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PHYSICS FOR THE LIFE SCIENCES

Solution Manual

Created by WebStraw

Physics for the Life Sciences – Forces Solutions

Introduction:

Dear student,

Thank you for opening this solution manual for the Forces chapter of the Physics for the Life Sciences Question Manual. This resource has been created by members of the Education Team at WebStraw who have previously taken an introductory university physics course.

Purpose:

This resource is meant to supplement the Physics for the Life Sciences Question Manual, by providing solutions to select questions. To access the full question manual, please click here.

Instructions

We recommend first trying to complete the problems in the question manual on your own. If you get stuck, you can use this resource to view the solution provided by one of our Education Team members. Once you are confident you understand how to solve that question, we recommend solving additional related problems in order to successfully master the topic.

Disclaimer

This resource assumes that you have a basic understanding of key concepts related to the Forces unit in physics. If you are looking to improve your understanding of specific physics content, check out the additional resources provided at the end of the question manual.

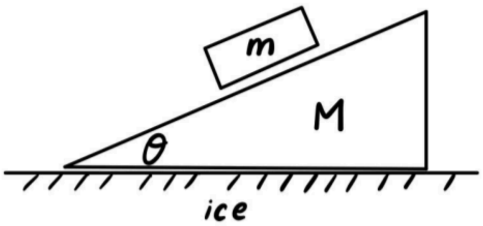
Note: There may be more than one correct method to solve some of the problems outlined in the question manual. Thus, the solutions provided may not represent the only acceptable solution.

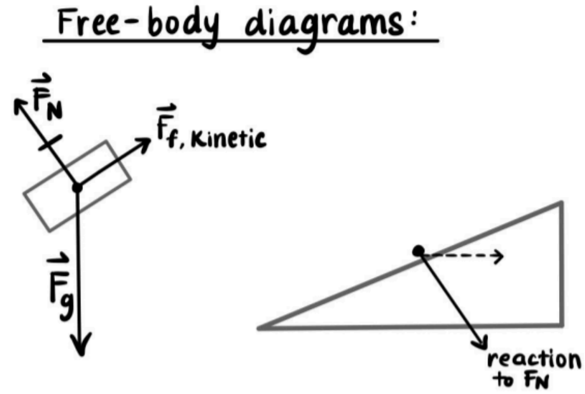
If you have any comments or feedback regarding this resource or the solutions contained in it, please do not hesitate to contact us at team@webstraw.ca

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

- The WebStraw Education Team

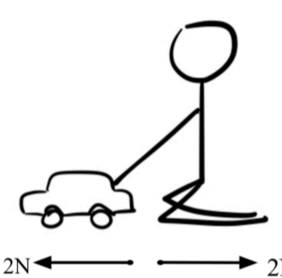
B1. <u>Given:</u> There is friction between m and M. There is no friction between M and ice.





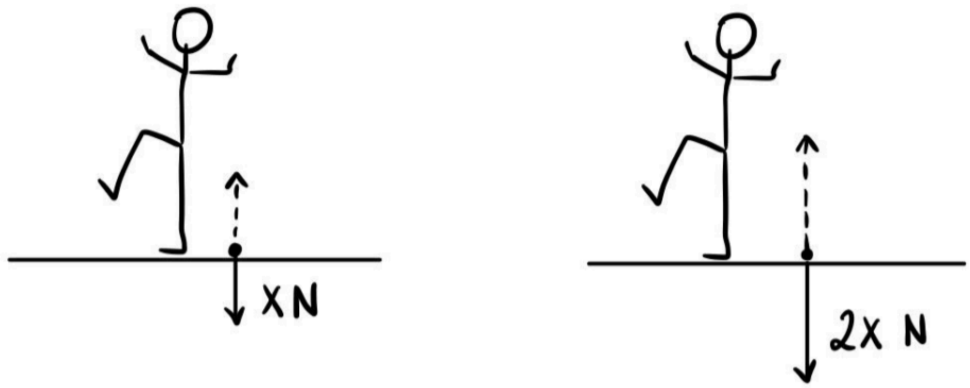
As shown, there are three forces acting on m: the normal force, a kinetic frictional force and the force of gravity. By Newton's third law, for every action force, there is a reaction force that is equal in magnitude and opposite in direction. Therefore, while M exerts a normal force up on m, it is also true that m exerts a reaction force of equal magnitude down on M. There is a y-component to this force that will not cause M to accelerate, but instead increase the normal force experienced by block M. However, there is also an x-component to this reaction force that will indeed create a net force in the right direction. For this reason, M will slide to the right, in the opposite direction to m.

B3. Newton's third law of motion states that, for every action force, there is a reaction force that is equal in magnitude and opposite in direction. The cousin from Milton is concerned that these two forces will therefore prevent any movement of her toy car. This is not true. The key to Newton's third law is that **the equal but opposing action-reaction pair of forces act on separate objects**. They do not both act on the same object. If the cousin from Milton were to pull back on the toy car with 2N of force, the applied force experienced by the toy car is 2N [backward]. A net force backward will cause the car to accelerate backward. The reaction force to this applied force is a 2N [forward] force exerted by the car on the cousin from Milton. Therefore, this reaction force will not interfere with the action force.



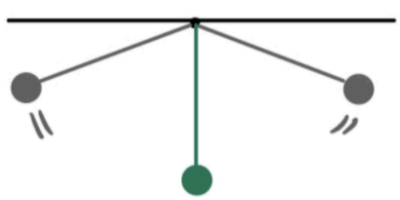
<u>Action force</u>	<u>Reaction force</u>
Exerted by cousin.	Exerted by car.
Acts on car.	Acts on cousin.

B5.

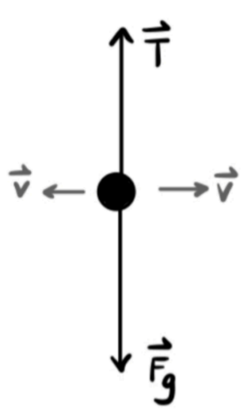


By Newton's third law of motion, if the athlete were to push down on the ground with a force of X newton, the ground would exert a force of X newtons up on the athlete. This force exerted by the ground on the athlete will result in a net upward force and consequently accelerate the athlete upwards. If the athlete were to double the force exerted downwards before jumping (i.e 2X newtons), the reaction force exerted by the ground on the athlete would similarly double. Assuming the athlete's mass remains unchanged, the athlete will experience a stronger net force upward and therefore accelerate upwards at a faster rate. As a result of a higher initial velocity, the athlete will have a longer air time and be a more successful athlete.

B7.



<u>Free-body diagram</u>
(when ball and string are vertically aligned)

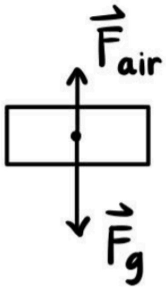


The ball is not accelerating in the y-direction at the instant the ball and string are vertically aligned, therefore:

$$\left|\vec{F}_g\right| = \left|\vec{T}\right|$$

$$\vec{F}_{net} = 0$$

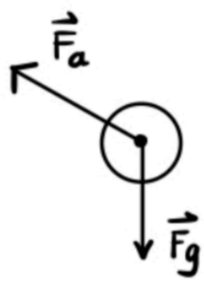
B9.



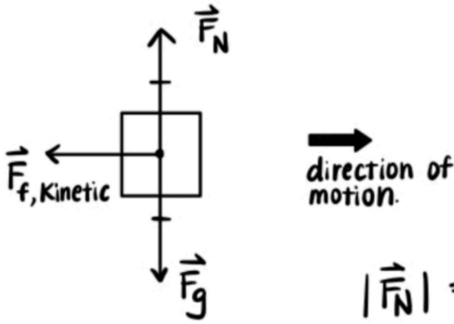
$$|\vec{F}_g| > |\vec{F}_{air}|$$

The paper airplane will eventually come to rest on the ground. It cannot continue gliding forever, so the force of gravity must be slightly larger than the upward force due to the surrounding air.

B11. a)

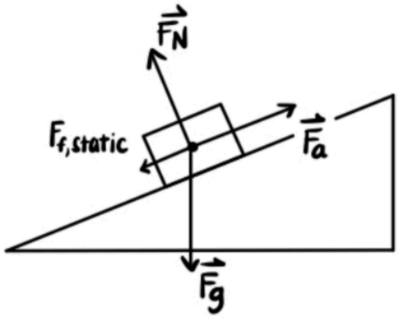


b)



$$|\vec{F}_N| = |\vec{F}_g|$$

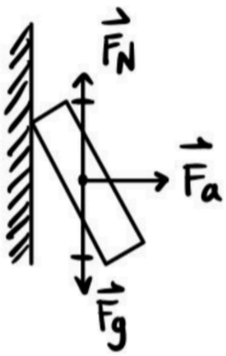
c)



$$|\vec{F}_a| > |\vec{F}_{gx}| + |\vec{F}_{f,\,static}|$$

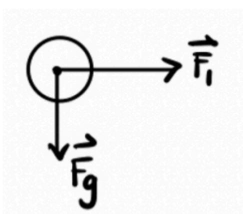
$$|\vec{F}_N| = |\vec{F}_{gy}|$$

e) Assuming the teenager is leading perpendicularly against the wall,



$$|\vec{F}_g| = |\vec{F}_N|$$

B13. Free-body diagram of first hit, letting F_1 be the force applied by the baseball bat.



$$F_{net,x} = m_1 a_x$$

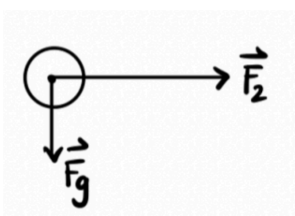
$$\therefore \quad F_1 \propto a_x$$

and

$$\frac{1}{m_1} \propto a_x$$

From Newton's second law of motion, it can be seen that acceleration is directly proportional to force and inversely proportional to mass.

a)

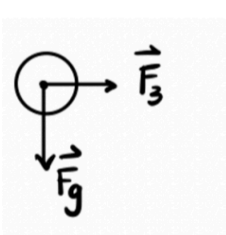


If $F_2 = 2F_1$ and $F_1 \propto 2a_x$, then $F_2 \propto 2a_x$.

$2 \times 30 \text{ m/s}^2 = 60 \text{ m/s}^2$

Therefore, the ball will accelerate at 60 m/s^2 if hit twice as hard.

b)

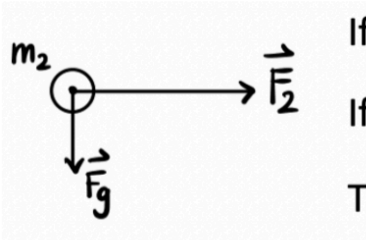


If $F_3 = \frac{1}{2} F_1$ and $F_1 \propto a_x$, then $F_3 \propto \frac{1}{2} a_x$.

$\frac{1}{2} \times 30 \text{ m/s}^2 = 15 \text{ m/s}^2$

Therefore, the ball will accelerate at 15 m/s^2 if hit half as hard.

c)



If $F_2 = 2F_1$ and $F_1 \propto a_x$, then $F_2 \propto 2a_x$.

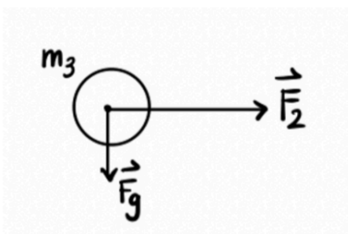
If $m_2 = \frac{1}{2} m_1$ and $\frac{1}{m_1} \propto a_x$, then $m_2 \propto 2a_x$.

The cumulative effect of F_2 and m_2 is a 4-fold effect on a_x.

$4 \times 30 \text{ m/s}^2 = 120 \text{ m/s}^2$

Therefore, the ball will accelerate at 120 m/s^2 if it is hit twice as hard and its mass is halved.

d)



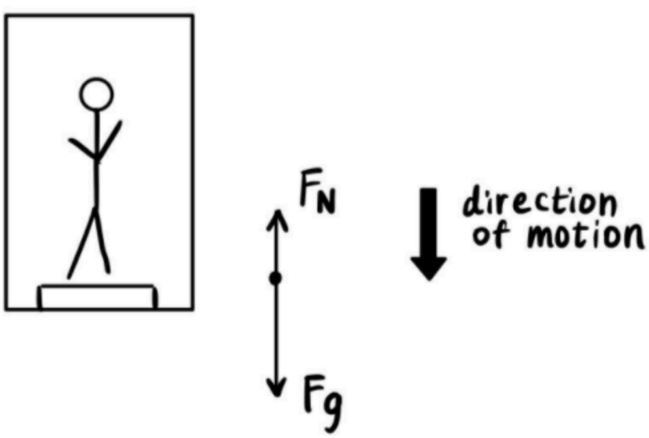
If $F_2 = 2F_1$ and $F_1 \propto a_x$, then $F_2 \propto 2a_x$.

If $m_3 = 2m_1$ and $\frac{1}{m_1} \propto a_x$, then $m_3 \propto \frac{1}{2} a_x$.

The cumulative effect of F_2 and m_3 equals no change to a_x.

Therefore, the ball will accelerate at 30 m/s^2 if it is hit twice as hard and its mass is doubled.

B15. The free-body diagram of the described situation is as follows:



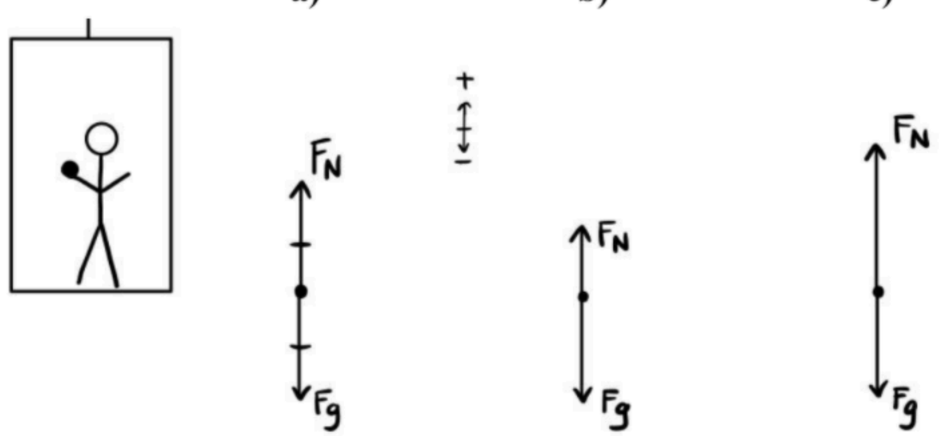
Scales will not read weight properly in elevators because scales cannot account for acceleration. Scales read the force of the normal as though you were standing in a static frame of reference.

The net force will be equal to the difference between your true weight and your normal force, which is read by the scale as being 70% of your true weight. Using Newton's second law, we can solve for acceleration.

$$
\begin{aligned}
F_{net} &= F_g - F_N \\
F_{net} &= F_g - 0.70\,F_g \\
ma &= mg - 0.70\,mg \\
\cancel{m}a &= 0.30\,\cancel{m}g \\
a &= 0.30\,g \\
a &= 0.30\,(9.8\ m/s^2) \\
\Aboxed{a &= 2.9\ m/s^2}
\end{aligned}
$$

Therefore the elevator's acceleration when you reach the third floor of the building is 2.9 m/s^2 [down].

B17. **a)** **b)** **c)**



$|F_g| = |F_N|$ $|F_g| > |F_N|$ $|F_N| > |F_g|$

Please note how the magnitude of F_g remains unchanged in all free-body diagrams. Zeyad and the rock's **true weight** never changes, no matter what the elevator's motion looks like. Only the normal force changes in magnitude, because their **apparent weight** (normal force) depends on whether Zeyad and the rock are in an accelerating frame of reference or a static frame of reference.

d)

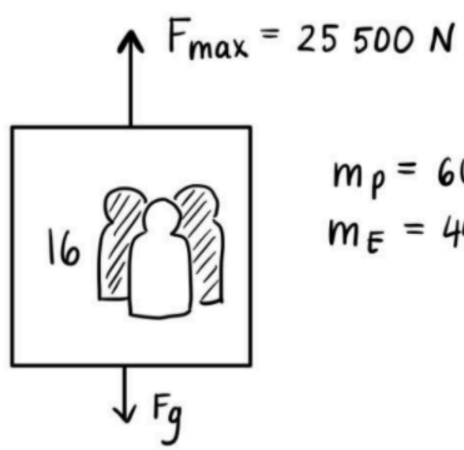
$$m_T = m_R + m_Z = 60\ kg + 112\ kg = 172\ kg$$

a) $$F_N = F_g = m_T g = (172\ kg)(9.8\ m/s^2) = \boxed{1.7 \times 10^3 N}$$

b)
$$F_{net} = ma$$
$$F_N - F_g = ma$$
$$F_N = ma + mg$$
$$F_N = (172\ kg)(-2\ m/s^2) + (172\ kg)(9.8\ m/s^2)$$
$$\boxed{F_N = 1.3 \times 10^3\ N}$$

c)
$$F_{net} = ma$$
$$F_N - F_g = ma$$
$$F_N = ma + mg$$
$$F_N = (172\ kg)(+2\ m/s^2) + (172\ kg)(9.8\ m/s^2)$$
$$\boxed{F_N = 2.0 \times 10^3\ N}$$

B19.



$m_p = 60\ kg$ each
$m_E = 440\ kg$

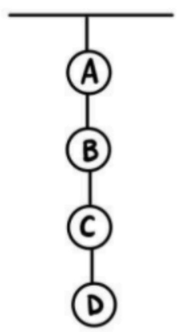
$$m_T = 16\ \text{passengers} \times 60\ \frac{kg}{\text{passenger}} + 440\ kg$$
$$m_T = 1400\ kg$$

$$F_g = m_T\ g$$
$$F_g = (1400\ kg)(9.8\ m/s^2)$$
$$F_g = 13\ 720\ N$$

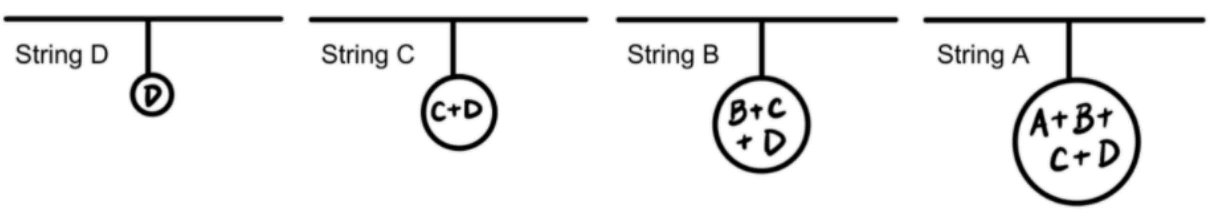
$$F_{net} = ma$$
$$25500 - 13720 = (1400\text{ kg})a$$
$$11780 = (1400\text{ kg})a$$
$$\boxed{a = 8.4\text{ m/s}^2\ [\text{up}]}$$

Therefore, the elevator can successfully (and safely) accelerate as fast as 8.4 m/s^2 [up] while carrying 16 passengers.

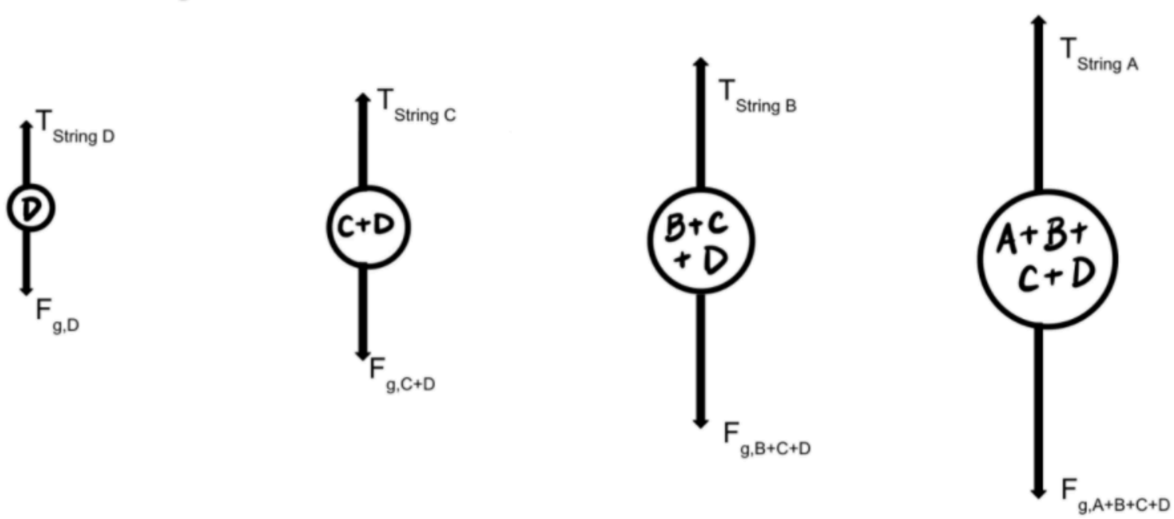
B21. Given: $m_A = 4$ kg
$m_B = 3.5$ kg
$m_C = 5$ kg
$m_D = 6.5$ kg



a) Assuming the mass of each string is negligible, simplified diagrams can be drawn at each location along the ornament.



If we were to now convert these simplified diagrams into free-body diagrams, we would get:



Each of these free-body diagrams represents a **static system**, which means that no part of the system is accelerating. The entire ornament is at rest. For this reason, the sum total of all forces in each free-body diagram must be zero. Therefore, the tension force in each string must be equal to the combined weight of all spheres beneath it.

Put this way, it is then simple to say that String D, which supports only sphere D, will have the smallest tension of all strings in the ornament. String A, which supports all of spheres A, B, C and D, will have the largest tension of all strings in the ornament.

b) The free-body diagram for sphere D is:

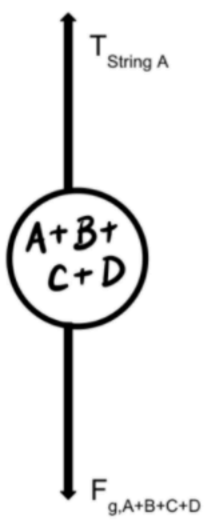
Since sphere D is static, $T_{\text{string D}}$ must be equal in magnitude and directly opposite in direction to $F_{g,\,D}$.

$$F_{g,\,D} = m_D \times g = (6.5\text{ kg})(9.8\text{ N/kg}) = 63.7\text{ N}$$

$$T_{\text{string D}} = F_{g,\,D} = 63.7\text{ N.}$$

Accounting for significant figures, the tension force in string D is 64 N.

c) To find the tension force in string A, the combined weight of all of spheres A, B, C and D is needed.



$$m_T = m_A + m_B + m_C + m_D$$
$$m_T = 4\text{ kg} + 3.5\text{ kg} + 5\text{ kg} + 6.5\text{ kg}$$
$$m_T = 19.0\text{ kg}$$

The tension force in string A must be equal in magnitude to the weight of m_T in order for the ornament to be in static equilibrium.

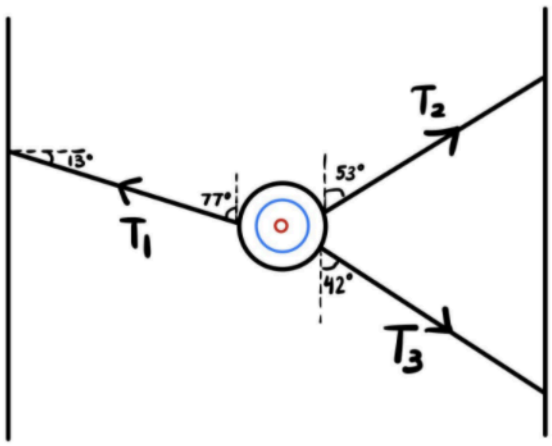
$$F_{g,\,A+B+C+D} = m_T \times g = (19.0\text{ kg})\ (9.8\text{ N/kg}) = 186.2\text{ N}$$

$$T_{\text{String A}} = F_{g,\,A+B+C+D} = 186.2\text{ N.}$$

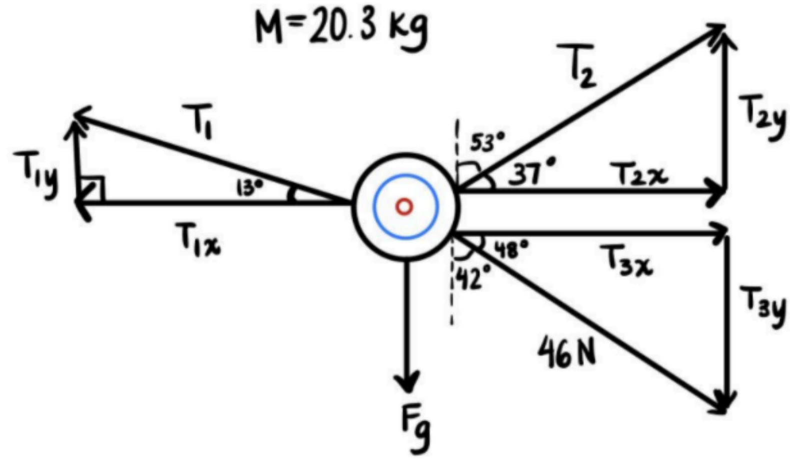
Accounting for significant figures, the tension force in String A is 1.9×10^2 N.

B23. Given the diagram below, we can construct a free-body diagram in which we break the three tension forces into their x- and y-components. Any necessary angles can be added in as well.

Provided Diagram



Free-Body Diagram



The archery target is not accelerating, therefore it represents a system in static equilibrium. The sum total of all forces acting on the archery target must equal zero in both the x- and y-directions. Being vectors, we must take direction into account before calculating vector sums. Let's take the right to be the positive direction in the x-dimension. Let's take up to be the positive direction in the y-dimension.

In the x-direction: $$-T_{1x} + T_{2x} + T_{3x} = 0\text{ N}$$

We are given that $T_3 = 46$ N. Using trigonometry, the x-component (T_{3x}) of this tension force is $46\cos 48^\circ$. The x-components of T_1 and T_2 can be similarly expanded.

$$\begin{aligned} -T_{1x} + T_{2x} + 46\cos 48^\circ &= 0\text{ N} \\ T_{1x} - T_{2x} &= 46\cos 48^\circ \\ T_1\cos 13^\circ - T_2\cos 37^\circ &= 46\cos 48^\circ \end{aligned}$$

In the y-direction: $$T_{1y} + T_{2y} - T_{3y} - F_g = 0\text{ N}$$

We can calculate the y-component of T_3 using the sine trigonometric ratio and we can calculate the weight of the archery target as the product of its mass and *g*.

$$T_{1y} + T_{2y} - 46\sin 48^\circ - (20.3\text{kg})(9.8\text{ N/kg}) = 0\text{ N}$$
$$T_{1y} + T_{2y} - 46\sin 48^\circ - 199\text{ N} = 0\text{ N}$$
$$T_{1y} + T_{2y} = 199\text{ N} + 46\sin 48^\circ$$
$$T_1 \sin 13^\circ + T_2 \sin 37^\circ = 199\text{ N} + 46\sin 48^\circ$$

a) Since we have two variables (T_1 and T_2), let's use a substitution method and write T_2 in terms of T_1. That way, our solution will solve for T_1.

From the x-dimension equation:

$$T_1 \cos 13^\circ - T_2 \cos 37^\circ = 46\cos 48^\circ$$
$$T_2 \cos 37^\circ = T_1 \cos 13^\circ - 46\cos 48^\circ$$
$$T_2 = \frac{T_1 \cos 13^\circ - 46\cos 48^\circ}{\cos 37^\circ}$$

Substitute T_2 into the y-dimension equation and solve.

$$T_1 \sin 13^\circ + \left(\frac{T_1 \cos 13^\circ - 46\cos 48^\circ}{\cos 37^\circ}\right)\sin 37^\circ = 199 - 46\sin 48^\circ$$

$$T_1 \sin 13^\circ + (T_1 \cos 13^\circ - 46\cos 48^\circ)\tan 37^\circ = 199 - 46\sin 48^\circ$$

$$T_1 \sin 13^\circ + T_1 \cos 13^\circ \tan 37^\circ - 46\cos 48^\circ \tan 37^\circ = 199 - 46\sin 48^\circ$$

$$T_1(\sin 13^\circ + \cos 13^\circ \tan 37^\circ) = 199 + 46\sin 48^\circ + 46\cos 48^\circ \tan 37^\circ$$

$$T_1(0.9592) = 256.4$$

$$\boxed{T_1 = 267.3\text{ N}}$$

Accounting for significant figures, the force of tension in rope 1 is 2.7×10^2 N.

b) We can now find T_2 by substituting the known T_1 value into the x-dimension equation from part a) and solving.

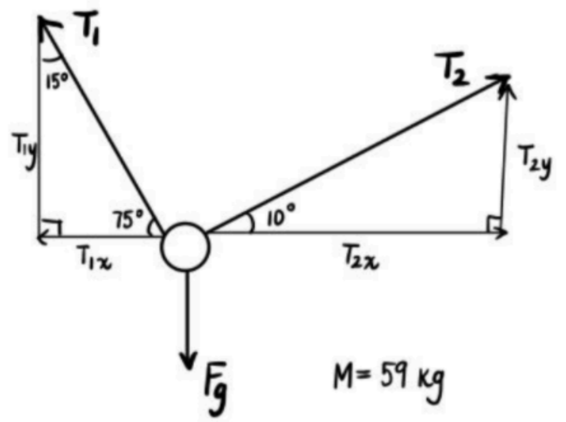
$$T_2 = \frac{T_1 \cos 13^\circ - 46\cos 48^\circ}{\cos 37^\circ}$$

$$T_2 = \frac{267.3\cos 13^\circ - 46\cos 48^\circ}{\cos 37^\circ}$$

$$\boxed{T_2 = 287.6\ \text{N}}$$

Accounting for significant figures, the force of tension in rope 2 is 2.9×10^2 N.

B25. A good place to begin is by drawing a free-body diagram that breaks each tension force into x- and y-components.



The lady (M = 59kg) remains motionless, therefore the system is in static equilibrium. The sum total of all forces acting on the woman– namely, the two tension forces and the woman's weight– must equal zero.

In the x-dimension:

$$F_{net\,x} = 0$$
$$\therefore\ T_{1x} = T_{2x}$$
$$T_1\cos 75^\circ = T_2\cos 10^\circ$$

In the y-dimension:

$$F_{net\,y} = 0$$
$$\therefore\ T_{1y} + T_{2y} = F_g$$
$$T_1\sin 75^\circ + T_2\sin 10^\circ = (59\ \text{kg})(9.8\ \text{N/kg})$$
$$T_1\sin 75^\circ + T_2\sin 10^\circ = 578.2\ \text{N}$$

There are two unknown variables (T_1 and T_2). By writing one variable in terms of the other, we can use the substitution method to solve for our variables.

Rearrange T_1 in terms of T_2:

$$T_1\cos 75^\circ = T_2\cos 10^\circ$$
$$T_1 = \frac{T_2\cos 10^\circ}{\cos 75^\circ}$$

Substitution:

$$\left(\frac{T_2 \cos 10^\circ}{\cos 75^\circ}\right) \sin 75^\circ + T_2 \sin 10^\circ = 578.2\ N$$

$$T_2 \cos 10^\circ \tan 75^\circ + T_2 \sin 10^\circ = 578.2\ N$$

$$T_2 \left(\cos 10^\circ \tan 75^\circ + \sin 10^\circ\right) = 578.2\ N$$

$$T_2 (3.849) = 578.2\ N$$

$$\boxed{T_2 = 150\ N}$$

Knowing T_1, we can now solve for T_2.

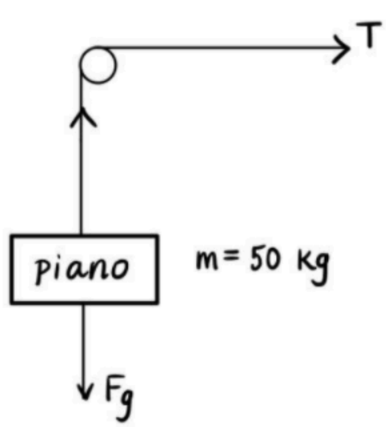
$$T_1 = \frac{(150\ N) \cos 10^\circ}{\cos 75^\circ}$$

$$\boxed{T_1 = 570\ N}$$

Therefore the tension in the section of rope closest to the wall is 570N and the tension in the section of rope held by the friend is 150N.

B27. A free-body diagram can help illustrate the pulley system that is lowering the piano. Assume the pulley has negligible mass and friction, and that the rope changes in direction by 90° over the pulley.

Free-body diagram:

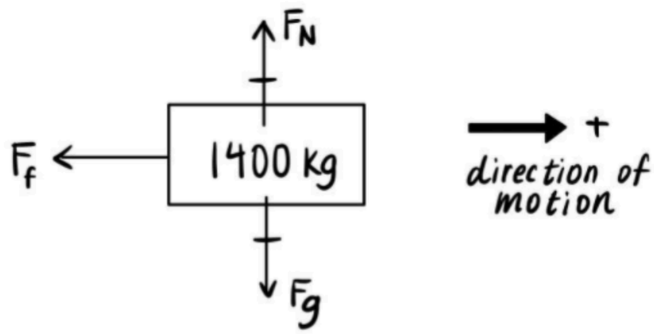


We are told that the piano is being lowered at a constant rate. This means that there is no net acceleration of the piano and no net force, by Newton's second law. Therefore, the tension in the string above the piano must be equal in magnitude to the weight of the piano.

$$F_{net} = 0$$
$$\therefore T = F_g$$
$$T = (50\ kg)(9.8\ N/kg)$$
$$T = 490\ N$$

Since the tension in the string must be constant throughout its length, 490N is also the magnitude of tension needed in the horizontal section of rope that is pulled by you. Therefore, you must pull with a force of 490N in order to lower the piano at a constant rate.

B29. Let's assume the car is moving toward the right, which is the positive direction of motion. A free-body diagram of the accelerating car would look like the following:



From this FBD, Newton's second law of motion can be written as:

$$F_{net} = ma$$
$$F_f = ma$$

The acceleration can be calculated as the change in velocity over time. However, velocity is written in SI units of meters per second. Therefore, the velocity of 70 km/h must be converted to m/s before acceleration can be calculated.

$$70\ \frac{km}{h} \cdot \frac{1000\ m}{km} \cdot \frac{h}{3600\ s} = 19.44\ m/s$$

$$a = \frac{V_2 - V_1}{\Delta t}$$

$$a = \frac{0 - 19.44\ m/s}{3.00\ s}$$

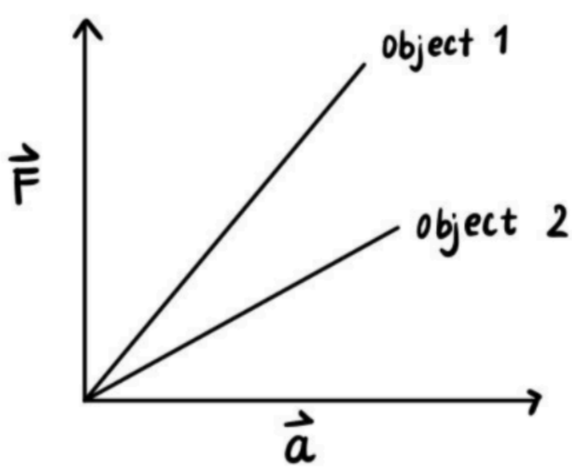
$$a = -6.48\ m/s^2$$

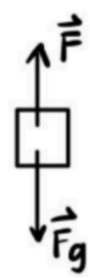
Reflecting, it makes sense that the acceleration is negative since we expect that the frictional force will **oppose** motion in the positive direction. Now, we can solve for the frictional force using the mass of the car and its acceleration.

$$F_f = ma$$
$$F_f = (1400\ kg)(-6.48\ m/s^2)$$
$$F_f = -9072\ \frac{kg \cdot m}{s^2}$$
$$\boxed{F_f = -9.1 \times 10^3\ N}$$

Therefore, the force of friction experienced by the car is of magnitude 9.1×10^3 N and it acts opposite to the direction of motion of the car. This frictional force will enable the car to stop before the red light.

B31. Shown below is a sample acceleration-versus-force graph for two objects in which one object produces a much steeper slope than the other.





We are told that the objects are being pulled upwards by a rope, therefore the measured force is a tension force. This tension force must exceed the weight of each object in order for the objects to accelerate upwards.

The graph shown above does indeed indicate which object is heavier than the other. The heavier object has the larger mass, and we can determine which object has the larger mass by assessing the slopes on the graph and the relationships contained between the variables of force, mass, and acceleration.

<u>Newton's second law:</u>

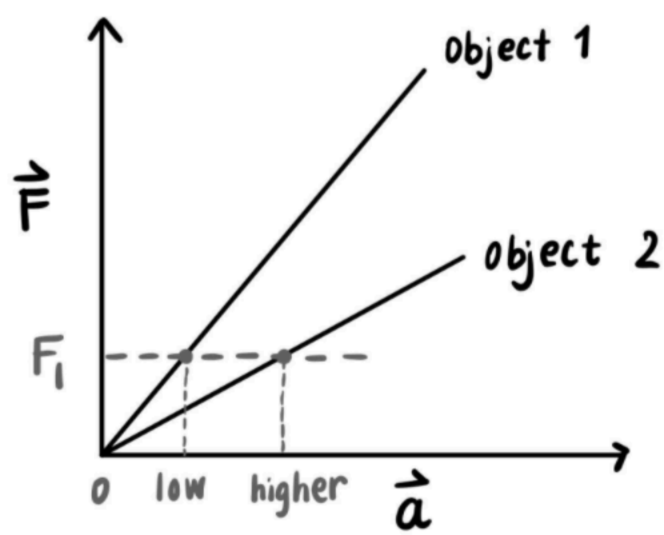
$$F_{net} = ma$$

$$a \propto F$$

$$a \propto \frac{1}{m}$$

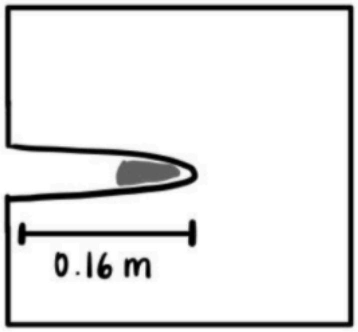
To establish these relationships, we look to Newton's second law, where it can be seen that acceleration is directly proportional to force and inversely proportional to mass.

Let's consider one fixed magnitude of force, F_1 (see diagram below). For this given value of force F_1, a different acceleration is produced for each object. F_1 produces a low acceleration in object 1 and an acceleration of higher magnitude in object 2. This is because the horizontal reference line that extends from F_1 intersects with the slope of object 1 at a location closer to the y-axis.



If force is a constant between the two objects, then only the mass of each object can influence acceleration. As derived above from Newton's second law of motion, mass is inversely proportional to acceleration. Therefore, the object of larger mass will accelerate at a lower rate. In the graph shown above, this would be Object 1.

B33.



$m = 0.015$ kg
$v_1 = 185$ m/s
$v_2 = 0$ m/s
$\Delta d = 0.16$ m

Begin by determining the acceleration of the bullet using one of the formulas for motion with uniform acceleration.

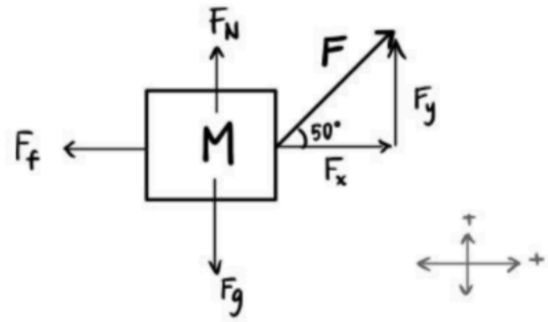
$$v_2^{\,2} = v_1^{\,2} + 2a\Delta d$$
$$0^2 = (185\text{ m/s})^2 + 2a(0.16\text{ m})$$
$$0 = 34\,225\text{ m}^2/\text{s}^2 + (0.32\text{ m})a$$
$$-34\,225\text{ m}^2/\text{s}^2 = (0.32\text{ m})a$$
$$a = -106\,953\text{ m/s}^2$$

This acceleration makes sense since the bullet is slowing down from a very high velocity. Finally, calculate the net force needed to stop the bullet using the known mass and calculated acceleration.

$$F_{net} = ma$$
$$F_{net} = (0.015\text{ kg})(-106\,953\text{ m/s}^2)$$
$$F_{net} = -1604\text{ N}$$
$$F_{net} \doteq -1.6 \times 10^3\text{ N}$$

Therefore, the force responsible for stopping the bullet in the block of wood is of magnitude 1.6×10^3N and acts in the direction opposite to the direction of motion.

B35. The question states that the two blocks accelerate as a system. For this reason, we can model the two blocks as one block with a combined mass of 6.0 kg to simplify the diagram. The free-body diagram of this system is as follows:



$\vec{a} = 1.8\ m/s^2$

$\mu = 0.30$

Sign convention places the positive directions as up and to the right.

From the diagram above, we must realize that:

$$|F_g| = |F_N| + |F_y| \quad \text{since no acceleration in the y-direction.}$$

Expanding upon each of these terms, we can derive **Equation 1**.

$$\begin{aligned} (m_1 + m_2)\,g &= F_N + F\sin 50^\circ \\ (2.0\ kg + 4.0\ kg)(9.8\ N/kg) &= F_N + F\sin 50^\circ \\ 58.8\ N &= F_N + F\sin 50^\circ \\ 58.8\ N &= \frac{1}{\mu}\cdot F_f + F\sin 50^\circ \end{aligned}$$

Since there are two unknowns– F_f and F– we need another formula that incorporates both these variables. Let's use Newton's second law to get **Equation 2**.

$$\begin{aligned} F_{net} &= (m_1 + m_2)\,a \\ F_x - F_f &= (2.0\ kg + 4.0\ kg)(1.8\ m/s^2) \\ F_x - F_f &= 10.8\ N \\ F\cos 50^\circ - F_f &= 10.8\ N \end{aligned}$$

Rearranging **Equation 1**, we can write F_f in terms of F.

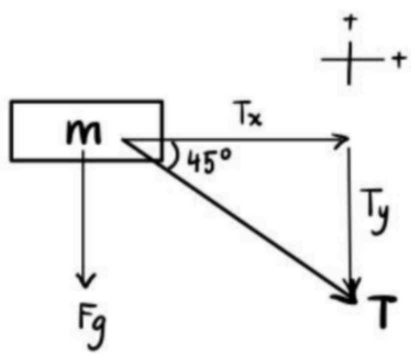
$$\begin{aligned} \frac{1}{\mu}\cdot F_f + F\sin 50^\circ &= 58.8\ N \\ F_f &= \mu\,(58.8 - F\sin 50^\circ) \end{aligned}$$

Now, using the substitution method, we can solve for F using **Equation 2**.

$$F\cos 50^\circ - (58.8\mu - F\mu\sin 50^\circ) = 10.8\text{ N}$$
$$F\cos 50^\circ - 58.8\mu + F\mu\sin 50^\circ = 10.8\text{ N}$$
$$F(\cos 50^\circ + \mu\sin 50^\circ) = 10.8\text{ N} + 58.8\mu$$
$$F(\cos 50^\circ + 0.30\cdot\sin 50^\circ) = 10.8\text{N} + 58.8\cdot 0.30$$
$$F\ (0.8726) = 28.44\text{ N}$$
$$\boxed{F = 33\text{ N}}$$

Therefore, the magnitude of force applied to accelerate the blocks is 33N.

B37. The free-body diagram of the boat just as it leaves the water would look like the following:



$m = 150$ kg
$T = 2800$ N
$\theta = 45^\circ$
$a = ?$

Let's set our coordinate system so that up and to the right are the positive directions.

In the air, there is no normal force and we assume the force due to air resistance is negligible. Therefore the boat is accelerating both to the right and down. We must determine the net force and acceleration in both the x- and y-dimensions and then find the total acceleration as a vector sum of its components.

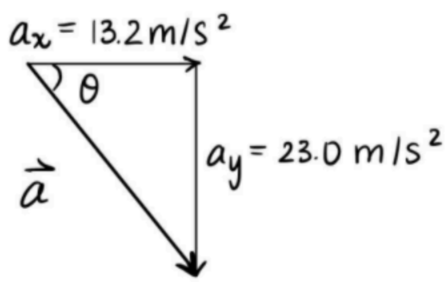
x-dimension:

$$F_{net\ x} = ma_x$$
$$T_x = ma_x$$
$$2800\cos 45^\circ\text{ N} = (150\text{ kg})\,a_x$$
$$a_x = \frac{2800\cos 45^\circ\text{ N}}{150\text{ kg}}$$
$$a_x = 13.2\text{ m/s}^2$$

y-dimension:

$$F_{net\,y} = ma_y$$
$$T_y + F_g = ma_y$$
$$2800 \sin 45° \text{ N} + mg = ma_y$$
$$2800 \sin 45° \text{ N} + (150 \text{ kg})(9.8 \text{ N/kg}) = (150 \text{ kg})\, a_y$$
$$2800 \sin 45° \text{ N} + 1470 \text{ N} = (150 \text{ kg})\, a_y$$
$$\frac{3450 \text{ N}}{150 \text{ kg}} = a_y$$
$$a_y = 23.0 \text{ m/s}^2$$

Finally, use the vector components of acceleration to calculate the overall acceleration. Since it is a vector, we must also determine the direction that the acceleration acts in. We cannot assume that this acceleration acts in the same direction as the tension force in the rope.

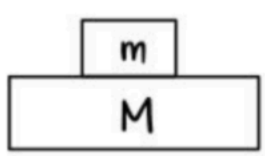


$$a = \sqrt{a_x^2 + a_y^2}$$
$$a = \sqrt{(13.2 \text{ m/s}^2)^2 + (23.0 \text{ m/s}^2)^2}$$
$$\boxed{a = 27 \text{ m/s}^2}$$

$$\tan\theta = \frac{a_y}{a_x}$$
$$\theta = \tan^{-1}\left(\frac{23.0}{13.2}\right)$$
$$\boxed{\theta = 60.° \text{ below the horizontal}}$$

Therefore, the acceleration of you and the tube is 27 m/s^2 [60.° below the horizontal].

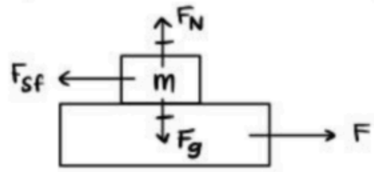
B39. a) The force of the mass on the wagon is its weight.



$$F_{gm} = mg$$
$$= (5 \text{ kg})(9.8 \text{ N/kg})$$
$$= 49 \text{ N}$$

Therefore, the force of the mass on the wagon is 49 N in magnitude.

b) Although it is the wagon that is being pulled by the force, the wagon will exert a force of equal magnitude at the surface between itself and the mass. A frictional force will resist this motion. The maximum force of static friction can be calculated as the product of the coefficient of static friction and the normal force of the mass.



$$
\begin{aligned}
F_{sf} &= \mu_s \cdot F_N \\
&= \mu_s \cdot F_g \\
&= 0.45 \cdot 49\ N \\
&= 22.05\ N
\end{aligned}
$$

This applied force on the wagon, F, cannot exceed this maximum force of static friction if the mass is to remain stationary. Since the applied force F acts on the wagon, it is equal to the net force. Furthermore, this force must accelerate the combined mass of the wagon and the mass sitting on top.

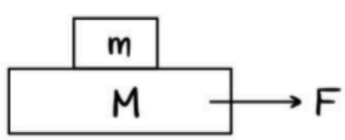
$$
\begin{aligned}
F_{a\,max} &= 22.05\ N \\
\because\ F_{net} &= ma \\
22.05N &= (10kg + 5kg)(a) \\
\end{aligned}
$$

$$\boxed{a = 1.5\ m/s^2}$$

Therefore, the maximum acceleration that the wagon can have such that the mass on top remains stationary is 1.5 m/s^2.

c) The wagon and mass will accelerate at separate rates, therefore we must consider each separately.

The wagon only has an applied force of 50 N acting on it. Its mass is also increased by the 5kg mass sitting on top of it.



$$
\begin{aligned}
F_{net} = F &= (m + M)a \\
50\ N &= (5\ kg + 10\ kg)\ a \\
a &= \frac{50\ N}{15\ kg}
\end{aligned}
$$

$$\boxed{a_{wagon} = 3.3\ m/s^2}$$

Therefore, the wagon will accelerate at 3.3 m/s^2.

The mass on top of the wagon has an additional frictional force acting on it. The 50N applied force exceeds the 22.05N needed to keep the mass stationary (calculated in part b) and so, the mass slides over the top of the wagon.

$$F_{net} = F - F_{Kf}$$
$$ma = 50\ N - \mu_K \cdot F_N$$

Since the mass is not accelerating in the y-direction, $F_N = F_g$.

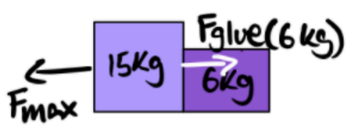
$$ma = 50\ N - 0.35 \cdot mg$$
$$(5\ kg)\ a = 50\ N - 0.35\ (5\ kg)(9.8\ N/kg)$$
$$(5\ kg)\ a = 32.85\ N$$
$$\boxed{a_{mass} = 6.6\ m/s^2}$$

Therefore, the mass on top of the wagon accelerates at 6.6 m/s^2.

B41)

a) 20N provided by Q

b)



$F = ma$

$F_{max} = F_{glue(6kg)} = 20\ N$

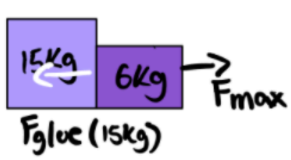
$F_{glue(6kg)} = ma$

$20 = 6 \cdot a$

$a = \frac{20}{6} = 3.3\ m/s^2$

c) 20N provided by Q

d)



$F_{max} = F_{glue(15kg)} = 20\ N$

$F_{glue(15kg)} = ma$

$20 = 15 \cdot a$

$a = \frac{20}{15} = 1.3\ m/s^2$

B43) $V_0 = 0\ m/s$

$t_1 = 5\ s \rightarrow x_1 = 10m$

$t_2 = 10s \rightarrow x_2 = ?$

$\boxed{\text{constant force} = \text{constant acceleration}}$

$V_1 = \frac{x_1}{t_1} = \frac{10}{5} = 2.0$

$V_1 = \cancel{V_0}^{0} + at_1$

$2 = a \cdot 5$

$a = 0.4\ m/s^2$

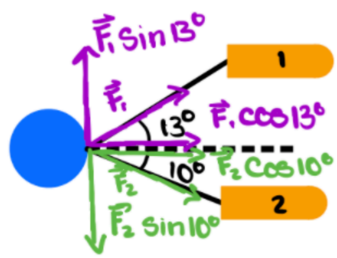
$V_2 = \frac{x_2}{t_2} = \cancel{V_0}^{0} + a\,t_2$

$x_2 = a(t_2)^2$

$= 0.4 \cdot 10^2$

$x_2 = 40m$

B45) a)



$\vec{F}_1 = \vec{F}_2 = 2000N$

$F_{x\text{-net}} = \vec{F}_1 \cos 13° + \vec{F}_2 \cos 10°$

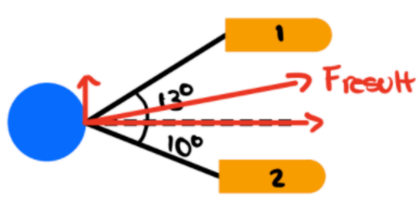
$= 2000\,(\cos 13° + \cos 10°)$

$= 3918.36\ N$

$F_{y\text{-net}} = \vec{F}_1 \sin 13° - \vec{F}_2 \sin 10°$

$= 2000\,(\sin 13° - \sin 10°)$

$= 102.61N$



$a^2 + b^2 = c^2$

$F_{result}^2 = F_{x\text{-net}}^2 + F_{y\text{-net}}^2$

$F_{result} = \sqrt{F_{x\text{-net}}^2 + F_{y\text{-net}}^2}$

$= \sqrt{3918.36^2 + 102.61^2}$

$F_{result} = 3919.70\ N$

b) $F = ma$

$F_{result} = 3919.70\ N$

$m_{buoy} = 50\ kg$

$a = \dfrac{3919.70}{50} = 78.39\ m/s^2$

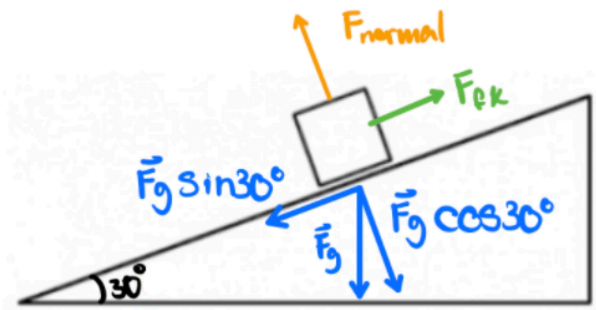
B47) $m = 10\ kg$

$V_{initial} = 7\ m/s$

$V_{final} = 0\ m/s$

Kinetic bc in motion → $\mu_k = 0.15$

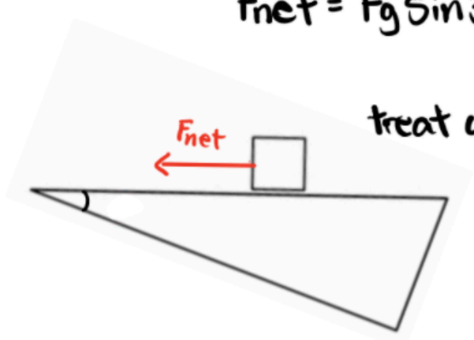
$F_g = mg = 10 \cdot 9.8$
$= 98\ N$



$F_{normal} = F_g \cos 30° = 98 \cdot \cos 30° = 84\ N$

$F_{fk} = \mu_k F_{normal} = 0.15 \cdot 84 = 12.6\ N$

$F_{net} = F_g \sin 30° - F_{fk} = 98 \cdot \sin 30 - 12.6 = 36.4\ N$



treat w/o slope

$F_{net} = ma_x$

$a_x = \dfrac{36.4}{10} = 3.64\ m/s^2$

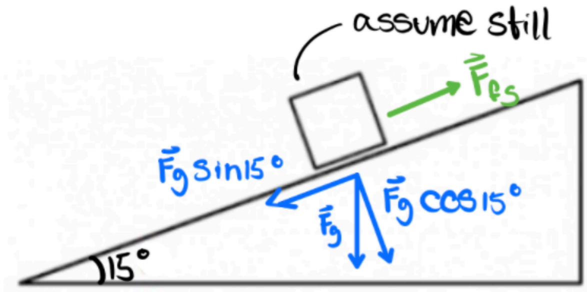
$\cancel{V_{final}^2}^{\,0} = V_{initial}^2 + 2a_x \Delta X$

$0 = 7^2 + 2 \cdot 3.64 \cdot \Delta X$

$\Delta X = -6.73\ m$

($\therefore$ travel 6.73m before coming to rest

B49)



F_{net} of slope $= 0$

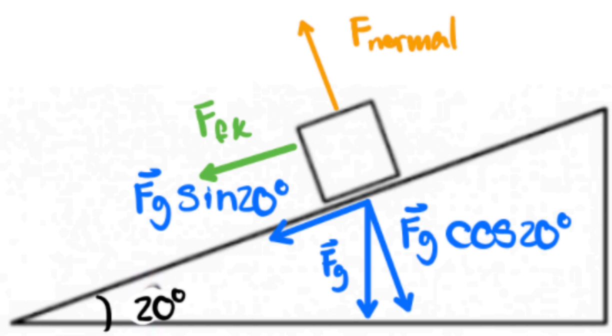
$\vec{F}_g \sin 15° = \vec{F}_{fs}$

$\vec{F}_g \sin 15° = \mu_s \vec{F}_{normal}$

$\cancel{\vec{F}_g} \sin 15° = \mu_s \cancel{\vec{F}_g} \cos 15°$

$\mu_s = \frac{\sin 15°}{\cos 15°} = 0.26$

B51)



$\boxed{\text{up slope as +ve}}$

$m = 777g = 0.777\ kg$

$\mu_s = 0.25 \quad \mu_k = 0.20$

$V_{initial} = 18\ m/s \quad V_{final} = 0\ m/s$

$F_{fk} = \mu_k F_{normal}$
$= \mu_k \vec{F}_g \cos 20°$

$F_{net} = 0 - (\vec{F}_g \sin 20° + F_{fk})$
$= -(\vec{F}_g \sin 20° + \mu_k \vec{F}_g \cos 20°)$

$F_{net} = -F_g(\sin 20° + \cos 20°)$

$\cancel{m}a = -\cancel{m}g(\sin 20° + \cos 20°)$

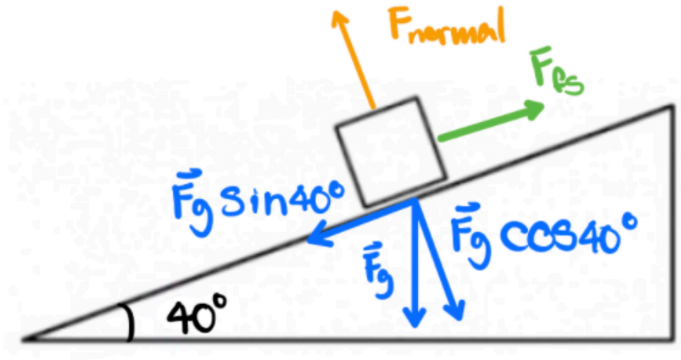
$a = -12.56\ m/s^2$

$\cancel{V_{final}^2}^{\,0} = V_{initial}^2 + 2a \times \Delta X$

$0 = 18^2 + 2 \cdot (-12.56)\Delta X$

$\Delta X = \frac{18^2}{2 \cdot 12.56} = 12.9\ m$

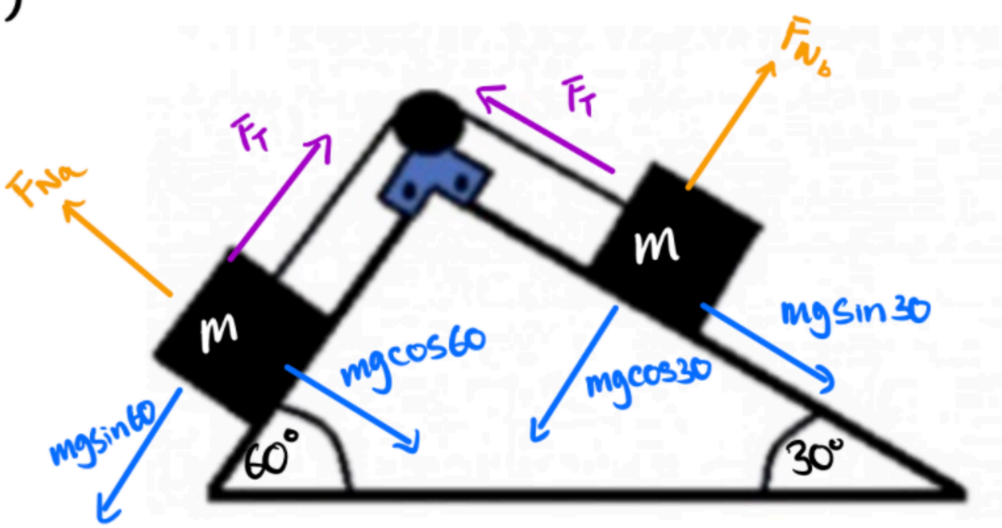
B53)



$\mu_s = ?$

$$F_{net} = \vec{F_g}\sin 40° - F_{fs}$$
$$= \vec{F_g}\sin 40° - \mu_s \vec{F_g}\cos 40°$$
$$= \vec{F_g}(\sin 40° - \mu_s \cos 40°)$$
$$0 = \cancel{\vec{F_g}}(\sin 40° - \mu_s \cos 40°)$$
$$\mu_s = \frac{\sin 40°}{\cos 40°} = 0.84$$

B55)



Set right as +ve

① $F_{net} = (m_1 + m_2)a = 2ma$ $\mu_K = 0.30$

$$2ma = mg\sin 30 - (mg\sin 60 + \mu_K mg\cos 60 + \mu_K mg\cos 30)$$

$$a = \frac{\cancel{m}g\sin 30 - (\cancel{m}g\sin 60 + \mu_K \cancel{m}g\cos 60 + \mu_K \cancel{m}g\cos 30)}{2\cancel{m}}$$

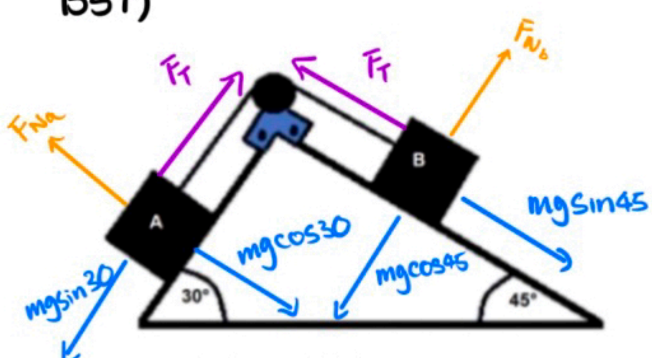
$$a = -3.8 \ m/s^2$$

② $\Delta x = \dfrac{v^2}{2a}$

$\Delta x = \dfrac{v^2}{2(-3.8)} = -\dfrac{5}{38}v^2$ travel toward left

---

B57)



$m_A = 15kg$ $m_B = 10kg$

let right be +ve

① $F_T - m_A g\sin 30 = m_A a \rightarrow F_T = m_A a + m_A g\sin 30$

② $m_B g\sin 45 - F_T = m_B a \rightarrow F_T = m_B g\sin 45 - m_B a$

$$m_A a + m_A g\sin 30 = m_B g\sin 45 - m_B a$$

iso a

$$a(m_A + m_B) = m_B g\sin 45 - m_A g\sin 30$$

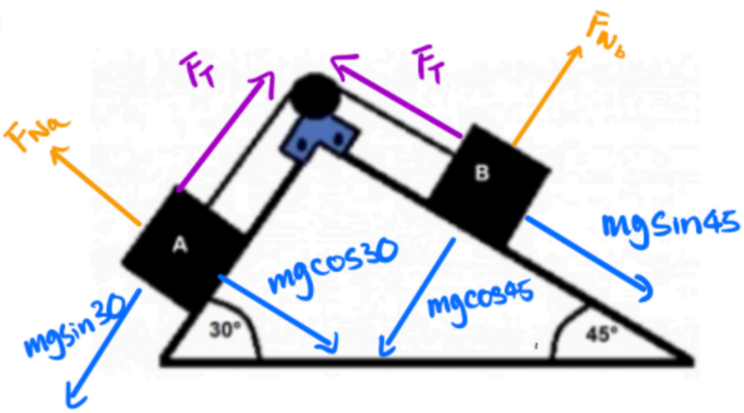
$$a = \frac{m_B g\sin 45 - m_A g\sin 30}{m_A + m_B}$$

$$= \frac{g(m_B\sin 45 - m_A\sin 30)}{m_A + m_B}$$

A go downward
B go upward

$$= -0.16 \ m/s^2$$

B59)



assume system stationary

$F_{Na} = M_A g \cos30$ $\quad F_{N_b} = M_B g \cos45$

Max friction for B

$F_{fsb} = \mu_s F_{N_b} = \mu_s M_B g \cos45$

$F_{netA} = F_{netB} = 0$ bc stationary

Max friction on A

$F_{fsa,max} = \mu_s M_A g \cos30$
$= 50.9N$

max to move

$F_T + F_{fsb,max} - M_B g \sin45 = 0$

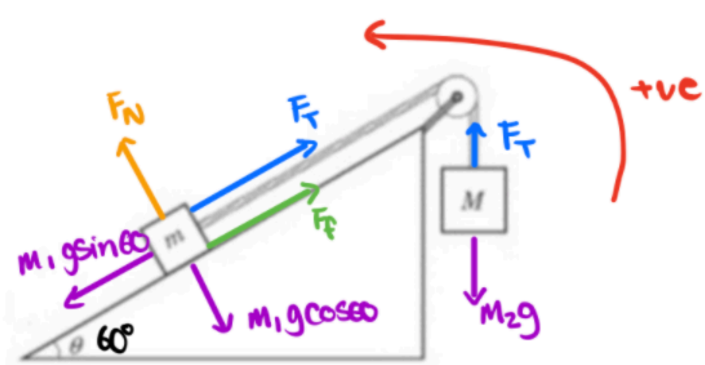
$F_T = M_B g \sin45 - \mu_s M_B g \cos45$

$F_T + F_{fsa} - mg\sin30 = 0$

$F_{fsa} = mg\sin30 - (M_B g \sin45 - \mu_s M_B g \cos45)$
$= 7.4\ N$

$50.9 > 7.4$ $\quad \therefore$ block A stagnant
so $a = 0$

B61)



$\mu_s = 0.55$

M_1	M_2
$M_1 g = 249N$	$M_2 g = 166N$
$M_1 g \sin 60 - F_T - F_f = M_1 a$	$F_T - M_2 g = M_2 a$
$F_T = M_1 g \sin 60 - F_f - M_1 a$	$F_T = M_2 a + m_2 g$

$$M_1 g \sin 60 - F_f - M_1 a = M_2 a + m_2 g$$

$$M_1 g \sin 60 - m_2 g - F_f = (M_1 + M_2) a$$

Assume F_{net} system $= 0 \Rightarrow a = 0$

$$\therefore F_f = M_1 g \sin 60 - m_2 g = 49.6N$$

$$F_{fs,max} = \mu_s F_N = \mu_s M_1 g \cos 60 = 68.5N$$

$\therefore$ $68.5 > 49.6$ acceleration is 0, under assumption if at rest

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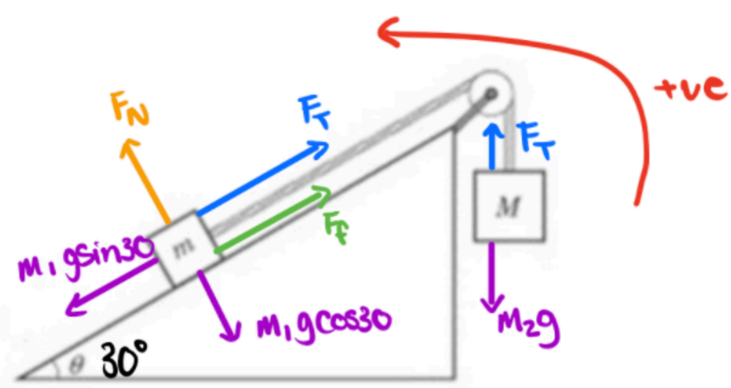
B63)



$m_1 = 6kg$

$a = 1.75\ m/s^2$

$\mu_k = 0.22$

$F_f = \mu_k F_N = \mu_k M_1 g \cos 30$

$M_2 = ?$

$T - m_2 g = m_2 a$

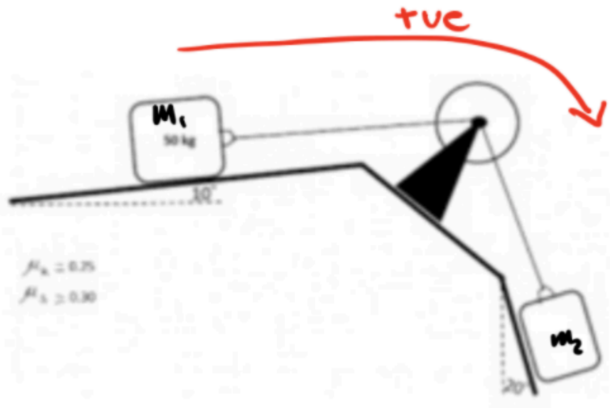
$T = m_2(g + a)$

$$F_{net\,a} = m_1 g \sin 30 - F_T - F_f$$
$$= m_1 g \sin 30 - m_2(g+a) - \mu_k M_1 g \cos 30$$

$$m_2 = \frac{m_1 g \sin 30 - m_1 a - \mu_k M_1 g \cos 30}{g + a}$$

$m_2 = 0.67kg$

B65)



$a = 0\,m/s^2 \leftarrow$ @ equlibrium

$M_1 = 50kg$

$\mu_s = 0.30$

M_1

$F_T - F_{f1} - m_1 g \sin 10 = 0$

$\hookrightarrow = \mu_s F_{N1} = \mu_s m_1 g \cos 10$

$F_T = \mu_s m_1 g \cos 10 + m_1 g \sin 10$
$= 230N$

M_2

$M_2 g \cos 20 - F_T - F_{f2} = 0$

$\hookrightarrow = \mu_s F_{N2}$
$= \mu_s M_2 g \sin 20$

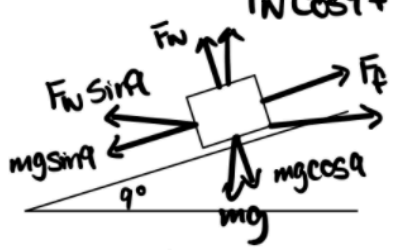
$M_2 g \cos 20 - F_T - \mu_s M_2 g \sin 20 = 0$

$$m_2 = \frac{F_T}{g(\cos 20 - \mu_s \sin 20)}$$

$M_2 = 28kg$

B67)

$F_N \cos\theta + F_f \sin\theta$



$V_{max} = 55\,km/h = 15.27\,m/s$

$r = \frac{600}{2} = 300m$

$F_c \quad + F_f \cos\theta$

$\hookrightarrow \frac{mV_{max}^2}{r}$ (centripetal force)

critical velocity

$\hookrightarrow V_c = \sqrt{rg\tan\theta} = 21.57\,m/s$

bc $V_c > V_{max}$ friction act outward

minimal friction

X-axis

$$F_N \sin\theta = \frac{m v_{max}^2}{r} + F_f \cos\theta$$

$$F_N \sin\theta = \frac{m v_{max}^2}{r} + \mu F_N \cos\theta$$

$$F_N = \frac{m v_{max}^2}{r(\sin\theta - \mu\cos\theta)}$$

Y-axis

$$F_N \cos\theta + F_f \sin\theta = mg$$

$$F_N \cos\theta + \mu F_N \sin\theta = mg$$

$$F_N = \frac{mg}{\cos\theta - \mu\sin\theta}$$

$$\frac{\cancel{m} v_{max}^2}{r(\sin\theta - \mu\cos\theta)} = \frac{\cancel{m} g}{\cos\theta - \mu\sin\theta}$$

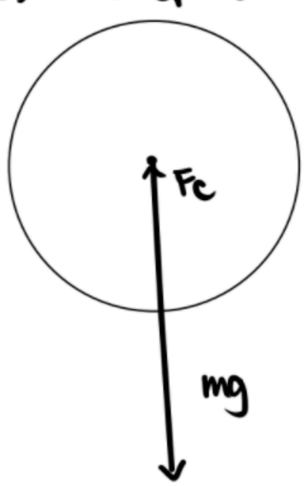
$$\frac{v_{max}^2}{rg} = \frac{\sin\theta - \mu\cos\theta}{\cos\theta - \mu\sin\theta}$$

$$\mu = 0.08$$

B69) a) $F_c = \frac{mv^2}{r}$

force keep object moving in curved path

b) Min speed



assume uniform circular motion

$F_c - mg = 0$ $\quad$ $r = 1\,m$

$F_c = mg$

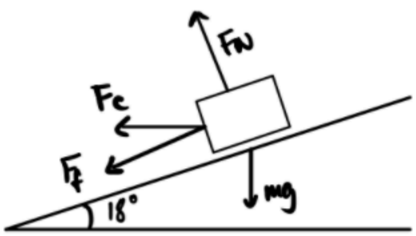
$\frac{\cancel{m}v^2}{r} = \cancel{m}g$

$v_{min} = \sqrt{rg} = 7\ m/s$

c) $\omega = \frac{2\pi}{T} \rightarrow = \frac{2\pi r}{v}$

$\omega = \frac{v}{r} = 7\ s^{-1}$

B71)



$r = 75m \quad \mu_k = 0.22$

$V_{max} = \sqrt{r g \tan\theta} = 15.33 m/s$

B73) a) only 1 person pull

$F_{net,x} = F_T$

$F_T = ma$

2 person pull

$F_{net,x} = 2F_T$

$m a_1 = 2F_T$

$a_1 = 2a$ double acceleration

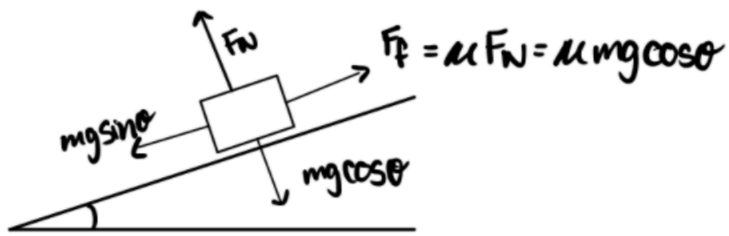
b) $2m\, a_2 = F_T$

$a_2 = \frac{F_T}{2m}$

$= \frac{\cancel{m}a}{2\cancel{m}}$

$a_2 = \frac{1}{2}a$ half acceleration

B75)



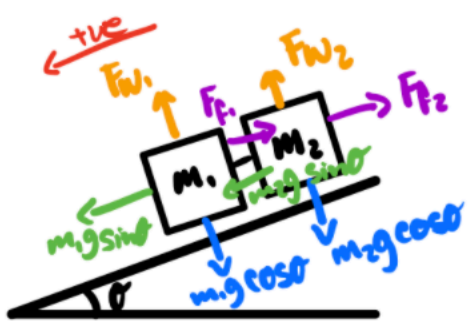
$$mg\sin\theta - F_f = ma$$

$$\cancel{m}g\sin\theta - \mu \cancel{m}g\cos\theta = \cancel{m}a$$

$$a = g(\sin\theta - \mu\cos\theta)$$

$$\frac{\frac{a}{g} - \sin\theta}{\cos\theta} = \mu \Rightarrow \boxed{\mu = \frac{a}{g\cos\theta} - \tan\theta}$$

B77)



a, b) $\mu_1 > \mu_2$ or $\mu_1 < \mu_2$ $\quad \mu F_N = \mu mg\cos\theta$

$$(m_1 g\sin\theta + m_2 g\sin\theta) - (F_{f_1} + F_{f_2}) = (m_1+m_2)a$$

$$(m_1 g\sin\theta + m_2 g\sin\theta) - (\mu_1 m_1 + \mu_2 m_2) g\cos\theta = (m_1+m_2)a$$

$$a = \frac{\left[(m_1+m_2)\sin\theta - (\mu_1 m_1 + \mu_2 m_2)\cos\theta\right] g}{m_1+m_2}$$

c) $\mu_1 = \mu_2$

$$(m_1 g\sin\theta + m_2 g\sin\theta) - (F_{f_1} + F_{f_2}) = (m_1+m_2)a$$

$$(m_1 g\sin\theta + m_2 g\sin\theta) - (\mu m_1 + \mu m_2) g\cos\theta = (m_1+m_2)a$$

$$(m_1+m_2) g\sin\theta - (m_1+m_2)\mu g\cos\theta = (m_1+m_2)a$$

$$a = \frac{\cancel{(m_1+m_2)} g\sin\theta - \cancel{(m_1+m_2)}\mu g\cos\theta}{\cancel{m_1+m_2}}$$

$$a = g(\sin\theta - \mu\cos\theta)$$
