force of 25 N at an angle of 40-degrees above the horizontal. His walk home from the store is 10 minutes long? How far does he live from the store? How much work does the man do to pull the cart? How would the amount of work done change if the cart is pulled at an angle of 30-degrees above the horizontal?

C27. In a factory loading zone, a force of 28 N is applied to 7.0 kg boxes to push them up a 45° frictionless ramp at constant speed to load them into a truck. The truck is 3.5 m above the ground.

(a) How much work is done by gravity?

(b) How much work is done on the surface of the ramp (use the force applied)?

C28. A 15 kg box was projected onto a spring attached to the wall. The print compressed until the box (which was travelling at a speed of 13 m/s) came to a stop. The measured compressed spring is about 15 cm. What is the spring constant k, and what was the kinetic energy before the box made contact with the spring?

C29. What is the work that is done on a 20kg sled that a little kid pushed up a 10 m long ramp at an angle of 20° above the horizontal? Find the work done by gravity on the sled and the work done by friction if you know that kinetic friction is 0.5.

C30. Before pitching a baseball, the pitcher throws it straight up at a speed of 25 m/s. When the 0.3 kg ball returns to the pitcher, its speed is now 18 m/s. Find the work done by air resistance on the ball.

C31. A large rock with a mass of 300 g thrown off the side of a cliff from a height of 150 m above the water, lands in the water at a speed of 30 m/s. Find the work done by air resistance.

C32. A pendulum holding a 2.0 kg ball swings back and forth. The ball moves at a speed of 8 m/s at its lowest point. Find the speed of the ball at its highest point. Find the tension in the string when at rest?

C33. In an arcade game, Mitch runs at 3 m/s and hangs from a rope that is 5 m long to swings to the cliff of the mountain. Do the organizers of the arcade have to worry about the length of the rope when considering how high they should make the mountain? How high will Mitch reach?

C34. A tube holding a person, weighs a total of 75 kg. Starting from rest, the tube slides down an incline that is 80 m tall and makes a 20-degree angle with the horizontal. It then travels a distance of 10 m before moving up an incline of 10-degree. How far up this second incline, will the tube system move if this second incline is frictionless surfaces? What is the net work done on the tube by gravity?

C35. A little boy on a scooter is moving at a speed of 5 m/s when he goes up a long ramp inclined at 150 degrees with respect to the horizontal. The little boy and scooter have a combined mass of 50 kg and moves up the ramp to 10m above the ground before coming to a halt. Find the net frictional force on the boy.

C36. A spring gun is shot, moving a 20 g projectile to a height of 3 m. If the spring is considered massless with a spring constant of 10 N/cm, how much is the spring compressed when shooting the spring gun?

C37. Will a non-conservative force change the kinetic energy of a box travelling on ice?

C38. A ball is dropped and bounces, returning to four-tenths of its original height. What type of energy transfer(s) happened here?

C39. At Scotiabank arena, Raptors employees launch shirts and prizes with t-shirt cannons. Shirts are launched at an initial speed of 25 m/s, at 50-degrees above the horizontal. How fast is a shirt traveling when it is caught by someone sitting in a seat that is 30m above the ground?

C40. Spring jumping is a new game that robots started playing in 2032. In spring jumping, the robot extrudes a spring (always has a spring constant of 100 N/m) and uses its propelling system to bump into a wall. If a 10 kg robot plays spring jumping and compresses their spring by 30 cm what is the amount of elastic potential energy stored in the spring before the robot charges out? What is the amount of work that the robot does carrying itself above the ground at a height of 0.12 m? Explain your reasoning!

C41. A steel ball (m= 30 g) is to be projected down a ramp using a spring with spring constant 100 N/m. This ramp is specially designed to look like a “V”. The steel ball will be projected from a spring at the top of the “V” shaped ramp. To project the steel ball, the spring was compressed by 5.0 cm from its equilibrium length of 10.0 cm. If the coefficient of friction is 0.30, will the steel ball compress the spring at the other end of the “V”? If so, how much would it compress it by? (The very ends of the ramp are 2.0 m above the ground and the angle between the two inclined sides of the ramp at the middle of the “V” is 36 degrees.)

C42. A box starting from rest slides down a frictionless incline. Find the speed of the box given a 15 m change in vertical height.

C43. A 250 g golf ball is hit with a force of 15 N for a duration of 285 ms and at an angle of 40°. At the highest vertical point, what is the projectile’s increase in gravitational potential energy?

C44. Determine the amount of energy that is lost to dissipative forces when a 65 kg person free falls at a terminal speed for 10 m.

C45. You and your physics professor perform an activity to introduce elementary school students to the idea of friction on surfaces and how friction affects the motion of objects. First, your professor slides a box over a surface of ice. After sliding a couple metres, the box compresses a spring at the end of its path (by 30 cm). Next, you slide a second identical box over an equal distance, but on a different surface. Your box also compresses a spring, but only by 10 cm. The elementary school students are amused. One student raises their hand and asks: "How could you calculate the energy that was lost by friction on the box that compressed the spring by only 10 cm?" Assuming that both the boxes were released to start with the same amount of energy (70 J), what is your response?

C46. A 70 kg person is working out on a Stairmaster and has climbed a total of 15 sets of stairs (equivalent to a 45 m change in vertical height). Find the amount of work done by the person.

C47. A spring at an amusement park stops your devastating punch (assume the punch carries with it a mass of 20 kg) as it travels 30 km/h. How much does the spring move if it has a spring constant of 500 N/m?

C48. It's the middle of summer, and temperatures are scorching. You decide to invest in an air conditioner, and are interested in knowing the electricity costs for having it on for about 8 hours per day during "peak" hours. If your AC uses 4000 watts of power, and the average price for a kWh is $0.18, calculate your daily expenditure.

C49. If an object's speed is quadrupled, what impact does this have on the kinetic energy of the object? Does it have the same impact on the object's potential energy?

C50. To keep the Moon in orbit around the Earth, certain force(s) act on it. In this scenario, identify the force(s) involved, and the amount of work done by each force. Is the answer what you expected? Explain any unexpected results.

C51. If an object is dropped from double the height of another object, but the kinetic energy as they hit the floor is the same, what does that say about the relationship between their masses?

C52. Given two objects, with one having X watts, and the other 20X watts, how can the object with less wattage still consume more energy in some cases?

C53. What is the relationship between energy and power? Based on your answer, explain how you would convert kWh (kilowatt hours) to joules.

C54. Jonathon (m = 50 kg) attempted to push his friend Andrew (m = 60 kg) with 6 N of force over 10 m in 5 seconds. Andrew replied by pushing Jonathon with the same force over the same distance in 1 minute. Who did more work? Note that they were both ice skating.

(a) Jonathon.

(b) Andrew.

(c) both Jonathon and Andrew did the same work.

C55. A bullet has a mass of 5 g. It is initially travelling at 100 m/s when it collides and then embeds itself in a solid block that is suspended by a string. The string is 1.5 meters long, the block is 5 kg. Once this bullet/block system begins moving, which of the following is conserved?

(a) Linear Momentum.

(b) Mechanical Energy.

(c) Both (a) and (b).

(d) None of the above.

C56. Using the same bullet/mass system in question **C55**, how high does the block/bullet system go up relative to its original position (essentially, assume the pendulum is at rest, and that rest position has y = 0. Where would the new maximum height be relative to that position).

C57. A golf ball of mass 0.068 kg is hit upon a parabolic trajectory. The golf ball is hit upwards at an angle of 30˚ and it reaches a maximum height of 12.8 m. What is the work done on the ball by gravity when it is half the way up, when it is at its maximum height and when it is about to hit the ground again?

C58. Imagine you are pushing a chair of 200 N up a frictionless incline that makes an angle of 40 degrees with the horizontal. If you are moving the box at a constant speed, how much work is being done on the box by your push?

C59. A hot air balloon is travelling North with a velocity of 350 km/h at an angle of 8 degrees below the horizontal when a child on it drops her favourite stuffed animal, Mr. Fluffle. What height was the stuffed animal dropped from if it hits the ground at a speed of 800 km/h?

C60. You roll a block across a frictionless surface at 5 m/s. Suddenly, the surface changes its properties, and now it is no longer frictionless. Its coefficient of kinetic friction is $\mu k = 0.3$. How far will the block travel across this new surface before stopping?

C61. Two people push against a large boulder that does not move. One person pushes for 2 minutes while the other pushes for 5 minutes. Which person did more work and how much more work?

C62. A spring, with spring constant 2000 N/m, is attached to the end of your horizontal table in preparation for an exciting physics experiment [frictionless surface]. There is a 3.0

kg block on one end of the spring and a 6.0 kg block on the other end. After the spring is compressed 9.0 cm, the spring is released and the blocks begin to oscillate. When the spring reaches its equilibrium length for the second time, the smaller block has a speed of only 0.14 m/s. What is the magnitude of mechanical energy that has been lost in this time?

C63. Three eggs of equal mass are thrown from the top of a school building. The first is thrown directly upwards, the second is dropped with an initial velocity of 0 m/s, and the third is given an initial velocity directly downwards. For which egg is the work done by gravity the greatest?

5. Rotation, Torque, and Statics

Conceptual Questions

D1. Pascal Siakam (Toronto Raptors player) releases Basketball A and Basketball B from the top of a ramp at a height of 10 meters. Both basketballs are released at the same time, but Basketball A rolls down the ramp whilst Basketball B slides down the ramp. Which ball will reach the bottom of the ramp first?

D2. Dr. Ian Malcom is attempting to enter the large wooden gates to Jurassic Park, but has an issue. The doors operate on hinges like a typical door but are quite large (6 m tall by 3 m wide). If Dr. Malcom wishes to open the door using the least amount of force possible, where should he be pushing? If he wishes to do the least amount of work possible, where should he be pushing?

D3. A spinning top has an angular velocity vector that is directed into the page. Viewing the object from above the page, what can be said about the direction of rotation and the axis the object is spinning about?

D4. A 21 kg girl is standing on a rotating merry-go-round. He is located at a point, P, that is equal distance from the centre and edge of the merry-go-round. Describe whether the girl experiences centripetal acceleration, a positive tangential acceleration, or both under the following conditions.

(a) The merry-go-round is spinning at a constant angular velocity.

(b) The merry-go-round comes to a stop.

(c) The merry-go-round begins spinning from rest.

D5. Imagine a spinning top rotating at a constant speed. Can the magnitude of the top's velocity change without changing its direction if a tangential acceleration is applied?

D6. A figure skater is performing a complicated triple-axel so she brings her arms in very close to her body. To complete and land the jump, she stretches her arms out and lands gracefully on one foot. Describe how the angular velocity of the skater is changing over the course of this jump.

D7. You are interested in the most efficient way to roll a soup can up a frictionless ramp. At first, the soup container slides up the ramp with some initial velocity. Next, the soup can is rolled up the ramp with the same initial velocity. Assuming that the soup can rolls without slipping, which of the two scenarios results in the soup can reaching a greater height.

D8. Without increasing the torque applied to an object, how can you increase the force applied?

D9. Three objects with the same radius are rolled down a tall hill. The objects are a solid sphere, hollow sphere and a solid cylinder. In what order will the objects reach the bottom of the hill?

D10. A full can of Coke and an empty can of Pepsi (both the same size and shape) are rolled down an incline. Which object will reach the end of the incline first? Explain.

D11. A ceiling fan is rotating in a counter-clockwise fashion. When you turn off the fan, what is the direction of angular acceleration as the speed of the blades decrease?

D12. Why is it that when you spin a string with something attached to it vertically, you need to move the string fast enough or else it goes slack?

D13. What can be said about the angular speed of an object whose angular velocity vector and angular acceleration vector are pointing in opposite directions?

D14. As you ride a bicycle forward in a straight line, you notice that you tend to drift to the left.

(a) Why is this?

(b) Would increasing your speed affect the force of this "drift"?

D15. A bowling ball and a heavy basketball have the same mass and diameter. How do their moments of inertia differ? Express your answer as a ratio of bowling ball:basketball.

D16. A piece of glass gets stuck to a car tire that is heading directly East at a constant velocity. What is the direction of the acceleration of the glass piece as it is lifted off the pavement?

D17. Angular velocity is an integral part of designing rotating systems. Using the right-hand rule, calculate the direction of angular velocity in the following scenarios

(a) Rollerblading in a straight line forward.

(b) If your laptop fan is rotating in a counterclockwise fashion.

D18. Three children are at the park playing on a roundabout. One sits near the centre, another near the edge and the third is pushing the friends. Which friend sitting on the roundabout has a smaller tangential velocity? Where should the third friend ask the other two to sit to make it easier to push them on the roundabout?

Rotational Kinematics

D19. A small beyblade turns once every 0.1 s.

(a) Calculate its angular velocity.

(b) Calculate the centripetal acceleration and the minimum value of the static friction coefficient of an object sitting 0.2 cm from the center of the beyblade.

D20. A car is being fixed at the shop, and the car's wheel is spinning with an initial angular velocity of 100 rpm and is stopped in 10 s. What is the angular displacement over this time?

D21. You are out on a nice day riding your bike when you see a skunk shortly ahead. How long does it take for your bicycle wheel rotating at an initial angular speed of 18.0 rad/s to come to a halt, if it's speed is decreasing at a rate of 2.33 rad/s^2.

D22. The angular acceleration of a wheel is 15 rad/s^2. How is the angular velocity of the wheel changing (in rev/s) each minute?

D23. A 100 g ball is swinging vertically on a string, making a circular path. This string is 2 meters long. At the bottom of the circle, the tension is 20 N.

(a) What is the speed of the ball at the bottom of the circle?

(b) What is the speed and tension of the ball at the top of the circle?

D24. What angular distance is covered by a rotating CD if its speed increases from 1600 rpm to 4000 rpm in a short time frame of 8.3 s.

D25. A farmer's electric power generating windmill can run at a maximum speed of 75 rpm before being subjected to a number of stressors which will reduce its functional lifespan. During a storm, the farmer notices that heavy winds are forcing the windmill's rotor to spin at 88 rpm, and wants to decelerate it to a safer speed. After two and a half turns, the rotor has slowed to 84 rpm. Determine the rate of angular acceleration in rad/s, and how much longer this acceleration must be applied to reach a safe speed.

D26. One day, the same farmer in **D25** (the question above) is re-orienting his farm. He hires a moving team to move one windmill, initially facing the East and idly rotating at 25 rpm, to the opposite side of the farm, and now facing the West. With a constant angular acceleration of 3 rad/s^2, how long will it take for the windmill to reach 25 rpm in the opposite direction?

Rotational Kinetic Energy and Moment of Inertia

D27. Kyle Lowry hustles after a basketball (r = 0.24 m, m = 0.625 kg) rolling down the court with a linear velocity of 10 m/s and an angular velocity of 5 rad/s. Calculate the total kinetic energy of the basketball.

D28. You are sewing a new top for yourself, when the 50 g hollow spool around which the thread is wrapped, is released by the sewing machine and begins falling with the end of the string held fixed to the machine.

(a) What is the linear acceleration of the spool as it falls from a table?

(b) Find its translational and rotational kinetic energy after 1 s of falling.

(c) Find the tension in the string, and is this tension affected by how long the spool has been falling?

D29. A large tire has an inner radius of 64 cm and an outer radius of 81 cm. Determine the wheel's rotational kinetic energy if it rotates with an angular velocity of 17 rad/s.

D30. Determine the moment of inertia of a skater whose body can be approximated by a cylinder with an 18 cm radius and mass of 56 kg, with her arm tucked in tightly to her chest? How would this moment of inertia change if the skater extends her arms?

D31. Assume you are at a distance L1 from the center of a carousel. Your friend, Jerry, is at a distance L2 from the center of the carousel. Assume that L2 is two times greater than L1 (Jerry is twice as far), how do your moments of inertia compare?

D32. Assume you have a circular, completely solid disc that is rotating horizontally with angular velocity W, radius 4R and mass 4M. A second disc of radius 2R and 2M is dropped onto this disc. The two discs keep moving together, at different initial velocities, until the small disc is eventually fully sped up and has the same angular velocity as the big disc.

(a) What force causes the small disc to increase its velocity?

(b) What is the final angular velocity of this disc system?

(c) What fraction of the initial kinetic energy is lost when the discs decouple?

(d) Discuss, and show, what would happen, if anything, if the mass and radius for each system were halved. What about doubled?

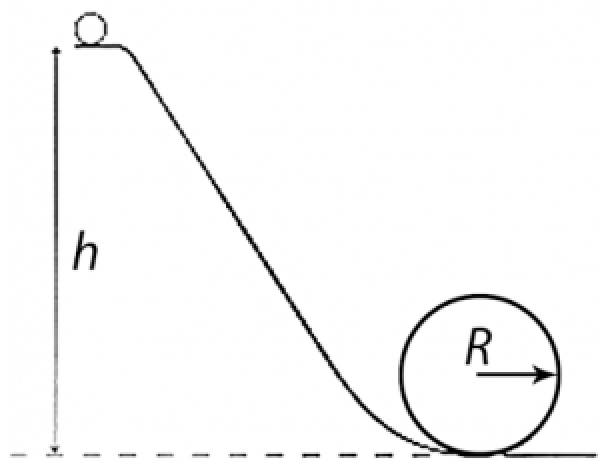
D33. A solid disk of mass M and radius R rolls down a ramp height h. Assume that the force of static friction is just right so that the disk does not slide, instead fully rotating. Recall that the moment of inertia of a solid disc is $I_{Ball} = 2/5MR^2$

(a) How fast is the disk moving at the bottom of the ramp?

(b) How fast is the disk rotating at the bottom of the ramp? As in, calculate its angular velocity

(c) Now assume we have a separate ramp with height Q (arbitrary letter). What is the minimum height before the ball is just able to go around the loop? Assume it can roll without slipping the entire time, even with the normal force.

(d) Compare this answer to the one you would get if it would have been a non-rotating block. Is it greater, or smaller? Why? Why would this intuitionally make sense?



D34. You are playing a game of skeeball, with a ball of radius 8 cm and a mass of 0.5 kg . At first, the ball travels at 2.8 m/s on a flat horizontal surface without slipping. It then travels up a ramp that makes an angle of 30° with the horizontal.

(a) If the moment of inertia is $I = 20MR^2$, what is the angular momentum of the ball as it first makes its way onto the ramp?

(b) What is the translational and rotational kinetic energy of the ball?

(c) At this speed, what is the maximum height that the ball will roll up the ramp before it comes to stop and rolls back down?

(d) Calculate the acceleration of the sphere as it rolls up the ramp.

D35. Imagine rolling a full can of beans of mass M and radius R down a hill that is 8 m tall and is at an angle of 30 degrees with respect to the horizontal. Next, you roll an empty can (approximated by a thin loop) of the same radius but with ¼ of the mass down the same hill. Determine the ratio of the kinetic energy for the two objects when they reach the bottom of the hill.

D36. A basketball with a radius of 20 cm rolls 50 m down a hill with an incline of 30°. What is its velocity after it has traveled 40 m?

D37. A solid cylinder has a diameter of 9.8 m and a mass of 4.6 kg. It starts from rest and begins rolling down a wedged-shaped ramp with a 30° incline. What is the cylinder's speed after rolling down 6 m of the ramp?

D38. What is the work done on the bottom of the tires of a car by the force of friction of the road assuming the car is moving at a constant velocity? Assume there is no sliding in the car, and that the tires are rolling.

D39 Starting from rest, a solid sphere with mass M and radius R is rolled down an inclined plane of height 7 m. At the same time a solid cylinder with mass M and radius R is rolled down an inclined plane of height 6 m. If the angle of the incline is 30 degrees with respect to the horizontal in both cases, which object will reach the bottom first? Which object will have a greater speed when it reaches the bottom?

D40. Determine the acceleration of a hollow ring rolling down an inclined plane with a coefficient of static friction equal to μ. Express your answer only in terms of the angle of the inclined plane, θ, and g (don't forget to consider both translational and rotational motion).

Torque and Newton's Second Law for Rotation:

D41. A fan is rotating at a constant rate and one blade makes a complete rotation in a period of 2.2 s. A small object gets stuck to the edge of one of the blades, located a distance of 28 cm from the centre.

(a) What is the centripetal acceleration of the object?

(b) What is the force that acts on this object resulting in this acceleration?

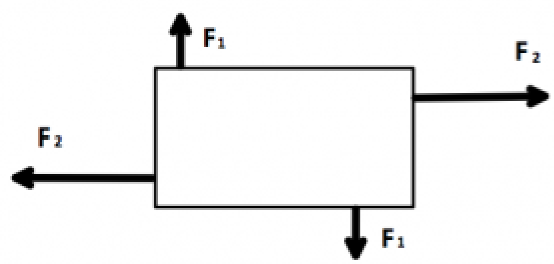
(c) Determine the minimum coefficient of friction between the object and the fan blade.

D42. A frisbee with a radius of 15 cm has a moment of inertia of 3 kgm^2/s and is rotated by a force of 15 N on someone's fingertip. What is the frisbee's angular acceleration?

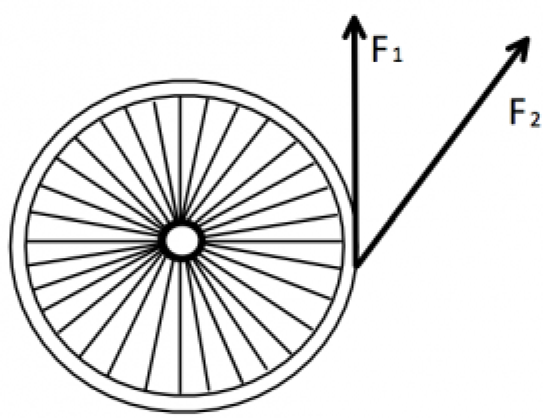
D43. A jet's propeller accelerates from 380 rpm to an angular velocity of 1400 rpm in 10.0 s. Assuming a constant torque of 2680 Nm, calculate the propeller's moment of inertia.

D44. A circular hoop has a radius 0.13 m and begins to spin about an axis perpendicular to the disk in its center. If a force of 8.0 N is applied along the rotation axis, and the disk has a rotational inertia of 5.0 kg m^2, determine the magnitude of the disk's angular acceleration.

D45. Four focrces are acting on a rectangle as shown below. F2 has a magnitude twice as large as F1. Determine if the rectangle will experience a net torque as well as whether the net force acting on the rectangle will be zero or non-zero.



D46. The two forces in the diagram produce the same amount of torque on the object. Which force is larger?



D47. You apply a force on a small wheel, causing it to accelerate tangentially at a rate of X at distance R from its center. You do the same thing with a larger wheel, but this time the force you apply, (which may or may not be the same), causes it to accelerate tangentially at a rate of 2X at distance of 2R from its center.

(a) Compare angular acceleration of the big wheel and the small wheel.

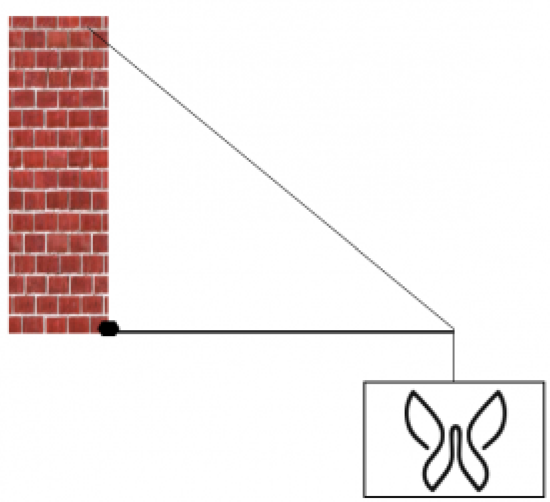
(b) Are the forces the same? If not, what force would be required to produce the tangential acceleration mentioned above (compare big wheel relative to small wheel).

D48. A plastic bucket filled with water is attached to the end of the string and twirled in a circle in the vertical plane. If you double the speed with which you are twirling the bucket without changing the length of the string, how does the magnitude of the centripetal acceleration of the bucket change?

D49. You and your friend want to test how radius and mass affect the tension in a string. You attach different masses, m, and 2m, to a rotating string with radius R. Call these systems, system A and system B. You then attach masses M and 2M to a rotating string with radius 2R. Call these systems, system C and system D. Rank the systems based on the tension of the string, with the highest tension ranking first, and the lowest tension ranking last.

Static Equilibrium and Stability

D50. A sign that weighs 20 kg hangs from a rod sticking horizontally from the side of a wall. A cable attaches the sign to the vertical side of the wall as shown in the diagram below. Assuming that the weight of the rod is 10 kg, find the angle between the cable and the rod.



D51. A uniform rod of length 48 cm and mass 0.28 kg is placed on a fulcrum 36 cm from the right end of the rod. At what distance from the right end of the rod should a 0.55kg mass be hung to balance the rod?

D52. Imagine that your cat (m = 18 kg) is stuck on the end of a tree branch that is 9 m long and has a mass of 6 kg. In order to prevent the branch from snapping, you attach a string on the branch 4 m from the base of the tree and attach it to a higher point on the trunk. If the string makes an angle of 68 degrees with respect to the horizontal, calculate the tension in the rope.

D53. One a plank of wood with negligible mass, 7 bricks of equal mass are placed. Two bricks are stacked on top of one another at the left end, three bricks are stacked on top of one another at the right end and two bricks are stacked in the middle. Where is the centre of mass with respect to the right end of the plank in terms of the percentage of the length of the plank?

D54. Three masses are hung from a metre stick with a mass of 100 g. A fulcrum is placed at 35 cm from the right end. There are two masses on the right of the fulcrum and one on the left. A mass of 25 g is hung at the right end and another mass of 35 g is hung 10 cm from the fulcrum. Where is the third mass of 100 g hung from to maintain a static and balanced metre stick?

D55. Two friends are attempting to carry a long plank of wood, of length L. One friend applies a force of 60 N upward on the left end of the plank. The other friend applies a force of 110 N upward on the right end of the plank. How far from the right end should a 7 kg toolbox be placed such that the system will remain in rotational equilibrium. Assume the mass of the plank is 10 kg.

D56. The mass of planet A is 1.4X the mass of planet B, which has a radius of 3.95 km. The planet's centres of mass are located 36 times the distance of the diameter of Planet B. What is the origin of the centre of mass of this system?

D57. Two students are balancing on a 10 m seesaw consisting of a massless board with a fulcrum at the midpoint. One student, weighing 70 kg, is sitting 3.4 m away from the centre on the right side. Another student, weighing 52 kg is sitting on the other side so that the seesaw remains in line with the ground. Determine how far away this student is sitting from the left side of the see-saw.

D58. One end of a 1.5 m wood beam is hinged to a wall. The other end is being held up by a worker who is keeping the plank horizontal. The mass of the plank is 15 kg, and there is an 8 kg chainsaw sitting on it, 0.5 m away from the worker, who is 1.5 m from the wall.

(a) What is the upward force exerted on the beam by the worker?

(b) What is the force at the hinge?

(c) If the worker were to let go of the plank, what would its angular acceleration be as it starts swinging down? For simplicity, assume that the chainsaw stops applying a force on the beam and the moment of inertia of the beam is $I = 1/4Ml^2$?

6. Fluids

Conceptual Questions

Conceptual Questions

F1. If the density of air is proportional to its pressure, how does altitude affect air density?

F2. A boy is riding his car way to his friend's birthday party in Manitoba with an inflated balloon. The car suddenly turns to the left around a corner, what will happen to the balloon?

F3. A common disorder in North America is varicose veins, where one's veins in their lower extremities become swollen and distended with fluid. Those suffering from this condition are often recommended to walk in water between 1 to 1.5 m deep. How might this help the condition?

F4. The fluid height of manometers with different diameters will reach the same level if they are exposed to the same atmosphere. Why is this the case?

F5. You drop several objects into a bowl of water, which float on the surface. How does the downward force on the bottom of the bowl of water change?

F6. In a weightless environment, will fluids be capable of exerting a buoyant force?

F7. In September of 2019, water was shooting high in the air (vertically) over West Georgia Street in downtown Vancouver. As the water shoots upwards, you notice that the stream broadens. On the other hand, water flowing directly downwards narrows instead. Explain why.

F8. A lawyer is driving down the highway when they decide to roll down all the windows to get a breath of fresh air. A stack of papers is present on the shotgun seat. What will happen to the papers (eg. Will it stay put)?

F9. Two square-based rectangular prisms of the same size and mass are placed in a bucket of water. One of the blocks is floating with its long rectangular face parallel to the water and the other is floating with its short square face parallel to the water. Which block displaces a greater volume in the water? Explain.

F10. A U-tube with uniform cross-sectional area is partially filled with water. If 10 cm of oil (p=0.75 g/cm^3) is poured into one arm of the column, how much will the water level in the other arm rise if the system is to remain in equilibrium?

F11. Imagine water flowing through a pipe. If the speed of the water decreases, what effect does this have on the pressure exerted against the walls of the pipe?

F12. Suppose you are designing the wings of an airplane. In the air, would you want heavy winds to flow above, or below the wings of this airplane? Why?

F13. You are on a ship that sails from the ocean (hint: salt-water) to a body of freshwater. Relative to salt-water, in freshwater, would the boat float higher, lower, or stay the same?

F14. Imagine two mercury barometers placed in environments with the same atmospheric pressure. If the cross-sectional area of the first barometer is 60 times larger than the cross-sectional area of the second barometer, what is the ratio of heights for the first barometer to the second?

F15. Sometimes, when you lower the window in a car moving quickly, light objects like hats, loose papers, or plastic bags can fly out of the window. Why might this be the case?

F16. If the volume of an object doubles, while the mass remains unchanged, what happens to the density?

F17. Suppose you're holding a garden hose. You notice that when you partially cover the end of the hose, water exits much more rapidly compared to when you leave the hose completely uncovered. Why might this be the case?

Properties of Fluids and Pascal's Principle

F18. If an object with a mass of 5 kg has a volume of 4900 mL, will the object float in fresh water (d = 1.000 g/mL)? What about in salt water (d = 1.024 g/mL)?

F19. What the percentage of the object (mentioned in F18) is above the surface?

F20. Identify which of the following represents a measurement of pressure.

(a) N/m

(b) J/m^3

(c) Torr

(d) Pascals

(e) Atmospheres

(f) Foot-pound

F21. Convert 760 torr to kPa, atmosphere and bar.

F22. A scuba diver goes deep diving into the ocean (d = 1.024 g/mL). At a depth of 50 m:

(a) What is the gauge pressure the diver experiences?

(b) What is the absolute pressure the diver experiences?

(c) Would the diver experience more or less pressure in freshwater? Why or why not?

(d) Suppose the diver, in ocean seawater, moves from a depth of 20 m to 40 m. Would the magnitude of the absolute pressure double? Why or why not?

F23. Consider a barometer containing fluid X on a planet with an atmospheric pressure of 40 kPa and has a height of Y. Assuming the vapour pressure of the fluid is negligible, write the new height of the fluid in the barometer in terms of Y if the atmospheric pressure were 80 kPa, 120 kPa and 160 kPa.

F24. A car of 770 kg rests on a hydraulic piston A with a radius of 3 m. At the other end of the piston is another hydraulic piston B with a radius of 1 m.

(a) If a mechanic wants to ensure these pistons are in equilibrium, how much force should they apply on the other side (1 m side)?

(b) Suppose the radius of hydraulic piston B is changed to 2 m. Does the amount of work required to lift the car change?

F25. Suppose a glass tube contains mercury. What is the height of mercury in the column required to create a pressure of approximately 3 atm?

F26. You place a toy boat in your bathtub filled with water, such that it floats with 25% of its volume below the waterline. Calculate

(a) The density of the toy boat.

(b) Assume that you add a 2.8 kg toy passenger on this boat that results in an additional 5% of the boat that is now under the waterline. If the toy boat with the passenger on it has a mass of 12.8 kg, what is the volume of the toy passenger you just added?

F27. A certain hydraulic lift uses Pascal's principle to lift a mass X, which is placed on a piston with a cross-sectional diameter of D, and connected to another piston of diameter D/2. How much force must be applied on the smaller piston (diameter = D/2) to lift the mass?

F28. Bonnie (52 kg) and Clyde (61 kg) are on a honeymoon cruise when suddenly, the ship sinks, and they are forced to jump in the freezing ocean. In the distance, they see a small wooden plank that has broken off from the side of the cruise and wonder if they could both survive if they both lay on top of it.

(a) If this plank is approximately 1.5 m x 1 m x 0.14 m, and the density of the ocean water is 1027 kg/m^3, what density must the wood be in order to ensure their survival in the freezing waters?

(b) Suppose that the plank was made of mahogany (d = 820 kg/m^3). Will Bonnie and Clyde survive? If not, could one of them survive?

F29. Prior to the advent of digital storage systems, music was typically stored on vinyl disks. These vinyl disks can be played by phonographs, which uses a needle in contact with the surface of the disks. If the needle, whose tip has a radius of 0.33 mm, supports approximately 1.44 g, calculate the pressure exerted on the record. State your answer in pascals (Pa).

F30. A fluid exerts a force of 25 N on a surrounding area of 10 cm^2. Find the pressure exerted by the fluid in mmHg.

F31. Suppose that the inside environment of a reaction chamber has a gauge pressure of 400 atm. If the lid of the reaction chamber is 40.0 cm in diameter, how much force must the lid of the reaction chamber withstand (assume the weight of the lid is negligible)?

F32. A golf ball has a mass of 49.53 g. When submerged in a graduated cylinder, a volume of 22.0 cm^3 of water is displaced. Calculate the density of this golf ball.

F33. On Tuesday, Taylor decides to wear high-heels which cover an area of 2.25 cm^3. On Wednesday, Taylor decides to wear a different pair of high-heels which cover an area of 1.50 cm^3. If Taylor weights 58 kg, calculate the magnitude in difference between the pressure exerted on the floor by the different high-heels.

F34. When you hit a nail with a hammer, a large amount of force is exerted at the tip of the nail. This enormous amount of pressure is what drives nails through various surfaces such as wood. Suppose a force of 65,000 N is applied to a nail with a 0.5 mm radius tip. How much pressure is generated at the nail's tip?

F35. At its deepest point, the Izu-Ogasawara Trench is 9,780 m below the surface of the ocean. Assuming uniform density, calculate the pressure at the bottom of the Izu-Ogasawara trench.

F36. Tacko Fall is 226 cm tall. Calculate the difference in blood pressure in their head and in their toes?

F37. Calculate the speed of fluid moving through a pipe with a diameter of 0.5 m and a volume flow rate of 12 L/s. Convert this value into m^3/s.

F38. In a small bucket that is 0.350 m tall, you first add water so that the bucket is half full. You then fill the bucket by adding the same volume of oil (d = 590 kg/m^3). Determine what the gauge pressure is at the bottom of the bucket. Contrast this value with the gauge pressure at the interface between the oil and water layer.

F39. A narrowing pipe brings water from the basement water tank up to the 2nd floor washroom of a house (approximately 19 m). Water leaves from this pipe out of a faucet of 8 cm diameter at a speed of 8 m/s. If the initial diameter of the pipe in the basement is 14 cm, determine the gauge pressure at this initial point.

Buoyancy and Archimedes' Principle

F40. Suppose you dropped a ball (r = 0.6 m) into the pool. If the ball experiences a buoyant force of 4.44N, what is the height of the ball submerged in the water?

F41. A ship releases a gold anchor (d = 19300 kg/m^3, m = 110 kg) as it docks. If a massless chain connects the anchor to the ship, calculate the tension in the chain.

F42. A miniature basketball with a diameter of 21 cm is attached to a scale. When measured in the air, the value of the weight is 54 N. The basketball is then weighed under an unknown fluid, with a weight of 28 N. What is the density of the unknown fluid?

F43. Oh no! You just dropped your diamond wedding ring (d = 3.51 g/cm^3) into the river! Will it float? What percentage of the ring's volume will be held up by the buoyant force?

F44 A. A traitorous pirate forced to walk the plank has several iron weights attached to his ankles to make him sink. If the pirate, in addition to the iron weights, weighs 95 kg and has an overall density of 1330 kg/m^3, how much upwards force must the pirate exert to stay afloat in the water?

F44 B. A toy block, with 10 cm side lengths and a mass of 20 g is placed into 3 different liquids of unknown density. When placed in liquid A, the block floats with 250 cm^3 of its volume above the waterline. When placed in liquid B, the block floats with the tip of the block at level with the waterline. When placed in liquid C, the block sinks.

(i) What is the specific gravity of liquid A?

(ii) What is the buoyant force acting on liquid B?

(iii) Rank the liquids in order of their density from largest to smallest.

Fluid Dynamics

F45. Water from the ground floor of an apartment building flows at 4m/s through a pipe with a diameter of 6 cm.

(a) If water on the 7th floor (h = 35 m) flows through a pipe with a cross-sectional area of $10cm^2$, calculate the speed of water flow on the 7th floor.

(b) Suppose the pressure on the 7th floor of the apartment is 4.20×10^5 Pa. Calculate the pressure on the ground level in kPa.

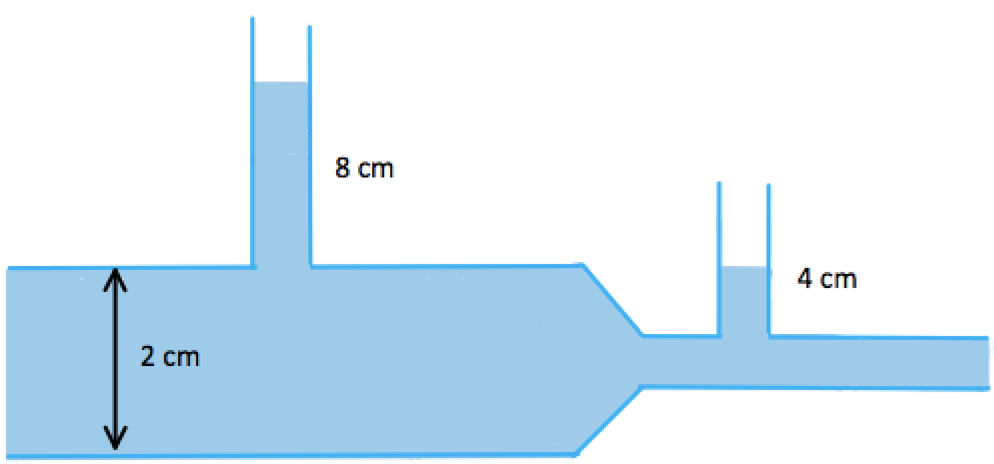
F46. Water flowing in an underground cylindrical sewage pipe flows at point A (r = 3 m) at a speed of X m/s.

(a) If the pipe expands to a radius of 6 m at point B, what is the new speed which water flows at?

(b) After 600 s, which point (A or B) of the cylindrical pipe has experienced a greater flow of water?

(c) Suppose the pipe section A expanded into two pipes sections C and D. Pipe section C has a radius of 2 m, and pipe section D has a radius of 1 m. At what speed does the water flow through points C and D?

F47. Water flows at a rate of 0.000345 m^3/s through a horizontal pipe which then narrows into a pipe with a smaller diameter. Using the small vertical tubes to provide information about the water pressure in the different size pipes, calculate the diameter of the smaller pipe.



F48. A large rain barrel has a faucet of diameter 0.045 m attached, and water leaves the faucet at a speed of 5.5 m/s. At what distance below the pipe will the cross-sectional area of the downward stream be 7×10^{-4} m^2 ?

F49. On a windy day, wind speeds reach 50.0 m/s. If the roof of your house is flat with an area of 250 m^2. According to Bernoulli's equation, what would the force be? Assume air density of 1.11 kg/m^3, a corresponding atmospheric pressure of 9.00×10^4 N/m^3, and negligible turbulence.

F50. A small teapot, with a cross-sectional area of 0.10 m^2 is slowly leaking from a hole 5 cm above the bottom. The owner, who doesn't want any tea to go to waste, places a small tube in the hole to collect any tea that leaks.

(a) Determine the tea's velocity as it leaks from the hole. Assume the tube is cylindrical, with a radius of 2 cm.

(b) Suppose that a bowl is placed 25 cm below the teapot to collect any spilt tea. How far from the teapot, horizontally, should the bowl be placed?

F51. Water is flowing through a narrow pipe that eventually opens up to a pipe with a much larger diameter. If the diameter of the pipe increases by a factor of 7/4, what impact will that have on the speed that the water travels, assuming a constant flow?

F52. Water is emptying from a large basin that is open to the atmosphere, through a hole that is X m below the top of the basin. If the water leaves the basin at a rate of 0.0390 L/s and the hole is 6 cm in diameter, determine X, the distance of the hole from the top of the basin.

F53. Suppose that a grounded supply of water supplies water to two ends of a pipe, which are at heights 60 m and 140 m above the ground. If the pressure at 60 m and 140 m are 3000 kPa and 800 kPa respectively, determine which end of the pipe will have water exiting at a higher initial velocity.

F54. A "pitot tube" is a device which can be used to measure fluid flow velocity. If the tube has a reading of 66 mmHg at a speed of 440 km/h, what will the fluid speed be at a pressure of 132 mmHg? Assume the altitude is equal.

F55. Suppose that water flowing through a body of water has a volume flow rate of 560.0 L/min with a pressure of 3.60×10^5 N/m^2. If this body of water is split, and directs flow into four separate streams each with a pressure of 8.40×10^3 N/m^2 and an equal diameter, what is the rate of flow in each of the separate streams?

F56. What is the speed of the fluid in a hose with a 4.0 cm radius carrying 60 L/s. Convert the flow rate to m^3/s.

F57. Water flows through a tube. It begins in the tube where the diameter is 0.6m and is moving at 10m/s, it then moves down by 3m in the vertical direction into a new region of the tube. What is the new speed at which the water is moving and diameter of the tube. Assume that the pressure stays the same.

F58. Your favorite goldfish tank, filled to the top with height H, needs emptying! Since you are lazy and do not want to carry it, you decide to poke a hole in it so that the water strategically goes into a bucket of your choice. However, your cousin questions your abilities, and so challenges you to send the water as far as possible. As a physicist, you laugh at her request and show her.

(a) At what height would the water that leaves the hole travel the farthest distance?

(b) How far would that distance be?

F59. Rainwater drains into an underground pipe which has a diameter of 5 m. At one point in the pipeline, the pipe bends 90° to the left (like a turn) and the diameter is reduced to 2 m.

(a) Assuming that no energy is lost as the water turns left, and the original speed of the water in the 5 m section was 15 m/s, what is the speed of the water in the 2 m turn section?

(b) Does the pressure change as the water flows from the first to the second section?

Viscosity

F60. Consider the laminar flow of water through a sewage pipe.

(a) Suppose the radius of the pipe was halved. How would the flow rate of the pipe change in this circumstance? What if the radius was doubled?

(b) Suppose the pressure gradient of the pipe was halved. How would the flow rate of the pipe change in this circumstance?

(a) Suppose the water in the pipe was replaced with some fluid with twice the viscosity. How would the flow rate of the pipe change in this circumstance?

F61. A water hose has a diameter of 1.23 cm. The flow rate through the hose is 0.408 L/s. Determine the Reynolds number for flow in the hose and classify the type of flow as laminar or turbulent.

F62. A dehydrated patient has an IV drip attached to them containing 1.5 L of saline solution ($\eta = 1.6 \times 10^{-2}$ Pa·s, d = 1037 kg/m^3) over 2 hours. Suppose that the diameter of the needle is 0.75 mm and a length of 40 mm, and the patient's veins are 84 mmHg above atmospheric pressure.

(a) If the needle is essentially horizontal, what must the pressure be surrounding the entrance of the needle (the saline side)? Assume negligible resistance in the tube connecting the bag to the needle.

(b) How high above the patient's arm should the IV bag be placed?

F63. On a summer day (20 °C), what is the maximum radius of a horizontal pipe that will maintain strictly laminar flow of water that is flowing at a rate of 2.6×10^{-2} L/s?

F64. A company which has no regard for the environment is disposing of mercury into a nearby river from their factory's sewage pipe, at a rate of 50 cm^3/min. In order to slow down the hazardous pollution as they attempt to shut the factory down, local officials increased the viscosity of their sewage pipe by a factor of 20. How will this affect the flow of mercury?

F65. A sewage pipe is clogged with inappropriately disposed waste like plastics and paper. Suppose that some waste was cleared out, increasing the radius of the pipe by 3 times the original value. How is the flow in this pipe affected?

F66. If the diameter of a tube is reduced by a factor of 4, how would the resistance of the tube change? How is resistance influenced if the diameter of the tube is doubled?

F67. Suppose that the flow rate of a pipe is a third of the original flow rate due to a change in the radius. By what factor would the radius have been changed, assuming that all other variables are kept constant.

7. Magnetism

E1. 6.0 A of current flows through a wire generating a magnetic field of 0.80 T. If the wire has loops of radius 6.0 cm, how many loops are in the wire?

E2. Two straight wires are 20 cm long, have a current of 1.1 A and 2.4 A respectively, and a force directed into the page. How far apart are these parallel wires?

E3. A 17 cm-long wire is wrapped into a solenoid. It has 410 loops and carries a current of 1.7 A. What is the magnitude of the magnetic field of the solenoid? What is the radius of the solenoid?

E4. A particle containing 2 protons and 4 electrons is traveling horizontally at a speed of 5.4 $\times 10^3$ m/s as it enters a vertical magnetic field of 0.38 T. What is the mass of the particle if it takes the particle 0.8 s to move a quarter of the way around a complete circle?

E5. A particle containing 2 protons and 4 electrons (the same particle as from E4) is moving horizontally with a speed of 1.9 $\times 10^3$ m/s in an electromagnetic region with an electric field of 5 $\times 10^{-4}$ V/m directed upwards. Determine the magnitude and direction of the magnetic field in this region.

E6. Two parallel wires are separated by a distance of 3.5 cm, with a current of 6 A running through wire 1. Determine the current in wire 2, at a point which is 4.5 cm away from wire 1 and 1.5 cm from wire 2, such that the net magnetic field is zero.

E7. Compare and contrast the motion of charged particles in electric and magnetic fields.

E8. Determine the magnitude and direction of the maximum force on a copper rod that has a charge of 0.200 μC and is moved with a speed of 6.0 m/s between a 1.8 T permanent magnet.

E9. A 0.40 μC charged particle is traveling to the East at a speed of 800 m/s over a magnetic field of 0.006 T that is pointing straight up. Determine the resulting magnetic force on this charged particle.

E10. A mad scientist is testing their newest invention, the "ProtoGun", which is a gun capable of shooting a bunch of protons in the direction it's facing. As the mad scientist starts maniacally firing protons at a speed of 800 m/s all across their room, they inadvertently generate magnetic fields by interacting with magnets scattered around the room. If these magnets all exert forces of 8 $\times 10^{-16}$ N, determine the angles of the magnets (respective to the proton's path) if field strengths of 12.5, 8.8, 6.9 and 6.3 T are produced, respectively.

E11. A particle consisting of 2 protons and 3 electrons is moving at a speed of 2800 m/s when it enters a magnetic field of 1.4-T with a magnetic force of 1.70 x 10^{-16} N. Determine the angle that the magnetic field makes with the moving particle.

E12. A proton is travelling at a speed of 6.80×10^{6} m/s in a direction perpendicular to a 5.00×10^{-4} T magnetic field. If an electron is to enter this magnetic field and follow the same path as the proton, what speed is it travelling at?

E13. What is the charge of a particle that is moving at 35.0 m/s in the Earth's magnetic field that has a magnetic force of 5.00×10^{-10} N? Assume the Earth's magnetic field has a magnitude of 1.00 Gauss and there is an angle of 34.0° between the direction of the particle's velocity and the Earth's magnetic field.

E14. A particle enters a region with a magnetic field perpendicular to its velocity and completes a circular path. If a second particle with the same mass but double the charge, enters this same magnetic field with half the velocity of the first particle, determine the ratio of the circumference of their paths.

E15. If a proton moves in a magnetic field with the same magnitude as the one in **E11**, and follows a circular path of radius 0.010 m , what speed is the proton moving at?

E16. Determine the magnetic field strength that holds a particle consisting of 2 protons and 4 electrons, moving at a speed of 6.30×10^{7} m/s in a circular path of 1.50 m radius.

E17. An ion with a mass of 2.76 x 10^{-26} kg follows a circular path with a radius of 0.275 m, while traveling in a 1.5 T magnetic field. If the charge on the ion is +2e, with what speed does it travel?

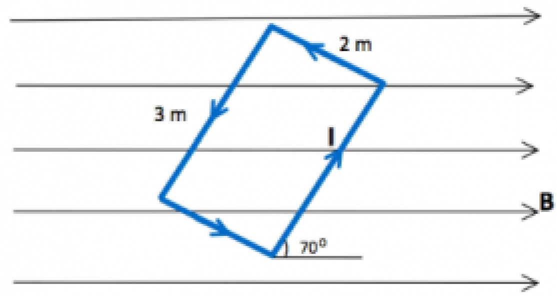
E18. A proton travels perpendicular to a 0.008 T magnetic field with a speed of 6.30×10^{7} m/s. An electric field is applied between two plates 1.5 cm apart, causing the electron to travel in a straight line. What is the magnitude of the voltage that is applied?

E19. Two singly charged ions of different mass are put through a mass spectrometer. The mass of the smaller ion is 2.66×10^{-26} kg and the mass of the larger ion is 2.99×10^{-26} kg. If they both enter a 1.40-T magnetic field with a velocity of 4.50×10^{5} m/s, what is their separation after they complete half of a circle?

E20. A mass spectrometer is being used to separate doubly charged ions of mass 2.80 x 10^{-20} kg and 2.40 x 10^{-20} kg. The ions enter the mass spectrometer at a speed of 2.8 x10^{5} m/s in a 0.300-T magnetic field. After the ions complete a semicircle and hit a detector, what is their separation?

E21. A lightning bolt strikes the equator, carrying 18,000A of current. If the current is perpendicular to the Earth's magnetic field of 5.00×10^{-5} T in a direction of due North, what is the magnitude of the force per meter and its direction?

E22. A current-carrying rectangular wire, with dimensions 20 m x 30 m is placed into a magnetic field at an angle, as shown in the diagram below. The magnitude of the magnetic force exerted on the wire is 103.3 N along the long part of the wire and 37.6 N along the short part of the wire. Given that the magnitude of current in the wire (in A) is 250X the magnitude of the magnetic field (in T), determine the amount of current in the wire and the magnetic field.



E23. You are the manager of a chocolate factory that is trying to create a new generation of robotic oompa-loompas. You realize you will require immense magnetic field strength to optimize the configuration of your precious oompa loompas.

(a) What current would you need to pass through a wire to produce a magnetic field strength of 10 T from 10m away from the wire?

(b) What shape and direction would the magnetic field lines take if the current in the wire is moving upwards?

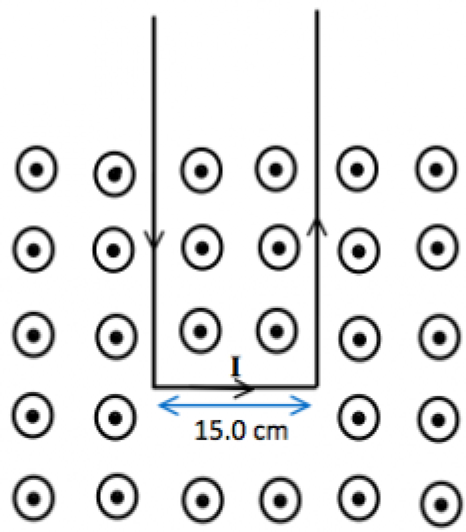
(c) Determine an equation for the force exerted by the wire as a function of its magnetic field and its current I.

(d) If the magical energy of the chocolate factory halves your current, how would that impact the final force?

E24. Magnetic fields are generated through the passage of current, or essentially, the movement of charged particles. A good example of an object which generates a magnetic field are power lines. Let's suppose that a novice engineer is making a 2 m section of a power line which carries 50 A of current. If this line section is surrounded by magnets (at an angle of 30 degrees) which exert 5 N of force on it, what is the strength of the magnetic field generated?

E25. A 14.0 cm section of wire carrying 15.0 A is in a magnetic field of magnitude 2.1-T. What is the angle between the wire and field if the resulting magnetic force on the wire is 3.1 N?

E26. In the underlying diagram, this rectangular loop carries a current of approximately 45 A. Based on the direction of the magnetic field, determine the magnitude and direction of the force felt by this particular loop.



E27. A 20-turn square loop that is 6.0 cm in width is placed in a 1.1 T uniform magnetic field. What must the current flowing through the loop be if a torque of 8.0 Nm is generated?

E28. You find yourself participating in a novel loop designing competition. The premise of the competition is as follows: you must design a square loop which experiences a torque of 1000 N/m for the following design categories. For each category, state the amount of turns (cannot be 0), current experienced (must be between 0 and 200 A), side length (minimum 2 cm), magnetic field strength (must be between 1 and 5 T), and angle between the loop and the magnetic field (must be between 30 and 90).

(a) Maximizes the amount of loops

(b) Maximizes the magnetic field strength

(c) Maximizes the side length

E29. If magnetism is closely correlated with current in a wire, then is magnetism closely related with the “current” of a single electron? That is to say, does the velocity of an electron impact its respective magnetic field? If so, what impact would doubling the velocity of an electron have on its magnetic field?

E30. A square loop, with 100 turns and a width of 8.0 cm, constantly has current flowing through. Calculate the maximum torque that can result from a magnetic field of 2.0×10^{-3} T perpendicular to the plane of the loop, if 53 A of current flows through.

E31. Two cables are 50.0 cm apart, each carrying 90.0 A of current running in the same direction. Determine the magnitude and direction of the force 35.0 cm away from one of the two wires.

E32. Two parallel wires are 3.0 cm from each other and carry current of equal magnitude but opposite direction. If the resulting force of one wire on the other is 45.0 N over a 25.0 cm section of wire, what is the current in the wires?

E33. A cable carrying 1200 A feels an attractive force coming from another cable that is 38.0 cm away. What is the current in the cable if the magnitude of the attractive force is 11.0 N/m?

E34. A segment of wire, 25 cm long, carries 60 A of current and feels a repulsive force from a parallel wire.

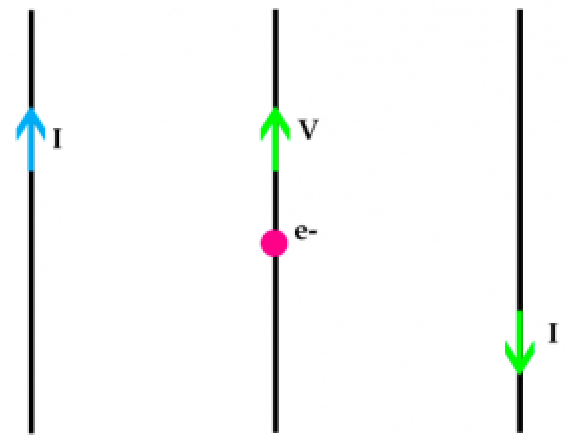
(a) What directions are the currents traveling in, relative to one another?

(b) If the wires are 5cm apart, what is the repulsive force felt by 60 A wire?

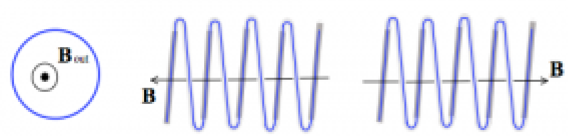
E35. As you're waiting for both your phone and laptop to charge (which are right beside each other) you notice that the charging cables are separated by an average distance of 6 cm. Let's suppose that these cables carry currents of 5 A each. Based on the direction of the currents, would you expect the force between the cables to be attractive or repulsive? Lastly, calculate both the average and maximum force per unit length for these cables.

Questions 36-40 were inspired by University Physics Volume 2. You can find the link to the full text for free at https://openstax.org/details/books/university-physics-volume-2

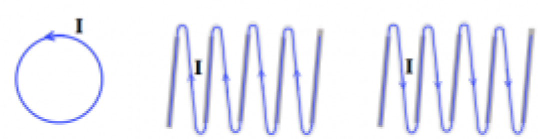
E36. In the wires below, the electric current has an impact on the direction of the magnetic field. What would the magnetic field lines look like here, and where would they be pointing to?



E37. Determine the direction of the magnetic field in the center of the coils below.



E38. Determine the direction of the current in these wires given the direction of the magnetic field shown below.



E39. A 12-turn square cable has a side length of 8 cm. Determine the magnetic field strength at the midpoint of the cable, if it carries 30.0 A of current.

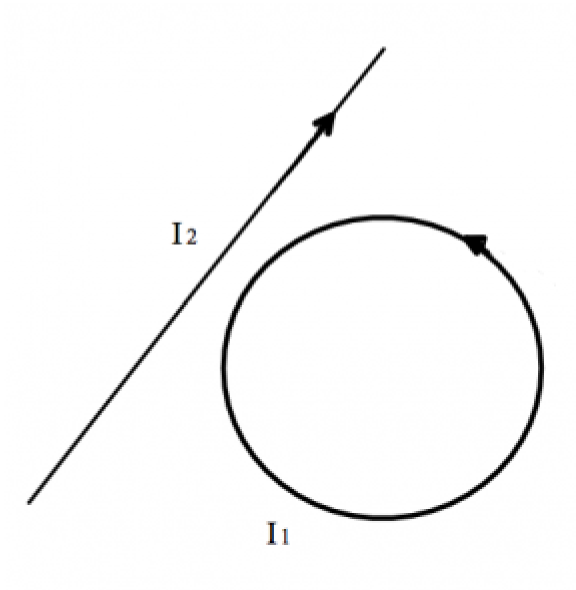
E40. A 20.0 m solenoid with 240 turns carries 18.0 A. What is the strength of the magnetic field inside the solenoid?

E41. A metal electric pole, connecting two floors of a futuristic building, carries 20,000 A of current in the vertical direction.

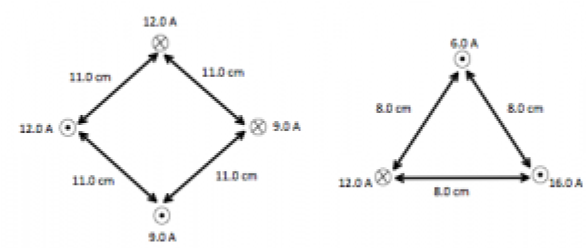
(a) How strong would the magnetic field be in an area 1 m around the wire in all directions?

(b) Where would the magnetic field be pointing up relative to the pole? Where would the magnetic field be on the left side of the pole?

E42. A current carrying loop with radius R and current I1, is very close to a current carrying linear wire, with current I2, as shown below. What is the ratio of the two currents (I2/I1) that results in a magnetic field strength of 0-T at the centre of the loop?



Use the figure below to answer the following two questions **(E43** and **E44)**. In each scenario, there are wires carrying current into and out of the page, and they are separated by a certain distance.

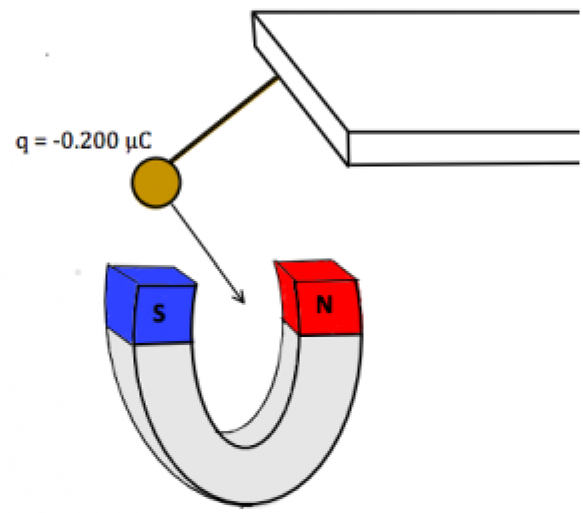


E43. Determine the magnitude and direction of the force that acts on the cable carrying 5.0A in the triangular wire configuration above.

E44. Determine the magnitude and direction of the force that acts on each of the wires carrying 12.0A in the rectangular wire configuration above.

E45. A proton travels in a circular path in a 1.30-T magnetic field. What is the direction of the magnetic field with respect to the proton and the radius of the circular path?

E46. A copper disk is released from a height of 4.5 cm above its lowest point and swings on a string between the poles of a magnet as shown below. If the disk has a charge of -0.200 μC and swings into a 1.60-T magnetic field, what is the magnetic force at the lowest point in the path?



E47. A proton is moving perpendicular to a 1.20-T magnetic field at a speed of 5.8 x 10^{-7}m/s. What is the difference in the radius of the path when compared with an electron that is moving at the same speed?

E48. A 200-turn circular wire with radius 3.3 cm carries 0.40-A of current. What is the maximum torque that can be applied to the wire in a 0.3-T magnetic field?

E49. You are skipping rocks and skip a 1.55 kg pebble coincidentally perfectly perpendicular to the magnetic field of Earth. Suppose that this pebble has a charge of 80 nC and travels 19.0 m horizontally. How much is the pebble diverted from its original path, assuming the Earth's magnetic field is 3.00 x 10^{-5} T where the pebble is traveling?

E50. A wire traveling West is carrying 5 A of current.

(a) Calculate the N/m due to a 0.01-T magnetic field directed South.

(b) If the direction of the current and magnetic field is the opposite, what is the direction of force per meter?

(c) If the wire now carries 10 A of current and the strength of the magnetic force is 0.0002 T, what is the the force per meter?

(d) Calculate the diameter of a copper wire needed to support this force and the resistance and voltage needed.

E51. A tennis machine angles a tennis ball to be launched perfectly perpendicular to the Earth's magnetic field. Upon release, it travels at a speed of 30 m/s, and subsequently experiences a magnetic force of 0.75 N. Calculate the tennis ball's charge, assuming a magnetic field of 2.5×10^{-5} T at that location.

E52. You stumble upon a particle-creating machine which can create particles with a charge and mass of your choice. Upon hearing about your discovery, a scientist decides to order a particle which will move at a speed of 7.47×10^{6} m/s in a 2.7 T magnetic field. The scientist further states that you should assume a circular path with a radius of 0.66 m. What is the ratio of mass to charge for this hypothetical particle?

E53. At what speed must a 3 metre long wire move to generate a 25 V power, sitting perfectly perpendicular to the Earth's magnetic field? Use a magnetic field value of 6.00×10^{-5} T in your calculations.

E54. What magnetic field strength is needed to get a voltage of 1 V for blood moving at 25 cm/s in a blood vessel with a radius of 0.5 cm?

E55. You're standing 40 m away from a DC power line which has a voltage of 100,000 V. To generate a magnetic field of 1×10^{-5} T, what current must be in the wire?

E56. What current is required to generate a magnetic field of 10^{-4} T, 1 m from a wire?

E57. Two parallel wires, wire A and wire B, are 1 m apart and attract each other with a force of 5×10^{-5} N/m. If the current in wire A is 5 A, find the magnitude and direction of current in wire B.

E58. What is the radius of motion of a proton in a magnetic field of 5.0 T with a velocity of 5.0×10^{5} m/s?

E59. What force is experienced by a proton and electron entering a magnetic field with a strength of 1.5 T and velocity of 4×10^{5} m/s?

E60. Solenoid A has 18 turns per meter and carries a current of 333 A. What is the magnetic field strength of Solenoid A?

E61. The Earth has its own magnetic field, which varies in strength depending on the location. Where would the Earth's magnetic field be the strongest? The weakest? Finally, consider if the magnetic field would be parallel to the ground in various locations.

E62. A magnetic field acts on a charged particle moving through some section of space. If this particle continues to move in a straight line throughout the section, what does this tell you about the direction and/or magnitude of the magnetic field acting on the particle?

E63. Can you distinguish the motion of positively charged, negatively charged, and uncharged particles in electric and/or magnetic fields? How would you do this?

E64. Consider the following scenario: Wire A and Wire B are parallel to each other and carry the same amount of current in the same direction. Using a diagram, determine if these two wires would attract each other, or repel each other. What if the wires carried currents in the opposite direction?

E65. If the magnetic field is zero, will the magnetic flux necessarily be zero as well? If the magnetic flux is zero, will the magnetic field necessarily be zero? (Hint: Analyze the equation for magnetic flux)

E66. Two parallel wires of distance d apart attract each other with a force F (N/m). If one wire has current I_1, calculate the magnitude and direction of the current in the other wire.

E67. Are alternating current (AC) and direct current (DC) wires capable of emitting electromagnetic waves? If they are capable, under what conditions would they do so? Overall, which type of wire would be more likely to emit electromagnetic waves?

E68. A powerline produces a magnetic field of 5×10^{-5} T a certain distance away. If this power line carries 600 MW at 100 kV, what is the unknown distance from the power line?

E69. Show that a proton with mass m (irrelevant here) moving horizontally when it enters an electric field E (moving vertically) will adopt a parabolic trajectory

E70. Under what circumstances would a particle with charge +q move in a circle in a magnetic field B?

E71. We discussed magnetism as being based on moving charges, and often through the analogy of current in a wire. However, if you have ever held a magnet on to a fridge, you quickly realize there is no wire inside it, nor an electric source. If that’s the case, go ahead and Google how permanent magnets actually work.

8. Electricity

Charges

G1. Two oppositely charged objects attract each other with a force F, and are separated by a distance D. What happens to the force F if we double the distance between the two objects and half the charge of each object?

G2. Two molecules, Particle A and Particle B, are a distance of Y apart. Particle A has double the charge of Particle B.

(a) Contrast the force of A on B with the force of B on A. Is the force of B on A double, the same, half, quarter, 4 times greater than the force of A on B? Justify your answer.

G3. What is the charge of a 10 kg object that, when going through an electric field of 2 N/C, accelerates at 20 m/s^2?

Parallel Plates and Electric Fields

G4. A nitrogen nucleus has a charge of +7e. Calculate the electric field strength at a distance of 1 nm from the nucleus.

G5. Calculate the electric field at a distance of 10 mm from a point charge with 4×10^{-9} C.

G6. If a point charge produces an electric field of 4E at a distance of 10 mm, what is the strength of the electric field at 5 mm?

G7. A proton accelerates in a uniform electric field of magnitude 1.14×10^6 N/C. How long would it take the proton to reach a speed of 5.3×10^5 m/s if it starts from rest?

G8. Give an example of a situation where the electric field does not create a force on an object. Draw the field lines to test your understanding.

G9. Calculate the force that an electron experiences when it passes through an electric field that is going in the positive X direction. How would this be different for a proton?

G10. A proton and an electron are held in place at the centre of a horizontal line. If the electric potential increases from left to right along this line, which direction would the proton move when it is released? What about the electron?

G11. As a mad scientist, you are playing with electric fields in your mom's basements while she goes grocery shopping. You think to yourself: "Can't I measure the weight of an object with the strength of the electric field required to carry it against gravity?". You begin producing an electric field of 100 N/C and throw an object with charge Q and mass M into the air, and alter the electric field till it floats. Calculate the mass of the object in terms of Q and the electric field strength.

G12. A parallel-plate capacitor with an electric field strength of 10,000 N/C is separated by 3.0 mm. A proton is released from rest at the middle of the plate, and moves towards the negatively charged plate. What will the speed of the proton be upon reaching the negatively charged plate?

G13. An electron is released from rest at the negative plate of a parallel-plate capacitor. Suppose that this capacitor has a strength of 25,000 N/C and the plates are separated by 10.0 mm. Upon reaching the positive plate, what will the electron's speed be?

G14. A point charge of $+1.5 \times 10^{-8}$ C is located a distance X away from an electron. If the electron is released and travels towards the point, what is the electron's speed if it is a distance 1/18 X from the point charge?

G15. What is the voltage of a 750 W toaster if it has a resistance of 20 Ω? While in use, what is the toaster's current?

G16. What is the resistance if a voltage of 11 V causes 110 A to flow through a wire?

G17. A proton accelerates from the rest through an unknown potential difference. If this proton reaches a speed of 24.4×10^{5} m/s at the end of the potential, determine the unknown potential difference.

G18. Are field lines closer together or farther apart when a field gets large? Justify your answer.

G19. Assume the voltage between two points is 1000 V. If a particle with charge C moves from one of these points to the other, what is the work done (magnitude only)?

G20. Electrons are fired horizontally at a speed of 8.67×10^{6} m/s, and pass through parallel plates (4.2 cm long) with an electric field of 9.0×10^{3} N/C upwards

(a) At the end of the plates, what is the angle of deflection experienced by these electrons fired?

(b) Assume we wanted the electrons to hit the plates. What is the maximum speed at which the electron would still collide with the plates?

G21. An electron is placed in an electric field with a magnitude of 5000 V/m, that is caused by charged plates. This electric field is travelling to the right. The plates which cause this field are 2.0 m apart. The electron starts at the right plate and moves to the left plate. How fast is the electron moving when it hits the left plate?

G22. An electron-positron pair comes into the universe! (note: positron has the same mass as the electron, but opposite charge). Assuming they are being shot out in opposite directions, what is the speed that each particle needs to escape the other when they are 100 nanometers apart?

G23. An electron enters a region with potential difference of 100 V going at a speed of 100,000 m/s. What is the final speed when the electron passes through this region?

G24. An electron with speed 1×10^6 m/s enters an electric field and stops.

(a) What causes this electron to stop?

(b) What potential difference would cause this electron to stop? What would that potential difference be if it was a proton instead of an electron?

G25. Suppose that charge “C” is travelling freely in an open space. Suddenly, it encounters an electric field moving from point B to A. Afterwards, charge “C” begins to move towards point A.

(a) Based on this information, determine the charge on point “C”.

(b) If the charge on “C” was doubled, how would that affect its movement along its path?

(c) If the charge on “C” was reversed, how would that affect its movement along its path?

G26. Two parallel plates, spaced apart by 50 cm, have a potential difference of 85 V applied. Calculate the surface charge density on the plates.

Electric Potential and Electric Potential Energy

G27. When two identical capacitors are connected in parallel to each other and then are switched to being connected in series, what would happen to the equivalent capacitance in the circuit, potential energy at each capacitor, and the charge at each capacitor?

G28. Negative point charges A and B are 22.5 mm apart. If the force between these two charges is 8.4×10^{-2} N, calculate the electric potential energy.

G29. Two parallel plates of opposite charge have a potential difference of 550 V between them. How much work is required to move an electron 3.6 mm to the negative plate, if it is initially 2.1 mm from the positive plate?

G30. If two uniformly charged electric plates have a voltage between them of 50 V and a distance between them of 1 m, what is the electric field between these two plates?

G31. What is the energy that a proton would get if it was accelerated through a potential difference of 100,000 V?

G32. What is the potential difference that is needed to stop a proton moving at an initial speed of 2.6×10^5 m/s? Would an electron travelling at the same speed require a greater or smaller potential difference to come to a stop?

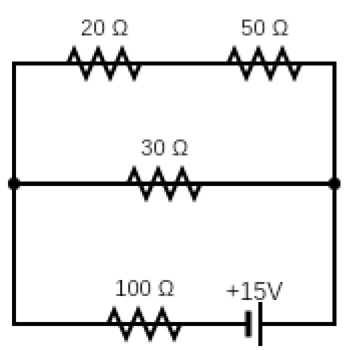
Capacitance

G33. Use the diagram below to answer the following question.

(a) Calculate the equivalent resistance of this circuit (hint, reduce this circuit).

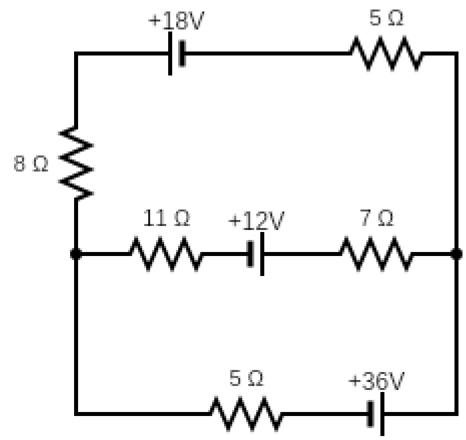
(b) Calculate the current delivered based on the equivalent resistance of this circuit.

(c) Determine the power delivered to the 30 Ω resistor.



G34. Capacitor 1 has a capacitance of 4 μF and is connected in a circuit with a second capacitor. When the two are connected in parallel, their capacitance is 4.5 times as great as when they are connected in parallel. Find the individual capacitance of the second capacitor.

G35. Find the current at every resistor at this circuit. Hint: Use Kirchhoff's rules.



G36. If the initial charge of a 20 μF capacitor is halved in 0.5 ms, what is the value of the resistor? By what factor would the resistor change if the initial charge was quartered?

G37. A 50 μF capacitor is linked to two resistors (400 Ω and 800 Ω) connected in series. What is the time constant, τ, of this circuit? What would happen to the time constant if these resistors were re-arranged in parallel?

Resistance

G38. At the bottom of a hypothetical hydropower plant, a generator converts mechanical energy from a turbine into electrical energy. Determine the resistance of the generator if 200 kV is generated as 3500 A flows through.

G39. Suppose we have three resistors. Resistors 1 and 2 are in series. Resistor 3 is parallel to resistors 1 and 2. These are the values of resistances for each resistor:

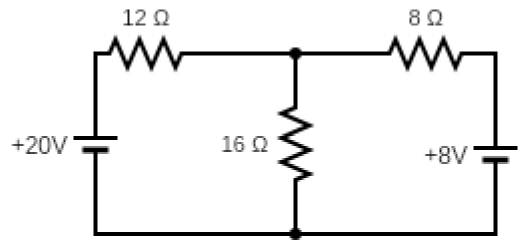
Resistor 1: 2.0 Ω

Resistor 2: 3.0 Ω

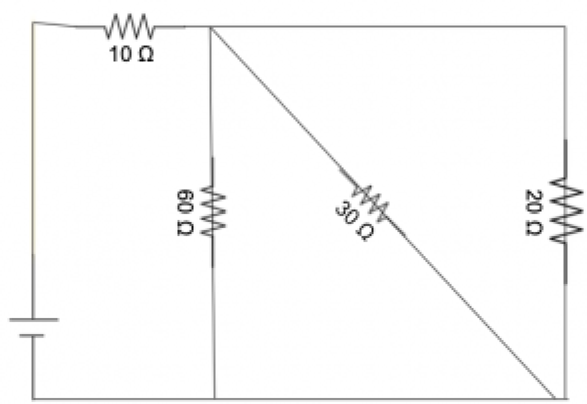
Resistor 3: 4.0 Ω

Based on these values, what is the equivalent resistance among these resistors?

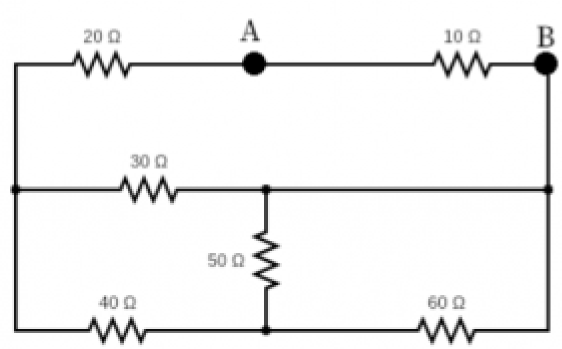
G40. Using Kirchhoff's rule, calculate the current in each branch of the circuit below.



G41. Find the equivalent resistance in the circuit below.



G42. Find the equivalent resistance between point A and point B.



G43. Two resistors are connected in parallel to a battery that has a resistance of 3.0 Ω and an EMF of 21 V.

(a) If one resistor has a resistance of 5.0 Ω, determine the energy expended in watts.

(b) If 30 W is used to power the second resistor, calculate its resistance.

G44. Suppose that a 49 W, and a 50 W light bulb are placed in series in a circuit. If the voltage source of the circuit is 100 V, determine the power consumed by each bulb. Which bulb would glow brighter? What would happen to the brightness of the two bulbs if they were placed in parallel?

G45. Electric fish have organs which can discharge shocks to stun prey. The voltage of shocks can reach upwards of 800 V, while the current can reach 1.0 A. Suppose that one species of electric fish has the best of both worlds, being able to dispense shocks and currents with both the maximum values and a total energy of 0.88 J. What is the duration of the shock?

G46. Suppose that resistors A, B, C and D have currents of 4.0 A, 4.0 A, 5.0 A, 5.0 A, respectively. If these resistors also have potential differences of 6.0, 10.0, 4.0 and 7.0 V, rank these resistors in order from largest to smallest resistance values.

G47. In the diagram below, calculate the following in order:

(a) The parallel resistance of the 20 Ω and 10 Ω circuits.

(b) Using the answer from part B, calculate the combined resistance of the 20 Ω, 10 Ω, and 8.0 Ω resistors.

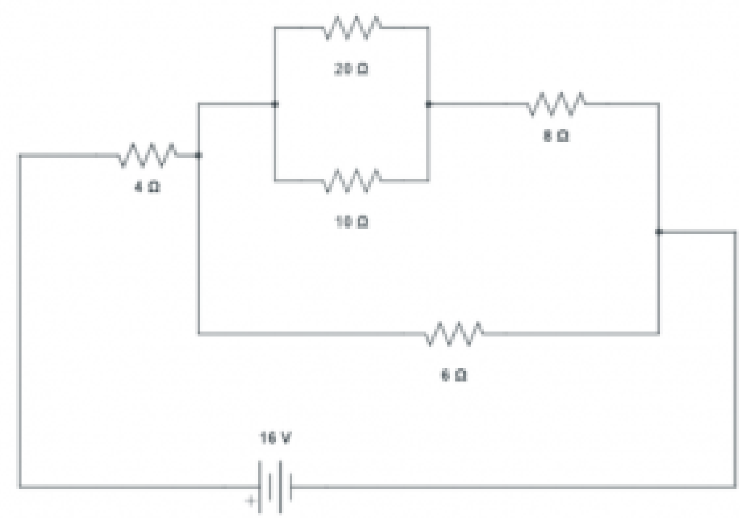
(c) Calculate the equivalent resistance in the resistors found in part B, and the 6.0 Ω resistor.

(d) Calculate the equivalent resistance of the resistors in part C with the 4.0 Ω resistor.

(e) Calculate the total current in the circuit.

(f) Calculate the current in the 6.0 Ω resistor.

(g) Find the voltage drop across the 4.0 Ω resistor.



G48. A stationary point charge of +1.5 x 10^{-8} C is located 135 cm from an electron that is released from rest. What distance is the electron from the point charge when it has a speed of 4.8 x 10^{6} m/s?

G49. Rank the following copper wires in terms of their resistance from greatest to least:

Wire 1 – radius r, length L

Wire 2 – radius 4r, length 16L

Wire 3 – radius 5r, length L/3

Wire 4 – radius r/2, length 3L/2

G50. A battery connects two wires of equal lengths, but the diameter of the first wire is twice the diameter of the second. Of the following characteristics, which ones would be the same across the two wires?

(a) Current

(b) Current Density

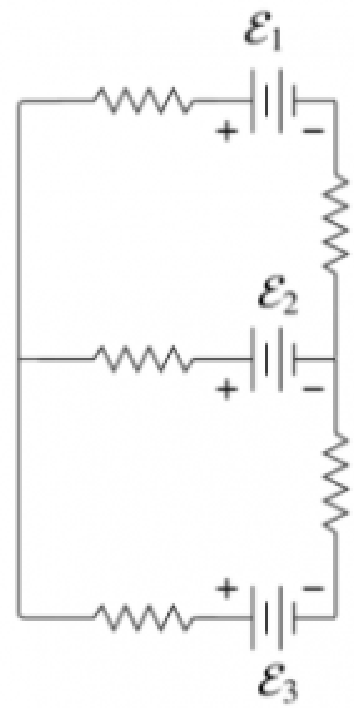
(c) Electric Field

(d) Resistance

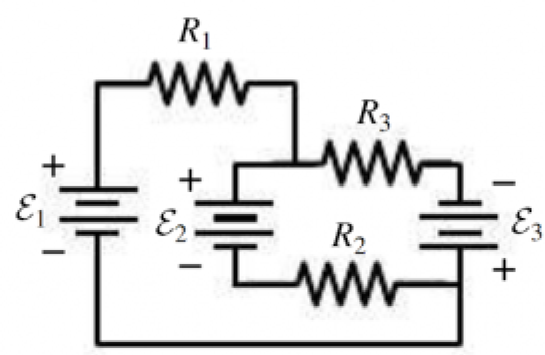
(e) Potential Difference

(f) Electron Drift Velocity

G51. The diagram below is an example of a circuit that models neurons. Each of the resistors have a value of R = 2.5 mΩ and the EMFs are $?_1 = 20$ mV, $?_2 = 35$ mV, and$\varepsilon_3 = 90$ mV. Find the current through ε_1 and its direction.

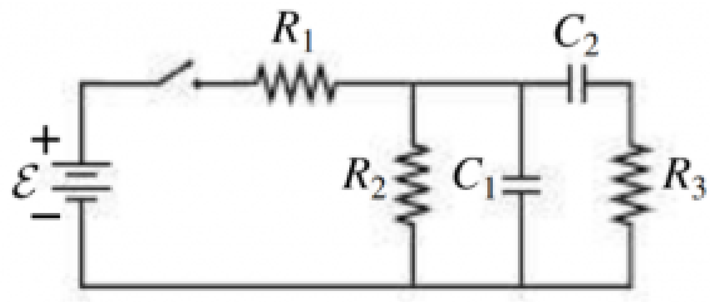


G52. The diagram below shows a schematic design of a circuit with 3 resistors and 3 EMFs. The EMFs are $?_1 = 15.0$ V, $?_2 = 10.0$ V, and $?_3 = 18.0$ V. The resistors have $R_1 = 3.00$ Ω, $R_2 = 2.00$, and $R_3 = 1.00$ Ω. Find the current through R_2 and its direction.



G53. Two resistors are connected in parallel where $R_1 = 51$ kΩ and $R_2 = 19$ kΩ. The pair of resistors are in series with a 27 kΩ resistor. What's the resistance of the circuit?

G54. In the figure below, let's imagine that the switch starts off open and both capacitors are uncharged. All resistors have the same value R (i.e. $R_1 = R_2 = R_3 = R$). Find an expression for the current in R_3 right after the switch is closed.



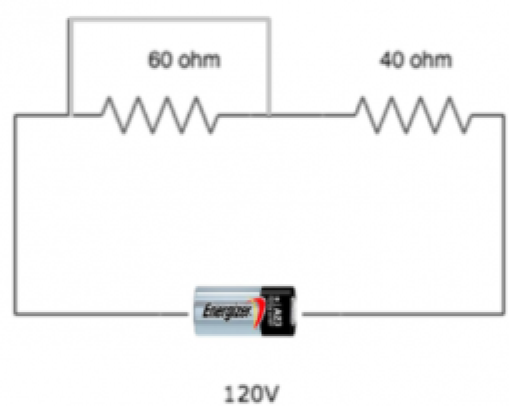
G55. Select the correct voltage across the 60 Ω resistor for the diagram below.

(a) 72 V

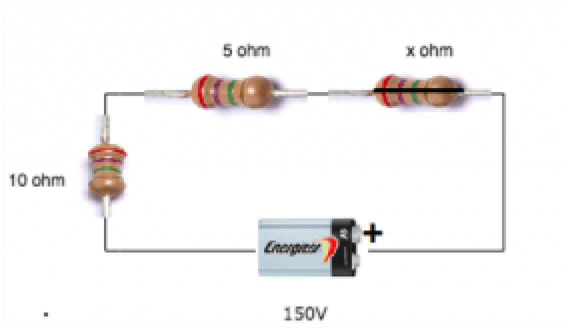
(b) 0 V

(c) 48 V

(d) 120 V



G56. What is the value of x if the current in the circuit is 5 A?



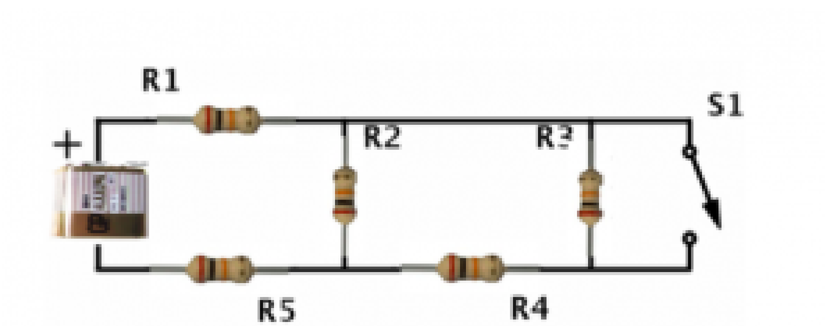
(a) 15 Ω

(b) 25 Ω

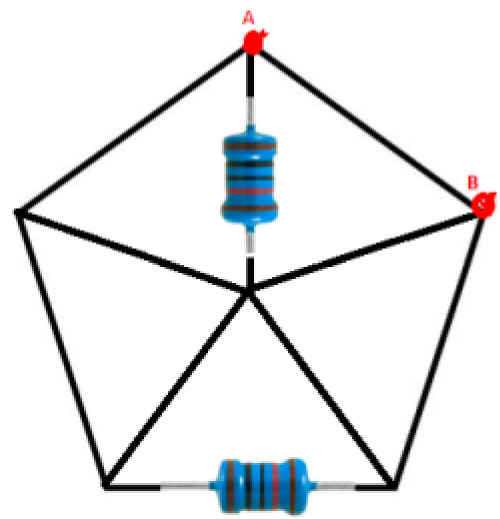
(c) 55 Ω

(d) 75 Ω

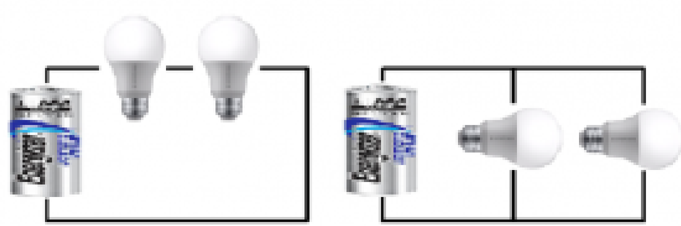
G57. Assuming all the resistors shown below are identical, what happens to the resistance if the switch (S1) was closed?



G58. Find the resistance (in Ohms) between the terminals A and B. Assume the resistance in the resistors is 5 Ω.



G59. Two identical light bulbs are connected first in a series circuit and then in a parallel circuit with the same battery. In which circuit will the bulbs be brighter? Select the correct option among (a) to (d).



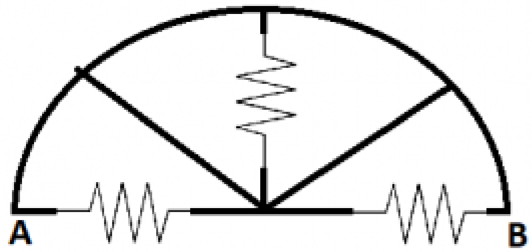
(a) The bulbs will be brighter in the series circuit.

(b) The bulbs will be brighter in the parallel circuit.

(c) The bulbs will be equally bright in both circuits.

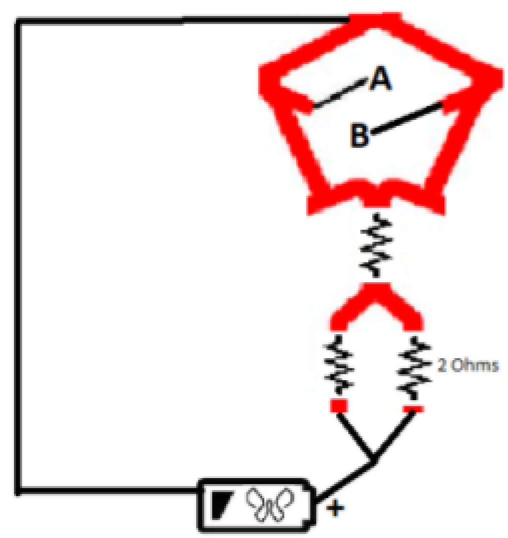
(d) There is not enough information provided to answer this question.

G60. The three resistors in the figure below are identical. Find the resistance between the terminals A and B.

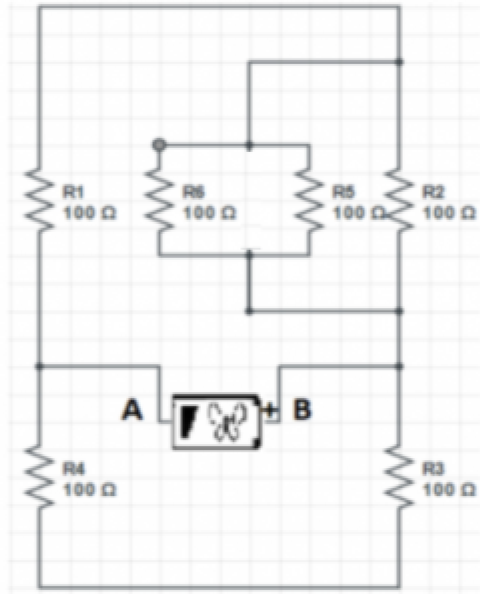


G61. If you take your fine crafted diamond long wire and expand its length by 0.5% what do you think would happen to its resistance?

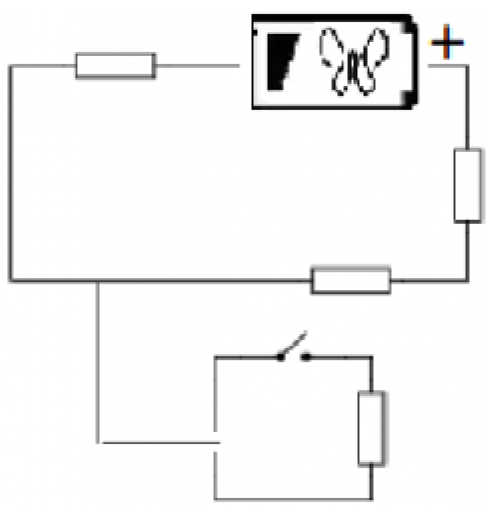
G62. Below is a segment of the Circle of Willis (the product of the articulation of the two major arteries that supply the brain with blood). Assuming we localize the resistance across the arteries to three identical resistors shown below. Find the resistance (in the form of R) across points A and B.



G63. Find the equivalent resistance between the terminals A and B in the network shown below.



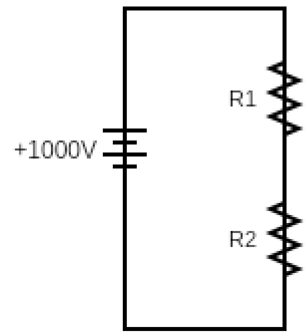
G64. If the switch in the diagram below was to be closed what would be the current and the total resistance in the circuit? Assume the WebStraw battery powers 10 V and the box resistors are 2.0 Ω.



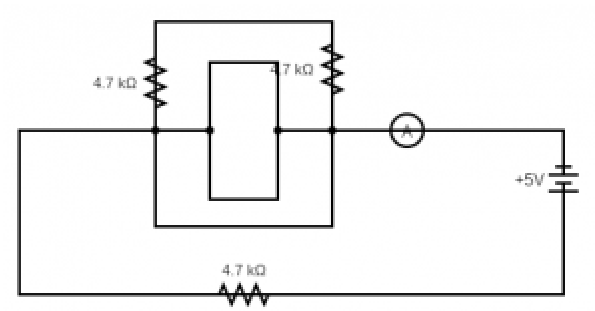
G65. If you place a voltmeter in parallel with a 5.0-Ω resistor, only 5% of the main current passes through it. Compute the resistance of the voltmeter and the current passing through the 15.0-V EMF source.

G66. A coil of metal wire has a resistance of 20 Ω at 150°C and 27 Ω at 100°C. Calculate the temperature coefficient. Do you think this is a reasonable shift in resistance?

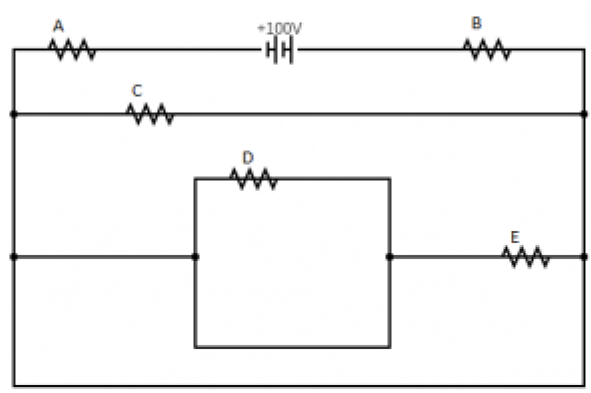
G67. In the diagram below, $R_1 > R_2$. Which of the two resistors dissipates more power?



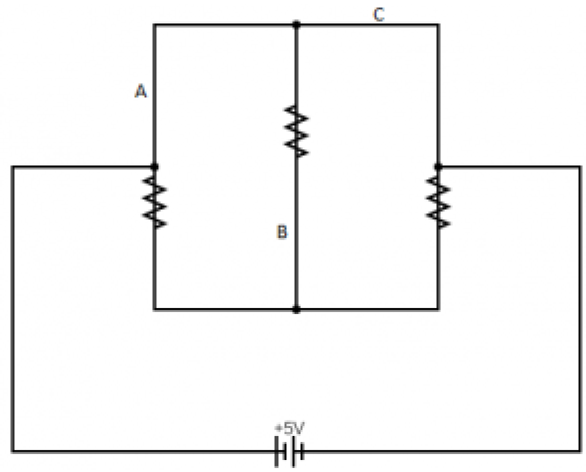
G68. Find the current that the ammeter would read in the following circuit.



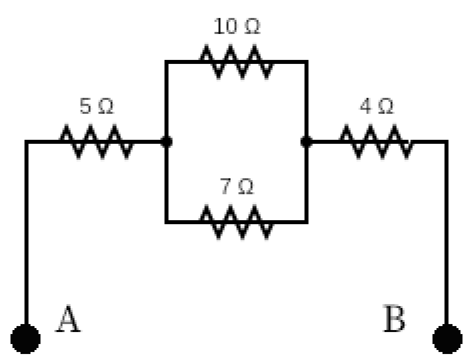
G69. Which of the following combinations of resistors (A, B, C, D, and E) are in series?



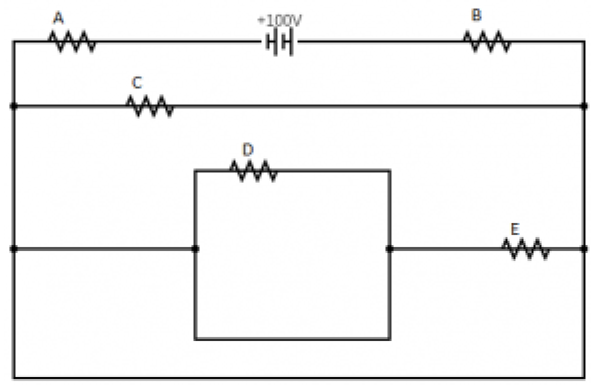
G70. Where (A, B, and C) is the current largest in the following circuit? All resistors are identical.



G71. In the diagram below, what is the equivalent resistance between point A and point B? Calculate the current in each resistor if a potential difference of V = 100 V is applied between points A and B.



G72. Which point (A, B, or C) in the circuit has the largest current?


A
+100V
B
C
D
E

9. Oscillations and Waves

General Simple Harmonic Motion (SHM)

I1. You are testing the depth of your grandma's swimming pool who lives in London Ontario. You hit a spoon at the top of the water, then using your extremely advanced sound detection technology, you hear a sound 0.2 seconds later. How deep is your pool?

I2. As a new engineer, you try to have some fun with a new elevator system you designed. As a beginner, you make sure that the elevator is moving upwards and downwards through simple harmonic motion, with amplitude 0.1 m and frequency, 4 Hz. There is a box on the floor with a mass of 1 kg.

(a) What are the maximum and minimum values for the normal force applied to the box by the floor?

(b) Using the idea of normal force, and some thinking as a young engineer, you realize that there is a certain amplitude where the box will start to float! What is that amplitude?

(c) How does doubling the amplitude affect the maximum normal force?

I3. An object of mass m is sitting on a board oscillating with frequency 3.1 Hz. Come up with an expression for the maximum possible amplitude for this board before the object begins to lose contact with the board (see question above for a similar idea).

I4. A string vibrates with a frequency of 100 Hz.

(a) What effect would increasing the tension have on its frequency?

(b) Describe in words, what it means when something "vibrates with X frequency."

(c) The vibrations of this string produce a wave with speed 500 m/s. What is the wavelength of this wave?

I5. A 5 m long, hollow tube has both ends open.

(a) What is the frequency of the air that passes through this tube if the speed of sound is 340 m/s?

(b) The speed of sound in helium is about 2.5 times that in air. How would that influence frequency? Logically, why does this make sense?

I6. A diving board with a mass of 9.0 kg, oscillates with a frequency of 30.0 Hz in SHM. If a 45.0 kg diver steps on the board, what will be the new frequency of SHM?

I7. An ancient organ pipe is open at one end and has length of L. When played, the pipe releases sound at a certain frequency. The frequency of the first harmonic emitted by the pipe is 13 Hz. The speed of sound in the pipe is 325 m/s. Calculate length L.

I8. An oscillator has angular frequency δ and amplitude A. What is the magnitude of the displacement when elastic energy is equal to kinetic energy?

I9. A man with mass M jumps onto a swing and causes it to oscillate with period T. Another man with the same mass as the original jumps onto the swing as well. With two people now on the swing, which of the following describes the new period?

(a) T

(b) 2T

(c) 1/2T

(d) New period is greater than the original, but not exactly 2T (note doesn't indicate it is 1/2T)

(e) new period is smaller than the original, but not exactly 1/2 T

(f)Not enough information to answer the question

Springs

I10. Sketch the following system and answer the questions that follow. Imagine a rectangular wall and spring box system, with the spring attached at one end to the wall, and at the other end to the box. Ignoring friction, you pull the block (m=0.25 kg) 10 cm to the right and release it to give it an angular velocity of 30 rad/s.

(a) Determine the spring constant, k.

(b) Calculate the amplitude of the oscillations.

(c) Assuming the direction "right", to be positive, at what point in the oscillation is the velocity minimum and what is the value?

(d) When, and at what points is the acceleration maximum and when is it at a minimum? Calculate the relative accelerations at these points.

(e) What is the total energy of the spring-block system?

(f) Assume that the block is released at t = 0. Write an equation which describes the position of the block in the system.

I11. How would you determine the period of oscillation of a mass (M) stuck exactly between two springs, who in turn are attached to opposite walls. Note, that when the system is in equilibrium, both springs are relaxed.

I12. A fixed wooden post and spring (k=90 N/m) are separated by a distance of 3.8 m and connected by a spring of mass 125 g. The spring is stretched a distance of 2.0 cm and the tension in the string is maintained by the spring. With what speed does the pulse propagate at?

I13. Assume you have two metal wires that are magnetic. They are each 1 m long. At the end of the wires, they are connected together by springs with a spring constant of 0.02 N/m. When un-stretched, these springs have a length of 10 cm. Whenever current travels through the loop, a magnetic force is created, and that pushes the two springs apart. How much current is required to stretch the springs to a length of 15 cm?

I14. A 2kg mass is hanging vertically from a spring. The mass is at rest when the spring has been stretched 3 cm from its original length.

(a) Calculate the spring constant, k.

(b) What is the frequency of oscillations if the spring was stretched 5cm downwards from its equilibrium position?

I15. The oscillating period of a 1.50 kg ball that is attached to a spring is 1.40 s. In order to increase the period by 0.60 s, how much mass must be added?

I16. A block with mass M is attached to a horizontal spring. The spring has mass M and the spring has force constant k. It is oscillating in a simple harmonic motion. As the block is just going through the equilibrium point, a piece of bubble gum (very big, heavy piece) lands and is now stuck to our block! The piece of bubblegum has mass m. If the original amplitude was A, what is the new amplitude after the collision?

I17. A mass of 0.450 kg is attached to a spring resulting in a spring length of 0.300 m. When a 1.85 kg mass is attached to the string, it has a spring length of 0.840m. Determine the length of the spring when there is no mass attached to it.

I18. You attach a spring to the wall out of spite after getting grounded for failing your physics test. You attach a coconut with mass M to a spring with spring constant 100 N/m to confuse your parents and display your physics skills. You stretch the spring 0.1 m and let the coconut move for 4 s. Where will the coconut be after 3 s of movement?

I19. A spring (k=180 N/m) has a cube of mass 0.4 kg attached to one end. The spring is extended 8 cm and the block is given a speed of 2.8 m/s. What is the amplitude of oscillation and the maximum speed of the cube?

I20. A 5 kg mass is attached to a horizontal spring with spring constant 20 N/m. Assume that the point x=0 is when the spring is unstretched (in equilibrium essentially). If the position of the mass at t=1 s is 0.5 m, with a velocity of 1m/s

(a) Fill in this equation with all relevant variables : $x(t) = A\cos(\omega t + \varphi)$

(b) Where is the kinetic energy of the mass the highest? What is the kinetic energy at this point?

I21. A 500 kg rhino is hanging on a bungee cord because he wanted to have the experience of a lifetime. The cord has a spring constant of 1000 N/m. To get him started warming up (rhinos get very dizzy), you pull the bungee cord 10 meters downwards past its unstretched position. After 4 seconds, you check back on the rhino!

(a) Come up with an equation that describes the rhino's motion (assume it is SHM).

(b) Where is the rhino going to be relative to the equilibrium point?

(c) How fast is he travelling?

(d) What direction is he travelling in?

I22. You're in physics class when your teacher is giving you a demonstration of simple harmonic motion. Two springs are on the teacher's desk, with unknown weights attached to the top of both springs. You notice one bounces up much more slowly than the other. Which spring has the heavier mass attached to it? Explain.

Waves

I23. What are two properties of a standing wave?

I24. Can sound waves travel through a vacuum?

I25. Why is it that tension at the middle of the rope is the average of the top and bottom, but wave speed is not? Justify your answer!

I26. A machine can produce sound frequencies between 24 and 44 kHz. Determine the range of wavelengths produced, assuming a constant wave speed of 290 m/s.

I27. You are doing an experiment with two strings. String A is 2M long, with mass density of μ = 0.001 kg/m. String B has a linear linear mass density of μ = 0.02 kg/m and is also 2M long. String B is attached to the wall, and string A is held by the young brilliant scientist (you!). You send a pulse down the string (assume tension is constant). What happens? Specifically, what happens at the interphase between string B and string A? Try to come up with a logical reason for why this works so that an 8-year old can understand it.

I28. Draw the displacement of a string, attached on both sides at f/4 and f/2. You know that at time=0, the string has maximum displacement.

I29. Two poles, 3.0 m apart are connected by two strings, each with the same tension of 800.0 N. The linear density of string 1 and 2, are 0.0040 kg/m and 0.00020 kg/m, respectively. Determine the time it takes for two simultaneously generated transverse waves to pulse past one another.

I30. An amplification of 6.0 x 10^5 times the threshold intensity is required for a lady to hear all frequencies with her hearing aid. Determine her overall hearing loss in dB.

I31. Your physics teacher shows you a cool application of waves on a string. You have a rope with length 3 m, and you calculate the tension in it being 200 N. You also guesstimate that it's linear density is 0.006 kg/m. You then impulsively pluck the string at one end! How long would it take a wave to travel from one end to another after you pluck the string?

I32. Calculate the decibels of a sound 3 times more intense than 80 db. What about 3 times less intense?

I33. Where would waves have a higher speed: a string with lower density or higher density? Assume tension is the same.

I34. A piano string with linear mass density 0.03 kg/m result in a frequency of 400.0 Hz and a tension of 800 N. Find the wavelength and the speed of the wave on the string.

I35. Your pet rope needs to enjoy its daily pulses for the day. The rope weighs 50 g, you hold it with an astounding tension force of 12,000 N. How long would it take for a pulse to travel from one end to another of your 10 m rope?

I36. Two poles support a string of length 1.50 m that travels with a wave speed of 40 m/s. Calculate the frequency and wavelength of the fourth node.

I37. From your observations, you know that 120 N will produce a transverse wave with a speed of 44 m/s in a guitar string that you are playing with. Based on this information, how much tension is required to reduce the wave's speed by 20 m/s?

I38. In a simple physics classroom demonstration, your teacher fixes a piece of string to two chopsticks, which stand vertically upwards and 2.5 m apart. Based on this setup, your teacher asks you to calculate the speed and period of a standing wave on the string resulting in three nodes and 2 antinodes, assuming the string has a linear mass density of 0.005 kg/m.

139. A 3 m long string has linear mass density of 0.0084 kg/m. Two of its resonance frequencies are 720 Hz and 840 Hz, with no frequencies found in between. Calculate the following:

(a) Speed of the wave that would be created on the string

(b) Tension in the string.

(c) The effect of doubling wave speed on tension.

(d) What would happen to the tension if the gap between resonant frequencies was increased? (higher frequency gets bigger, smaller frequency gets smaller). Why is this the case?

140. A buoy attached to a large boat moves up and down in 0.80 s when traveling at 23.0 m/s in the same direction of the wave. When traveling in the opposite direction of the wave, it moves up and down in 0.6 s. Calculate the wavelength of this wave.

141. How would the frequency of oscillations differ between a regular pendulum and one in free fall?

142. If you have two pipes of equal length, but one is closed on one end, and the other is open on both ends, which pipe could produce the lowest frequency?

143. If a transverse wave travels through a rope with speed 15 m/s and there is tension T, how fast does it travel when tension is:

(a) 2T

(b) T/2

[c] What's the logic behind these changes ?

144. A wave is described by the following equation:

$y(x,t)= 10.00\text{m} (\cos 2\pi(x/10 \text{ cm} - t/300 \text{ s}^2))$. Using this equation, calculate the following:

(a) Wavelength

(b) Amplitude

(c) Frequency

(d) Speed and direction of propagation

145. A heavy rope is 10 meters long and weighs 20 N. You decide you want to hang it on the ceiling to make your mom mad at you because you are too tired to do your physics homework. You then tie a 1 kg mass to the bottom of the rope. Calculate the speed of a transverse wave:

(a) At the top of the rope

(b) At the middle of the rope

(c) At the bottom of the rope

146. The motion of a particle is given by the expression 10m(cos10t), where t is seconds.

(a) What should be on the left side of that equation? Be aware that this equation should be relevant to this chapter.

(b) What is the first time where the kinetic energy is twice the potential energy? What about half the potential energy?

(c) At which point is the kinetic and potential energy the same? Can you think of a way to change this point?

147. A nearby truck is pretty loud. The sound it makes travels through a sinusoidal wave with source frequency fs= 400 Hz. Assume speed of sound in air is 340 m/s. Calculate the frequency you hear (hint, Doppler effect):

(a) When both you and the train are at rest

(b) When you move towards the train at 20 m/s.

(c) When the train moves towards you at 20 m/s

(d) When the train moves away from you at 20 m/s.

(e) When you move away from the train at 20 m/s.

(f) When you both move 20 m/s away from each other.

(g) When you both move 20 m/s towards each other (but making sure not to collide! Safety first).

148. You decide to create a transverse wave by fixing one end of a rope to the wall, and moving the other end up and down.

(a) Describe the motion of the medium's particles and the wave itself, relative to the direction of propagation.

(b) Consider different sections of the rope. Does each section share the wave's period, or does it have its own distinct period?

(c) Suppose you decide to increase the amplitude of the transverse wave. How is the wave speed affected?

I49. Two stationary observers are stationed on either side of a source moving at constant speed (essentially, the source is moving away from one observer.) They both experience the Doppler effect. Who will experience the highest frequency, and who will experience the lowest frequency? How come?

Pendulums

I50. How does length affect the action of pendulums? If we have a pendulum A with length L, and a pendulum B with length 2L, how many oscillations will pendulum B complete for each full oscillation of pendulum A?

10. Optics

Conceptual Questions

J1. What is the difference between a real image and a virtual image? How can you tell whether an image will be real or virtual?

J2. A ray of light crosses the boundary between ice (n = 1.31) and air (n = 1.00). If the ray of light travels initially through the ice, will the ray bend toward or away from the normal as it crosses into air? Illustrate this using a ray and wave fronts.

J3. When a ray of light crosses the boundary between two mediums, what characteristic(s) of the ray change and what characteristic(s) remain constant? What is the relationship between any changing characteristics?

J4. If a lens has a focal length that is negative, is it a diverging lens or a converging lens?

J5. How far from a converging lens should an object be placed so that the image is *not* real and inverted?

J6. A patient has a near point of 1.5m. Is he nearsighted or far sighted? Should the corrective lens be converging or diverging?

J7. LASIK eye surgery is used to correct the shape of the cornea to allow for correction of vision. If the doctor needs to correct nearsightedness in a patient, how should they reshape the cornea?

J8. A lens with a certain power is used as a simple magnifier. If the power of the lens is quadrupled, how is the angular magnification affected?

J9. Why does white light become split into the different colors of the rainbow when it passes through a water droplet (hint; different wavelengths for different colors)?

J10. Flat pieces of glass (like windows) are often related to a lens with an infinite focal length/radius of curvature. Where do these pieces form an image? How are do and di related for these "lenses"?

J11. What are some similarities and differences when comparing the eye against a camera? Hint: Breakdown each part like the iris, retina and cornea of the eye.

J12. Jisoo is a farsighted individual, the nearpoint / farpoint is located closer than infinity / 25.0 cm from her eyes while the corrective lens should be converging / diverging.

J13. Bit-na is a nearsighted individual, the nearpoint / farpoint is located closer than infinity / 25.0 cm from her eyes while the corrective lens should be converging / diverging

J14. While Somi started swimming she realized that she was unable to see clearly beneath the water, everything seemed to be blended and blurry. Why do her eyes react in such a way? What is the potential solution?

Snell's Law

J15. You are standing outside of a pool of water (n = 1.33) that is 3.2 m deep. At the bottom of the pool, you spot a coin. If you are 1.6 m tall and you are standing 45 cm away from the edge of the pool, what is the minimum distance the coin can lie from the wall of the pool?

J16. A ray of light of wavelength 500 nm travels through two media. It begins by travelling through water (n = 1.33) and then crosses into diamond (n = 2.42). In which medium is the 500 nm ray travelling faster and by what factor more?

J17. On a frozen lake, a 620 nm ray of light travels through the air to refract through a thin layer of ice (n = 1.31) from an angle of 38.0° above the horizontal. After travelling through the ice, the ray of light refracts once more to travel through the water (n = 1.31) below the ice. By how much is the ray of light deflected from the normal when it passes from the ice into the water below? What is the ray's final speed?

J18. Imagine that a beam of monochromatic light travels through the air and shines upon a flat surface of glass at an angle of 60° with the normal. The reflected and refracted beams are perpendicular to each other. What is the index of refraction of the glass?

Total Internal Refraction

J19. A Google satellite travels 300 km above the earth and is used to capture images for Google Maps. It has a camera with a lens diameter of 40.0 cm. If the angular resolution of the camera is limited by diffraction, what is the estimated separation of two objects on Earth's surface that are in the yellow-green light range (λ=500nm).

J20. You are underwater (n=1.33) looking above the water into the air (n=1). At what angle (relative to the surface of the water when looking from below) are you unable to see the surface anymore (aka, what is the critical angle)?

J21. Elon Musk builds a telescope (w/ 10.0 m diameter) on Mars, under the lighting conditions of 600nm, what is the minimum separation that can be identified between two objects on Earth (3.91×10^8 km away)?

Mirrors

J22. A concave mirror has a focal point of 0.87m. What is the radius of curvature?

J23.

A 5cm tall action figure is 20 cm away from a concave mirror with a focal length of 14cm.

1. Draw and label a ray diagram.
2. Find the distance and height of the image produced.

J24. A convex mirror is 10cm away from a thumbtack that is 2cm tall. If the radius of curvature is 26cm, find the location of the image. Consider using a ray diagram to verify any calculations.

J25. A concave mirror is 5cm away from a small ladybug. The ladybug is 2cm tall and the focal point of the mirror is 3cm. When the ladybug looks into the mirror what height will the lady bug see itself at?

J26. You are at a fun house and see a massive mirror, the magnification is said to be 20. You are 120cm tall yourself. What is the height you appear to be? If you are 100cm away from the mirror what is the distance of the image to the mirror?

J27. Predict the general distance between the mirror and the object for the following scenario: an object sits in front of a concave mirror, producing a real and inverted image. Where specifically is the object originating from.

J28. A mirror gives a positive value for magnification, exploring the possibilities of what distances and heights could allow for this positive magnification.

J29. An image, if real and inverted, comes up with a scenario of how an object and specific mirror could lead to this outcome. Consider drawing a ray diagram to illustrate how a real and inverted image could be produced.

J30. You are working as an intern for a mirror company, the company caters to customers specific optical requirements. You are pitching a customer and they ask you on the spot that they want a upright and virtual image produced from a mirror, what mirror would you suggest them purchasing, and where should they stand in order to see their image as upright and virtual?

J31. An object is 10cm in front of a convex mirror. If the image produced is located 5cm behind the mirror, what is the focal point of the mirror?

Lenses

J32.

A 10cm high flower is placed 30cm away from a positive convex lens with a focal length of 12 cm.

a. Draw and label a ray diagram.

b. Find the distance from the lens to the resulting image.

c. Calculate the magnification of the image.

d. What is the height of the image?

J33.

A 24cm ball is 60cm away from a concave lens with a 35 cm focal length.

a. Draw and label a ray diagram.

b. Is the image real or virtual, what is the distance of the image from the lens?

c. If the ball deflated to 10cm would the location of the image change? Why or whynot, if so, by how much?

J34. A 10cm tall picture is standing upright in front of a concave lens with a focal length of 20cm. An image is produced 12cm in front of the lens. Where would the standing picture be located with respect to the lens in order to produce this image?

J35. An object produces an image with a height of 10cm. The magnification is 30. What is the height of the object?

J36. An object that is 5cm upright and 15cm in front of a convex lens with a focal length of 10cm produces an image. Use a ray diagram to estimate the location and nature (i.e. real or virtual, upright or inverted) of the image. Confirm the answer by calculating a numerical value.

J37. A convex lens has an object placed at d away from it, the image produced is located at 3d. What is the magnification of the lens? What does this magnification mean in terms of the image height?

J38. An object is located 6cm away from a concave lens, the lens has a focal length of 20cm. Where does the image end up?

J39. Natasha is currently learning about optics and how to estimate various parameters relevant to lenses using ray diagrams. Her fellow classmate Eddie, a veteran in the ray diagram drawing game, suggests that she always draw a diagram before she attempts to solve, so she will be better able to see if her calculations are correct. Use Eddie's advice, draw a ray diagram for the following situation and write a statement that estimates the location and nature of the image produced: a paperclip with a height of 1.5cm sits 4.5cm away from a convex lens with a focal length of 3cm.

J40. If a lens has a focal length of 12cm, a magnification of 24, and a height of an image of 48cm, and a distance from the object of 3cm in front of the lens. What information is missing to solve for the distance of the image, is there a way to solve as is?

J41. The Popeye refracting telescope has a 2.00 m diameter while also having its objective focal length at 25.0 m. The NASA space team uses its classic 3.0 cm focal length eyepiece, what would the magnification of Pluto be seen through Popeye and would the image be upright or upside down?

J42. During the Bio1001 lab students use a simple magnifier to examine a culture of yeast. The culture is held around 4.0 cm in front of the lens while the image is formed 45.0 cm away from the eye. What is the focal length of the lens and angular magnification?

J43. The overall magnification required by the Lebron Lab on compound microscopes is 300x. The objective lens alone produces a magnification of 15x, what focal length would be required on the eyepiece?

The Human Eye

J44. What is the length of the image on the retina of a 10cm long human hair, held at arm's length (60cm) away? Assume the lens-to-retina distance to be 2cm. As you move the hair closer to your eye, does the image get larger or smaller? Explain why (consider drawing ray diagrams to justify your answer!).

J45. If a patient has myopia, should they be prescribed a diverging or converging lens? Explain why with a ray diagram.

J46. If a student who is farsighted wears glasses that allows him to see objects 20cm away from his eyes, and his near point distance is 63cm, what is the refractive power of his glasses (assume 1.5cm glasses-to-eye distance).

J47. A runaway prisoner was deserted on Angel Island after escaping Alcatraz prison, he managed to smuggle some glasses before escaping the prison. The power of the lens was +1.8 diopters and +3.6 diopters. What is the maximum magnifying power he can create with the lens to lookout for officers who are on the hunt for him?

J48. The TWICE-beta telescope has a focal length of 750cm. If using the telescope to observe the moon, how long would a 2.0 cm long image correspond to the actual distance on the planet-beta9 in kilometers (distance between earth and the planet-beta9 is 3.8×10^8 m)?

J49. While stranded on an island, Yuqi uses her eyeglasses as a magnifying glass to generate a fire 10.0cm away. Yuqi's eyes have a near point of 20.0 cm. What is the potential max magnification her glasses can generate to help kindle a fire?

J50. Seulgi's near point for her eyes is 45.0 cm. What power should her optometrist prescribe her so she can see in at 30.0 cm? After prescribing the corrective lens, Seulgi can now see clearly for objects at 33.0 cm but not at 30.0 cm, how many diopters did the machine grinders cause?

J51. Jennie's profession requires her to perform lots of tasks in dim conditions causing difficicy in her eyesight where she is unable to see clearly beyond 30.0 cm. Lisa, her best friend and optimistic, is wondering what power and lens could help her correct her vision?

J52. The near point of Rosé' eye is 70.0 cm. To see objects with clarity 25.0 cm away, what should be the focal length and power of the appropriate corrective lens?

J53. Jennie cannot see beyond 10.0 cm from their eyes. What lens power would be needed to correct her vision and the type of lens required (diverging vs converging)?

J54. The accommodation limits for Lisa's nearsighted eyes are 20.0 cm and 60.0 cm. If wearing her glasses, objects far away can be seen clearly. What is the minimum distance she is able to see objects clearly?

Interference

J55. Red light (ƛ = 620 nm) is passed through 2 slits that are 3.0 x 10-4 m apart. An interference pattern is seen on a wall that is 4.0 m away.

a. At what angle (to the central maxima) would you find the fifth order minima?

b. How far is it from the third order minima to the third order maxima (on the same side)?

c. If the light source was changed to blue (λ = 475 nm), by how much would the second order maxima move, and in which direction (relative to where it was for the red light)?

11. Answers

Kinematics

A1. 2.15km/h, 0.597m/s

A3. 2700kg/m^3

A5. 1.47X

A7. a) N seconds b) (2/3)N seconds

A9. 3.13m

A11. 250,000 years

A13. 9.41m/s, 80.63 degrees South of West

A15. 13.44 degrees East of South

A17. 2.55 m/s

A19. a) -0.6 m/s^2 b) initial velocity = 60m/s, final velocity = 0m/s

A21. a) 56.57s b) 567.7 m/s (downwards) c) 93257.65 m

A23. 360,000km/hr; mom was not correct

A25. 0.81 m/s^2

A27. a) 19.5/X m/s b) No additional variables needed but other answers possible

A29. 0.162 m/s^2, 8.98m

A31. -1.6 m/s^2

A33. Long written explanation

A35. top speed = 55.56 m/s, acceleration = 11.1 m/s^2

A37. a) final velocity = 9.9 m/s; bird survives b) final velocity = 17.15 m/s; bird dies

A39. functions in solution

A41. 0.02 hrs or 1.2 minutes

A43. a) 108 km/hr b) 0.28 m/s^2 c) 38 m/s

A45. 24.5s

A47. 60m

A49. a) 9.0 m b) 30.36 degrees to the left of the normal, velocity = 2.0 miles/hr c) 15.6 s

A51. a)2.7s b) -5.4 m/s^2 acceleration c) 3.3s

A53. 3.5s

A55. a) 25 m b) duck survives

A57. 99 m/s

A59. Acceleration is directed downward and due to gravity

A61. 6.7 m/s

A63. She clears the target and ends up at (163.3m, 40.8m) position

A65. 44 degrees

A67. 20 m/s

A69. Vector sum of X or Y component of velocity are neither parallel or perpendicular to acceleration

A71. Considering acceleration is constant in y-direction and velocity is constant in x-direction, acceleration should be directed downward

A73. Longer solution provided on the website

Forces

B1. M will slide to the right, in the opposite direction to m

B3. reaction force will not interfere with the action force

B5. More successful

B7. Option C

B9. paper airplane will eventually come to rest on the ground

B11. Longer solution provided on the website

B13. a) 60 m/s^2 b) 15 m/s^2 c) 120 m/s^2 d) 30 m/s^2

B15. 2.9 m/s^2

B17. a) 1.7 x 10^3 N b) 1.3 x 10^3 N c)2.0 x 10^3 N

B19. 8.4 m/s^2 [up]

B21. a) b) 64N c) 1.9 x 10^3 N

B23. a) 2.7 x 10^2 N b) 2.9 x 10^2 N b)

B25. 150 N, 570 N

B27. 490 N

B29. 9.1 x 10^3 N [opposite to motion]

B31. Yes, object with steeper slope is heavier

B33. 1.6 x 10^3 N [opposite to motion]

B35. 33 N

B37. 27 m/s^2 [60.$^\circ$ below the horizontal]

B39. a) 49 N b) 1.5 m/s^2 c) wagon: 3.3 m/s^2; mass: 6.6 m/s^2

B41. a) 20 N b) 3.3 m/s^2 c) 20N d) 1.3 m/s^2

B43. 40 m

B45. a) 3919.7N b)78.39 m/s^2

B47. 6.73 m

B49. 0.26

B51. 12.9 m

B53. 0.84

B55. (-5/38)v^2 toward left

B57. -0.16m/s^2 with A going downward and B going upward

B59. block stays stagnant a = 0 m/s^2

B61. a = 0 m/s^2, under assumption if initially at rest

B63. 0.67 kg

B65. 28 kg

B67. 0.08

B69. a) F_c= mv^2/r b) v_{min}=7m/s c) w= 7 s^{-1}

B71. v_{max}= 15.3 m/s

B73. a) double acceleration b) halved acceleration

B75. friction = a/g*cos(theta) – tan(theta)

B77. a) a= [(m1+m2)sin(theta) – (μ1m1+μ2m2)cos(theta)]g/m1+m2 b) a= g(sin(theta)-μcos(theta))

Momentum

M1. 50%

M3. 3:1

M5. v_1 = 1/2V; v_2 = – 1/2V

M7. Option B

M9. Longer solution provided on the website

M11. 4 m/s [toward bowling ball]

M13. 0.033 m/s

M15. 0.08 kg·m/s

M17. 4.4 kg·m/s

M19. 6 x 10^2 kg·m/s [down]

M21. 7.2 m/s [same direction as truck was originally]

M23. 0.034 m/s [forwards]

M25. a) 19 m/s b) 8.0×10^{-3} m/s opposite of bullets motion

M27. (mp vpf)/(vbi + vpf)

M29. a) 16 m/s b) 19 m/s

M31. 30 N onto ball

M33. a) 17000 kg·m/s directed 40 degrees east of south b) 41km/hr (54 degrees east of south)

M35. approximately 4.0 m/s north

M37. 4.4 m/s north relative to the ground

M39. 3.8×10^{-3} s

M41. 3.0 kg

M43. 116 m/s 0.21 degrees

M45. 18 km/hr

Energy

C1. James misses the rope

C3. 1.5×10^{4} W

C5. Longer solution provided on the website

C7. 760 W

C9. Longer solution provided on the website

C11. a) 31 m/s b) 8.0s

C13. 0.3 m/s

C15. 0.26 m

C17. 34.0 m/s for both

C19. Longer solution provided on the website

C21. 3/(√2)

C23. Longer solution provided on the website

C25. 1.6 x 10^2 W

C27. a) 240Nm against upward motion b) 69Nm with upward motion

C29. work done by gravity was -670 Nm and by friction was -920Nm

C31. 135 J

C33. 1.3 m

C35. 210 N

C37. Longer solution provided on the website

C39. 6.1 m/s

C41. The ball will not reach the spring on the other side. It only reaches 1.8 m high

C43. 15.0 J

C45. 62.0 J

C47. 2.6 m

C49. Sixteen-fold increase in kinetic energy, no change to potential energy

C51. Object raised to 2h must be half the mass of the other object

C53. Longer solution provided on the website

C55. Option b

C57. way up: -4.3J; max height: 0 J; way down: 15J

C59. 2.0 x 10^3 m

C61. $\Delta d = 0$, therefore neither does any work

Rotation

D1. Ball B

D3. Clockwise

D5. Yes

D7. Longer solution provided on the website

D9. Solid sphere, solid cylinder, hollow sphere

D11. Velocity and acceleration vectors point down

D13. Angular speed will decrease

D15. 3:5

D17. a) To the left b) Coming out the page

D19. a) 20π rad/s b) 7.90 m/s^2, 0.806

D21. 7.73s

D23. a) 19.5 m/s b)

D25. -0.24 rad/s^2, 3.925s

D27. 31.55 J

D31. I_2 is 4x greater

D33. a) v=√10gh/7 b) w=√1-gh/7r^2 c) Q=27R'/10 d) Q'=5R'/2

D35. Kinetic energy of the empty can is 4x greater

D37. 6.24 m/s

D39. a) t_c=2.71s > t_s= 2.83s b) v_s=9.9m/s > v_c= 8.9 m/s

D41. a) a=2.27 m/s^2 b) F=2.27*m N c) μ = 0.29

D43. I = 243.4 kg·m^2

D45. F_{net} = 0 N

D47. $\alpha_{small} > \alpha_{large}$, therefore larger wheel require greater force

D49. $T_B > T_A = T_D > T_C$

D51. 0.42 m

D53. 42.9% from right end

D55. C is 14.3% from right end

D57. $Child_2$ sits 4.57m from left end

Fluids

F1. higher altitude = lower density

F3. Water reduce weight causing pressure on vessel

F5. downward force is changed by addition of gravitational force

F7. area increases

F9. both object displace same volume of water

F11. pressure is forced to increase to balance

F13. boat in freshwater float less leading to more submerged

F15. objects are pulled out to balance the difference in pressure

F17. reducing area increases velocity by principle of continuity

F19. 1.9% of the object is floating

F21. 101.3 kpa, 1.01 bar, 1.0 atm

F23. @ 80 kpa h=2y , @ 120 kpa h=3y, @ 160 kpa h=4y

F25. h = 2.28 m

F27. require x*g/4 N of force

F29. exert $4.13*10^4$ Pa

F31. $F = 5.06 \times 10^6$ N

F33. $\Delta P = 126.3 \times 10^4$ Pa

F35. 9.59×10^4 kPa

F37. 0.06 m/s

F39. 215 kPa

F41. 1022 N

F43. 28.5%

F45. 11 m/s, 760 kPa

F47. 1.8 cm

F49. 2.3×10^7 N

F51. velocity changes by a factor of 49/16

F53. velocity at end that is 140m up is faster

F55. 140 L/min

F57. v_2 = 13m/s and d_2=0.53 m

F59. 94m/s; pressure does change

F61. 42100, turbulent flow

F63. 8.3×10^{-3}

F65. decreases by a factor of 9

F67. the radius would need to change by a factor of 1/(sqrt(3))

Magnetism

E1. 1.3×10^4 loops

E3. $5.3 \text{ X } 10^{-3}$ T; 6.6×10^{-5} m

E5. 2.6×10^{-7} T [out of the page]

E7. Longer solution provided on the website

E9. 1.9×10^{-6} N [South]

E11. 16°

E13. 2.55 x 10^{-7} C

E15. 1.3 X 10^{6} m/s

E17. 4.7 X 10^{6} m/s

E19. 0.0134 m

E21. 0.90 N

E23. a) 5.0 x 10^{8} A b) Concentric circles; counter-clockwise direction from top view of wire c) F = ILB sinθ d) Force is likewise halved

E25. 45°

E27. 1.0 x 10^{2} A

E29. Longer solution provided on the website

E31. 6.2 x 10^{-3} N towards the wire it is closer to

E33. 17416.67 A

E35. attractive; 8.33E-5 N/m

E37. Longer solution provided on the website

E39. Longer solution provided on the website

E41. a) 0.004 T b)

E43. 0.00022 N/m, 36.87 degrees CCW from line connecting it to 16 A wire

E45. 1.2 m

E47. 1840x greater radius for proton

E49. 1.3 x 10^{-12} m

E51. 1000 C

E53. 138888.9 m/s

E55. 2000 A

E57. 50 A, in same direction as A's current

E59. 9.6×10^{-14} N

E61. Longer solution provided on the website

E63. Longer solution provided on the website

E65. Longer solution provided on the website

E67. Longer solution provided on the website

E69. Longer solution provided on the website

E71. Longer solution provided on the website

Electricity

G1. Longer solution provided on the website

G3. 100 C

G5. 359600 N/C

G7. 4.8×10^{-9}s

G9. Longer solution provided on the website

G11. QE/9.8

G13. 2.19×10^{5} m/s

G15. 122 V, 6.12 A

G17. 31070 V

G19. 1000 x C

G21. 1.38×10^{6} m/s

G23. 170768 m/s

G25. Longer solution provided on the website

G27. C_{eq} halves. Energy decreases by a factor of 4. Charge at each capacitory plate doubles

G29. 8.8 x 10^{-17} J

G31. 1.6 x 10^{-14} J

G35. 2.9 A; 0.42 A; 3.3 A

G37. Time constant decreases if in parallel

G39. 2.2 Ω

G41. 20 Ω

G43. a) 88 W b) 15 Ω

G45. 1.1 ms

G47. a) 6.67 Ω b) 14.7 Ω c) 4.26 Ω d) 8.3 Ω e) 1.9 A f) 1.4 A g) 7.6 V

G49. Wire 4 > Wire 1 = Wire 2 > Wire 3

G51. 3.3 A, moves from positive terminal to negative terminal

G53.

G55. Option a

G57. Req increases

G59. Option b

G61. Resistance will likewise increase by 0.5 %

G63. 80.0 Ω

G65. R = 95 Ω; I = 3.2 A

G67. R_1 will dissipate more power

G69. A & B

G71. Req =13 Ω; $I_1 = I_4$ = 7.6 A; I_2 = 3.1 A; I_3 = 4.5

Oscillations and Waves

I1. 148m

I3. Longer solution provided on the website

I5. a) f_n= 34.0 Hz b) F'_n=60.0 Hz

I7. L = 6.25 m

I9. Option a

I11. $T = \pi\sqrt{2m/k}$

I13. I = 27.39 A

I15. Additional 1.56 kg added

I17. 0.126 m without the weight

I19. Max amplitude is 0.24 m

I21. a) $x= 10*\cos(\sqrt{2}*t)$ b) 9.95 m from equilibrium point c) rhino traveling 1.39 m/s d) traveling opposite to the equilibrium

I23. can be transverse or longitudinal, disturbance confined between start and end of reflecting points, etc

I25. tension will be average because they cancel out

I27. destructive interphase

I29. 0.0012s

I31. 0.016s

I33. Longer solution provided on the website

I35. 0.0065s

I37. 35.7 N

I41. Longer solution provided on the website

I43. a) 21.2 m/s b) 10.6 m/s c) Longer solution provided on the website

I45. a) 12.08 m/s b) 9.85 m/s c) 6.93 m/s

I47. a) 400 Hz b) 423.53 Hz c) 425 Hz d) 377.28 Hz e) 376.47 Hz f) 355.56 Hz g) 450 Hz

I49. Longer solution provided on the website

I51. Longer solution provided on the website

Optics

J1. Longer solution provided on the website

J3. Speed and wavelength changes, frequency does not; increase in speed = increase in wavelength

J5. Object distance is less than or equal to focal length

J7. Flatten the cornea

J9. Longer solution provided on the website

J11. Apparatus of the camera is like an iris, the retina is like film, etc.

J13. Farpoint, 25cm, diverging

J15. 67.0 cm

J17. 36.4 degrees, 2.26×10^8 m/s

J19. 0.51 m

J21. 28.6 km

J23. 1.74 m

J25. 3.0 cm

J27. outside of the focal point

J29. Longer solution provided on the website

J31. focal point is 10cm, object directly on focal point

J33. b. virtual, 22.1cm from lens c. location independent of height

J35. 0.33 cm

J37. image enlarged by 3x

J39. real and inverted image

J41. 833.3x, inverted

J43. 0.013 m

J45. diverging

J47. 2x magnification

J49. 3.0x

J51. -3.33 D, -0.3 m

J53. 5 D, diverging

J55. a) 0.53 degrees b) 2.1cm c) 0.39cm above central maxima

PART II

ADDITIONAL RESOURCES

Since this is just a question booklet, we also wanted to give you additional resources to improve your understanding of content

1- Khan Academy

- The Go-To resource for learning physics for life sciences in our opinion.

2- Youtube

- Ilectureonline
  - Dr. van Biezen is an excellent lecturer that goes into a lot of detail for his explanations
- Physicshelp Canada
  - A great overall channel for physics with many examples
- Professor Dave Explains
  - An excellent channel that can explain a wide variety of concepts well.
- Organic Chemistry Tutor
  - A great channel that goes in a lot of depth for concepts. Not everybody like their style, but their range of topics is quite substantial.
- Bozeman Science
  - Just a great overall channel for many science topics, including physics
- Strong Medicine
  - The physics videos overviewed by this channel are excellent resources for the physics sectin in the mcat, and as a result, would also be a great way to learn for most life science physics courses.
- Chris Doner
  - Although an IB teacher (a high school program), Chris's videos have a good level of depth that can get you started in university physics.
- BigBangPhysics
  - A great channel for many topics. Although no longer active, some of their non-

calculus based physics videos are excellent.

- **EHowEducation**
  - Very basic overview of some mathematical concepts used in physics. Refresher on highschool math can be found here (although also found on khan academy)

More Fun-Based Physics Channels

- **Veritasium**
  - This is a more niche resource just due to the nature of the videos being more sensational. However, some of his older videos are excellent quality.
- **Minute physics**
  - an interesting way to learn about physics principles. Not as high-yield as other resources, but fun nonetheless
- **Crash course**
  - A great way to get an overview of concepts at a beginner level. You probably want to use this when you start learning a new concept.

3- Textbooks

- **University physics** – A great resource to start out your physics learning. It is an acceptable series of textbook, but might not be specific enough, or challenging enough, for your learning
  - Volume 1
  - Volume 2
  - Volume 3
- **College physics –** A very similar resource to university physics. It is much easier however, and again, shares the same disadvantages as its larger companion.
  - Link here
- **Introductory Physics: Building Models to Describe Our World** – An excellent book that overviews physics from the ground up. The only issue is that it is calculus based, which most life science physics is not. Nonetheless, you should be able to find some excellent explanations for difficult concepts here.
  - Link here

4- Other

- MIT open courseware
    - MIT opencourseware has courses for a wide range of topics, including physics. For this resource, go find a course with the title **Classical Mechanics** and just cherry pick the lectures you want to watch.
- Physics Classroom
    - Just a website that explains things in text. Pretty good when learning a new concept
- Hyperphysics
    - This is an excellent resource, although the interface is a bit confusing to go through. Just find topics you are confused about on the right hand side and it should help out.

12. Rules for Using Significant Figures

Since physics is largely a quantitative science, it is critical to understand how to correctly report final numerical answers. We do this by adhering to the rules of significant figure use. Significant figures identify which digits in a given value contribute to the accuracy of that value. In essence, we cannot report final solutions that are accurate to a higher degree than values used in calculations. Significant figures are key to grading schemes on all physics examinations, so it is imperative that you understand how to use them.

Which figures in a number are exact and which are uncertain?

- The last digit that is considered significant in a measured or calculated value is considered uncertain. The rest of the digits in the measured or calculated value are certain.

  EXAMPLE: For the number 2.46581, the digits 2, 4, 6, 5, and 8 are certain. Since the digit 1 is the last digit in this number, it is uncertain. If 2.46581 is a measured value, the last digit is uncertain because of inherent limitations to the precision of measuring tools. If 2.46581 is a calculated value, the last digit is uncertain because we have no further information on whether the digit is the product of rounding up or down.

Rules for Using Significant Figures

Identifying Significant Figures

- Non-zero numbers are always significant (1, 2, 3, 4, 5, 6, 7, 8, or 9)
- Zeros between non-zero numbers are always significant

  EXAMPLE: 2408 is a 4 sig-fig number.

- Trailing zeros (to right) are significant if there is a decimal point present in the number

  EXAMPLE: 24.0800 and 24080.0 are both 6 sig-fig numbers.

- Leading zeros (to left) are never significant

EXAMPLE: 0.002408 is 4 sig-fig number.

- Trailing zeros (to right) without a decimal point in the number may or may not be significant. When in doubt, use scientific notation to report your answer.

EXAMPLE: 240800 is a 6 six-fig number.

Adding and Subtracting Using Significant Figures

- The number of decimal places in the final answer is equal to the number of decimal figures in the least precise number (i.e the number with the smallest number of decimal places)

EXAMPLE: 2.46 + 3.1 = 5.6

EXAMPLE: 4.73 + 8.3215 = 13.05

Multiplying and Dividing Using Significant Figures

- The number of significant figures in the final answer is equal to that of the number with the least significant figures entering the operation.

EXAMPLE: 2.3 × 7.325 = 17

EXAMPLE: 5.2 × 1.34 = 6.9

Intermediate Values

- Keep 2 uncertain figures in intermediate values and one uncertain figure in the final answer

EXAMPLE: First multiply 5.4 and 3.94. Then divide the product by 6.8.

1. 5.4 × 3.94 = 21.3 (intermediate value)
2. 21.3 ÷ 6.8 = 3.1 (final solution)

Rounding Rules

1. If the digit to be rounded is followed by 6, 7, 8, or 9.... Round up

2. If the digit to be rounded is followed by 0, 1, 2, 3, or 4... Round down

3. If the digit to be rounded is followed by 5 and this is not the last digit in the number... Round up

EXAMPLE: 2.351 rounded to 2 sig figs is 2.4.

EXAMPLE: 2.358 rounded to 2 sig figs is 2.4.

4. If the digit to be rounded is followed by 5 and this is the last digit in the number... Round to the nearest even number

EXAMPLE: 2.35 rounded to 2 sig figs is 2.4.

EXAMPLE: 2.45 rounded to 2 sig figs is 2.4.

Note on Scientific Notation

Scientific notation is primarily used to express very large or very small numbers. In using scientific notation, we must still be aware of significant figures.

A number is written in scientific notation when a value between 1 and 10 is multiplied by a power of ten. Only one digit is allowed to precede a decimal place.

EXAMPLE: If we had to express the number 2856000 in scientific notation using 3 significant figures, we would write 2.86×10^6.

EXAMPLE: If we had to express the number 0.0002856 in scientific notation using 2 significant figures, we would write 2.9×10^{-4}.

PART III

HOW TO APPROACH ANY PHYSICS PROBLEM

The following outlines how to solve physics problems and follows the GRASS scientific method (given, required, analysis, solution, and statement). Although this method is not required to achieve the correct answers to problems it does provide a more comprehensive way to approach and understand complex problems:

- Read the question and extract key info:
  - Look for key terms, values, and red herrings (something that misleads or distracts from key information).
  - Consider highlighting or underlining information.
  - Reread the question to avoid missing information or approaching the problem incorrectly.
- Write down the **GIVEN** information:
  - Sometimes the hardest part of solving a problem is starting, by writing down given values and information you get yourself better prepared to answer the question.
  - Taking an inventory of known values makes what is missing clear.
  - Sometimes values are given indirectly (i.e. the weight of the car is equal to that of a 100 pound person), identify these indirect given values and add them to the inventory.
- Find out what is **REQUIRED** and write it down:
  - Write down what you need to find out.
  - Think ahead and determine what units will be associated with the required value.
- Time to **ANALYZE** the problem:
  - Drawing diagrams and graphs can be particularly helpful at this time to better visualize the scenario the problem is verbally describing. Kinaesthetic learners may even consider acting the problem out when appropriate to do so or using models.
  - Consider different ways in which you can solve and/or verify your answers. Perhaps there are multiple ways to approach the problem and you have a preferable way.
  - Consider applicable theories, equations, and concepts applicable to the question, tie these into the intended approach.
- Time to **SOLVE**:

    - At this point the question is perfectly set up to solve, use the given information and general understanding of the problem to plug numbers in and work with relevant equations.
    - Once an answer is achieved, reflect on the answer and determine if it makes sense in the context of the questions.
    - Leave the answer with the right amount of significant digits.
- End it off with a clear **STATEMENT**:
    - Use this final statement to clearly show what the answer of the question is, perhaps the question is asking a yes or no question, in this case although the solution likely involved numbers now is the time to demonstrate how these numbers verify the answer.
    - Consider tying in various theories if the question is more conceptual.

Example of GRASS method

Formula Sheet

Formula sheet (1)