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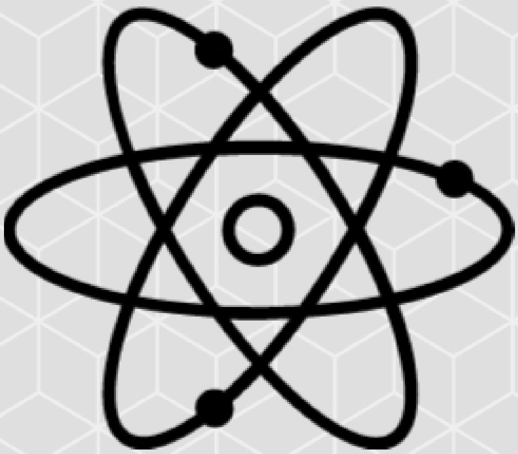
PHYSICS FOR THE LIFE SCIENCES

Solution Manual



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Physics for the Life Sciences – Energy Solutions

Introduction:

Dear student,

Thank you for opening this solution manual for the Energy 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 Energy 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.

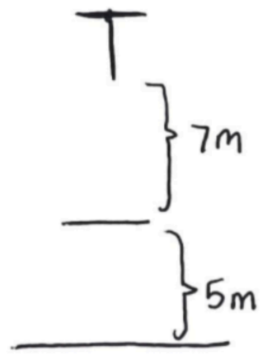
Note: There may be more than one correct method to solve some of the problems outlined in the question manual. Thus, the solutions provided may not represent the only acceptable solution.

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

C1.



Given:

$V_i = 10\,m/s$

$h_i = 5m$

Asked for:

$h_f = ?$

need to compare to $(5+7=12)$ 12m to see if stunt performer can grab rope

Conservation of Energy: $ME_i = ME_f$

$$KE_i + PE_i = \overset{0}{\cancel{KE_f}} + PE_f$$ *Factor out mass

$$\frac{1}{2}\cancel{m}V_i^2 + \cancel{m}gh_i = \cancel{m}gh_f$$

$$\frac{1}{2}V_i^2 + gh_i = gh_f$$

$$h_f = \frac{\frac{1}{2}V_i^2 + gh_i}{g}$$

$$h_f = \frac{\frac{1}{2}(10\frac{m}{s})^2 + (9.8\frac{m}{s^2})(5m)}{9.8\frac{m}{s^2}}$$

$$h_f = 10.1m$$

$$h_f = 10m$$ ← 2 m short of the rope

∴ James Bamford does not make the rope.

C3. Given:

$m = 2000\,kg$

$\theta = 3.00°$

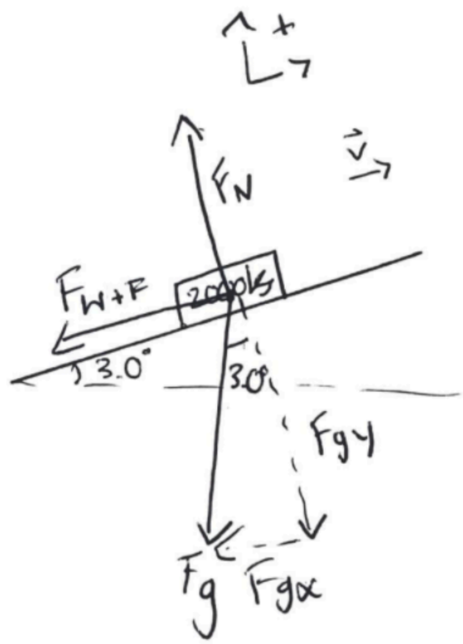
$\vec{V} = 10.0\,m/s$ [up the hill]

$F_{W+F} = -500\,N$ [down the hill]

Asked For:

$P = ?$

FBD



Formula:

$$P = \frac{W}{\Delta t} = \frac{F \cdot d}{\Delta t} = F \cdot \vec{V}$$

$F_{Total} = ?$

$$F_{Total} = -500N + F_{gx}$$
$$= -500N - 1025.78N$$
$$= -1525.78N$$

Note $F_{gy} = F_N$ thus vertical component cancels out

$$F_{gx} = -F_g \cdot \sin(3.0°)$$
$$= -mg\sin(3.0°)$$
$$= -(2000kg)(9.80\tfrac{m}{s^2})(\sin 3°)$$
$$= 1025.78\,N$$

$$P = |F|\,\vec{V}$$
$$= 1525.78N \cdot 10\,m/s$$
$$= 15257.8\ kg\,m^2/s^3$$
$$= 1.5 \times 10^4\ kg \cdot m^2/s^3 \text{ or } W$$

∴ the power needed to overcome gravity, wind resistance, and friction is 1.5×10^4 W. In order to move this is the min power required.

C5.

a) Requires inital velocity of bullet in order to solve.

b) Assume $V_i > V_f$ because bullet slows down (loses KE as it pierces the barrel)

Lets say $V_i = 800\,m/s$

$$\text{Amount of energy taken out of bullet} = \Delta KE = W_{barrel} = \frac{1}{2}m\left(V_f^2 - V_i^2\right)$$

$$W_{barrel} = \frac{1}{2}(0.01\,kg)\left[(785\,m/s)^2 - (800\,m/s)^2\right]$$

$$W_{barrel} = -118.875\,N\cdot m$$

$\therefore$ the amount of energy (magnitude) taken out of bullet is 118 N·m.

c) Collision Question: Conservation of momentum:

$$P_i = P_f$$

$$P_{bullet\,i} + P_{barrel\,in} = P_{bullet\,f} + P_{barrel\,f}$$

$$m_{bu}V_{bui} + \cancel{m_{ba}}^{0} V_{bai} = m_{bu}V_{buf} + m_{ba}V_{baf}$$

$$\frac{m_{bu}(V_{bui} - V_{buf})}{m_{ba}} = V_{baf} = \frac{(0.01\,kg)(800\,\frac{m}{s} - 785\,m/s)}{(0.9\cdot 5\,kg)} = 0.033\,m/s$$

$\therefore$ final velocity of barrel is $3.3\times10^{-2}\,\frac{m}{s}$

C7. Given:

$m = 310 \text{ kg}$

$V = 0.25 \text{ m/s}$

Asked For:

$P = ?$

Formula:

$$P = \frac{W}{\Delta t} \qquad W = F \cdot d$$

$$P = \frac{F \cdot d}{\Delta t} \quad \frac{d}{\Delta t} = V$$

$$P = F \cdot V$$

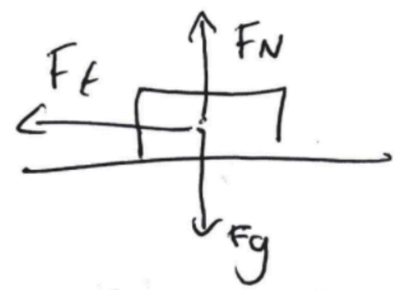
Force to lift object vertically is simply $m \cdot g$

Work:

$$P = mgV$$
$$= (310 \text{ kg})(9.8 \tfrac{m}{s^2})(0.25 \tfrac{m}{s})$$
$$= 759.5 \text{ kg} \cdot \frac{m^2}{s^3}$$

$\therefore$ the machine's power output is $760 \text{ kg} \frac{m^2}{s^3}$ or 760 W.

C9. Work done by a non-conservative force changes the mechanical energy of a system. Friction is an example of a force that can change mechanical energy into thermal energy. In the ice scenario friction has the potential to decrease the mechanical energy of the system if it does work (moves).



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c11. Given:

$m = 98\,kg$
$F = 380N$
$d = 4m$

Asked For:
a) $\vec{V}_f = ?$
b) $\Delta t = ?$ (and factors influencing Δt)

Formulas / principles:

$W = F \cdot d$ $\quad F = ma$ $\quad a = \frac{\Delta V}{\Delta t}$

Work-Energy Principle:

$W = \Delta KE$
$W = KE_f - KE_i$
$W = \frac{1}{2}m(V_f - V_i)$

* Assume $V_i = 0$

a) $F \cdot d = \frac{1}{2}m(V_f - \cancel{V_i}^{0})$

$(380N)(4m) = \frac{1}{2}(98\,kg)\,V_f$

$V_f = 31\ m/s$

∴ the final velocity is 31 m/s

b) $F = ma$

$F = m\frac{\Delta V}{\Delta t}$

$\Delta t = \frac{m \Delta V}{F}$

$= \frac{(98\,kg)(31\,m/s)}{380N}$

$= 8.0\ s$

∴ the time it takes to move the boulder 4m is 8.0 s as seen by the equation m and ΔV are directly proportional to time and Force is indirectly proportional.

C13. Given:

$P = 2450\ W$

$m = 800\ kg$

Asked For: $v = ?$

Formula:

$$\left.\begin{array}{l} P = \dfrac{W}{\Delta t} \\ W = F \cdot d \end{array}\right\} P = F \cdot v$$

$$v = \frac{P}{F}$$

$$v = \frac{2450\ W}{(800\ kg)(9.8\ \frac{m}{s^2})}$$

$$v = 0.3125\ m/s$$

∴ the object is being lifted at 0.3 m/s.

C15. Given:

$m = 2.8\ kg$

$v = 10\ m/s$

$k = 600\ N/m$

$\mu_k = 0.6$

Conservation of energy:

$$KE_i + \cancel{PE_i}^{\,0} + W_{friction} = \cancel{KE_f}^{\,0} + PE_f$$

$$\frac{1}{2}mv^2 + F_{kf}d = \frac{1}{2}kx^2$$ assume $x = d$

$$\frac{1}{2}(2.8kg)\left(\frac{1}{3}\cdot 10\frac{m}{s}\right)^2 + F_N(0.6)d = \frac{1}{2}kx^2$$ $F_N = F_g$

$$15.555 kg\cdot\frac{m^2}{s^2} + 16.464Nd = \frac{1}{2}\left(600\frac{N}{m}\right)x^2$$

$$0 = 300x^2 - 16.464x - 15.555$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-(-16.464) \pm \sqrt{(-16.464)^2 - 4(300)(-15.555)}}{2(300)}$$

$$= \frac{16.464 \pm \sqrt{18937}}{600}$$

✓ $= 0.2567$ ✗ $= -0.2019$

∴ the maximum compression is 0.257 m.

Solution for C17 not available.

C19.

$m = y\ kg$

a) $KE = ?$

$KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}(y)x^2$

$\boxed{KE = \frac{1}{2}yx^2}$

the KE formula is independent of an angle or direction.

b) Cons. of Energy $ME_i = ME_f$

$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + \cancel{mgh_f}^{\,0}$

$\frac{1}{2}yx^2 + yg(1.5) = KE_f$

$\boxed{KE_f = y\left(\frac{1}{2}x^2 + 14.7\,m^2/s^2\right)}$

c) $R = \frac{v^2\sin(2\theta)}{g} = \frac{x^2\sin(60°)}{9.8\,m/s^2} = \frac{x^2}{0.08837\,m/s^2}$

$\boxed{R = \frac{x^2}{0.08837\,m/s^2}}$

C21. Given:

$m_1 = x \qquad m_2 = \frac{3}{2}x$

$KE_1 = 3KE \qquad KE_2 = KE$

$$\frac{3\cancel{KE}}{\cancel{KE}} = \frac{\cancel{\frac{1}{2}}\cancel{m}\, V_1^2}{\cancel{\frac{1}{2}}\, \frac{3}{2}\cancel{m}\, V_2^2}$$

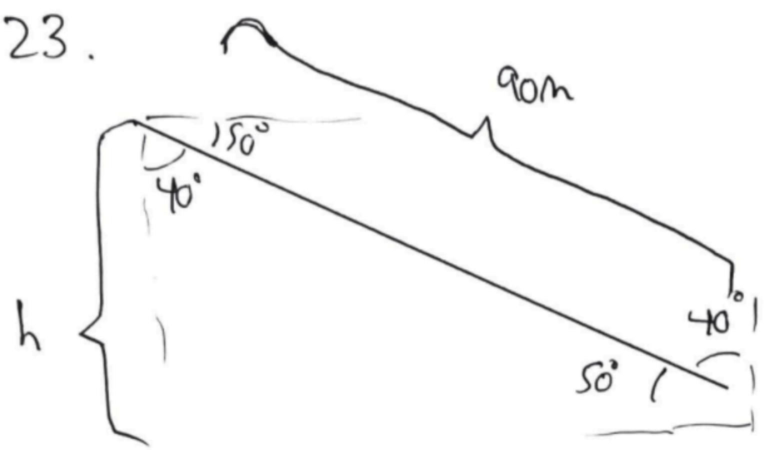
$$3 = \frac{V_1^2}{\frac{3}{2} V_2^2}$$

$$\sqrt{\frac{9}{2}} = \sqrt{\frac{V_1^2}{V_2^2}}$$

$$\frac{3}{\sqrt{2}} = \frac{V_1}{V_2}$$

$\therefore$ the ratio of object one to object 2 in terms of speed is $\frac{3}{\sqrt{2}} \approx 2.12132\ldots$

C23.



Use Trig to find height of slope

$$\sin 50° = \frac{h}{90m}$$

$$h = (90m)\sin 50°$$

$$h = 68.94m$$

Conservation of energy

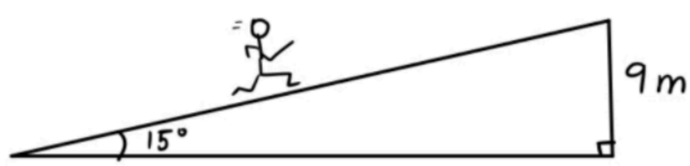
* assume $v_i = 0$, $h_f = 0$ and $W_{friction} = 0$

$$ME_i = ME_f$$
$$\cancel{KE_i} + PE_i = KE_f + \cancel{PE_f}$$
$$\cancel{m}gh_i = \frac{1}{2}\cancel{m}v_f^2$$
$$\sqrt{2gh_i} = v_f$$
$$v_f = \sqrt{2(9.8\,\tfrac{m}{s^2})(68.94\,m)}$$
$$= 36.7589\ m/s$$
$$\approx 36.8\ m/s$$

$\therefore$ by using conservation of energy one can determine a maximum final velocity of 36.8 m/s.

C25.

$V = 12\ km/h = 3.33\ m/s$
$P = 750\ W$
$m = 70\ kg$
$eff = 25\%$
$h = 9\ m$



<u>Note:</u> we assume the watch measures power based on work output.

① $\Delta E = E_k + E_g$

$\Delta E = \frac{1}{2}mv^2 + mgh$

$\Delta E = \frac{1}{2}(70\ kg)(3.33\ m/s)^2 + (70\ kg)(9.8\ N/m)(9\ m)$

$\Delta E = 6562\ J$ This 6562 J is equal to Issa's work output.

② $eff = \frac{W_{out}}{W_{in}} \times 100\%$

$25\% = \frac{W_{out}}{6562\ J} \times 100\%$

$W_{out} = (6562\ J)(0.25)$

$W_{out} \doteq 1640\ J$

③ $\Delta d_{ran} = \frac{9\ m}{\sin 15°}$

$\Delta d_{ran} = 34.8\ m$

④ $\Delta t = \frac{\Delta d}{v}$

$\Delta t = \frac{34.8\ m}{3.33\ m/s}$

$\Delta t = 10.4\ s$

⑤ $P = \frac{W_{out}}{\Delta t} = \frac{1640\ J}{10.4\ s} = \boxed{1.6 \times 10^2\ W}$

∴ Issa consumes energy at a rate of 1.6×10^2 W as he runs up the slope.

C27. Given:

$m = 7.0\,kg$

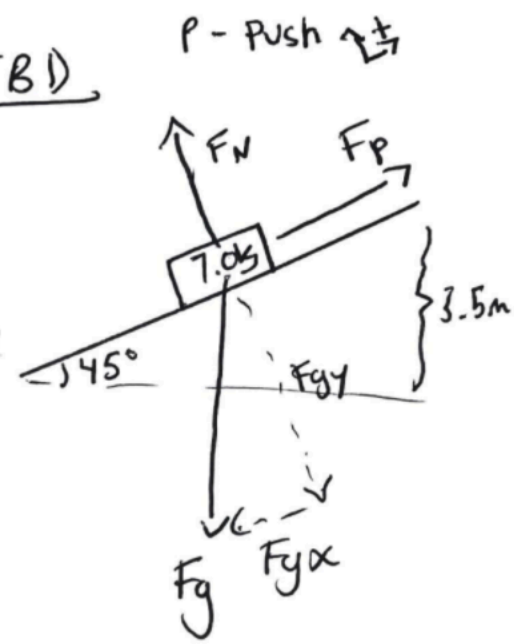
$F_p = 28\,N$

$F_g = mg = (7.0\,kg)(9.8\,m/s^2) = 68.6\,N$

$\theta = 45°$

$h = 3.5\,m$

FBD



Asked For:

a) $W_g = ?$

b) $W_p = ?$

a) $W_g = F_g \, d \cdot \cos\phi$ ← ϕ between F_g and d

$= (68.6N)(3.5m)\cos(180°)$

$= -240.1$ N·m

$= -240$ N·m

∴ 240 N·m of work is done by gravity that opposes the upward motion

b) $W_p = F_p \cdot d \cdot \cos\phi$ ← now ϕ is between F_p and d

$= (28N)(3.5m)\cos(45°)$

$= 69.3$ N·m

$= 69$ N·m

and 69 N·m of work is done when a force is applied to the boxes that helps push them up the ramp.

C29. Given:

$m = 20kg$

$\theta = 20°$

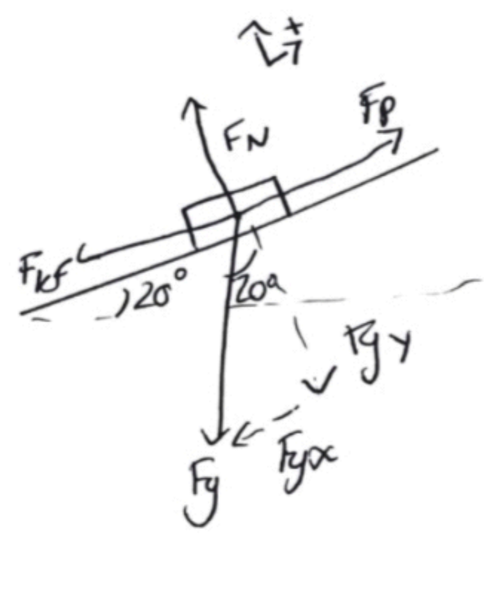
$\mu_k = 0.5$

Asked For:

$W_g = ?$

$W_{kf} = ?$

FBD



$$W_g = F_g \cdot d \cdot \cos\theta$$
$$= (20kg)(9.8\,\tfrac{m}{s^2})(10m)\cos(110^\circ$$
$$= -670.4\ N \cdot m$$
$$= -670\ N \cdot m$$

$$W_{kf} = F_{kf} \cdot d \cdot \cos\theta$$
$$= \mu_k F_{gy} d \cos\cancel{\theta}$$
$$= (0.5)(184.2N)(10m)\cos180^\circ$$
$$= -920.89\ N \cdot m$$
$$= -921\ N \cdot m$$
$$= -920\ N \cdot m$$

$$F_{gy} = F_g \cdot \cos20^\circ$$
$$= (20kg)(9.8\,\tfrac{m}{s^2})\cos20^\circ$$
$$= 184.2N$$

∴ the work done by gravity and kinetic friction is $-670\ N \cdot m$ and $-920\ N \cdot m$, respectively. consult conventions to see that both oppose motion up the ramp.

C31. Given:

$m = 300g = 0.3kg$

$V_i = 0$

$V_f = 30\ m/s$

Asked For:

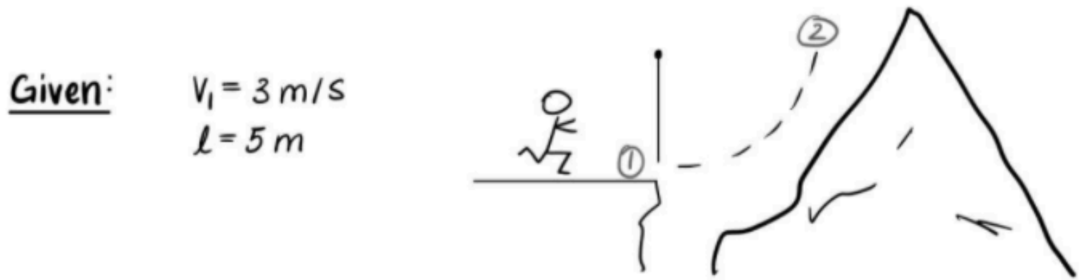
$W = ?$

Formula: Work-Energy Theorem

$$W = \Delta KE = KE_f - KE_i$$
$$= \tfrac{1}{2} m V_f^2 - \cancel{\tfrac{1}{2} m V_i^2}^{\,0}$$
$$= \tfrac{1}{2}(0.3kg)(30m/s)^2$$
$$= 135J$$

∴ the work done by air resistance is 135J.

C33.



The organizers of the arcade do **not** need to consider the length of the rope when determining the height of the mountain. Mitch's ability to swing up the mountain depends solely on a conservation of energy. All the kinetic energy Mitch has while running is converted into gravitational potential energy as he swings up. Therefore, the maximum height of his swing will be at whatever point Mitch's gravitational potential energy is equivalent to Mitch's initial kinetic energy.

Mathematically, this maximum height only depends on his initial speed, as shown.

$$E_{T1} = E_{T2}$$

$$E_{K1} + \cancel{E_{g1}}^{0} = \cancel{E_{K2}}^{0} + E_{g2}$$

$$\frac{1}{2}mv^2 = mgh$$

$$\frac{1}{2}v^2 = gh$$

$$h = \frac{v^2}{2g}$$

$$h = \frac{(5\ m/s)^2}{2(9.8\ m/s^2)}$$

$$h = \frac{25\ m^2/s^2}{19.6\ m/s^2}$$

$$\boxed{h = 1.3\ m}$$

Mitch will reach a maximum height of 1.3 m on his swing.

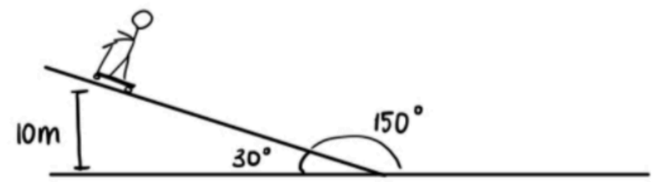
C35. <u>Given:</u>

$V = 5\ m/s$

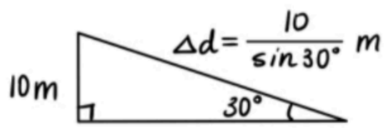
$\theta = 150°$

$m = 50\ kg$

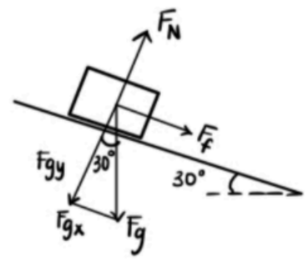
$h = 10\ m$



<u>Finding Δd</u>



<u>FBD</u>



$$E_{T_1} + W_{friction} = E_{T_2}$$

$$\frac{1}{2} m v^2 + F_f \Delta d = mgh$$

$$\frac{1}{2}(50\ kg)(5\ m/s)^2 + F_f\left(\frac{10\ m}{\sin 30°}\right) = (50\ kg)(9.8\ N/kg)(10\ m)$$

$$625\ \frac{kg\cdot m^2}{s^2} + {}_f\ (20\ m) = 4900\ N\cdot m$$

$$F_f\ (20\ m) = 4900\ N\cdot m - 625\ N\cdot m$$

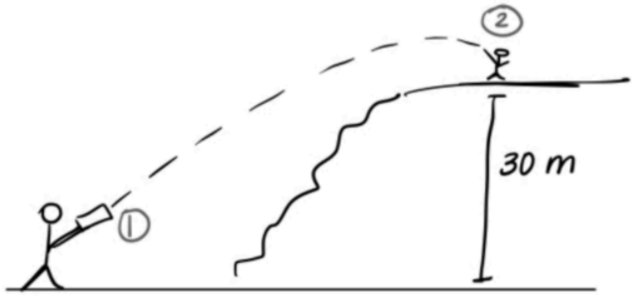
$$F_f\ (20\ m) = 4275\ N\cdot m$$

$$\boxed{F_f = 210\ N}$$

∴ The net frictional force on the boy is 210 N.

C37. A non-conservative force is one that will cause a change in the mechanical energy of a system. An example of a non-conservative force is the frictional force, which removes mechanical energy from a system by converting it into thermal energy. Although ice has a very small coefficient of friction, the frictional force is not completely negligible. Therefore, if a box were sent gliding over a surface of ice, a small frictional force would remove kinetic energy and convert it into thermal energy. This non-conservative frictional force cannot remove gravitational potential energy from the system, therefore only the amount of kinetic energy would be altered. This non-conservative frictional force would be more pronounced over rough areas of ice and remove a greater amount of kinetic energy from the system.

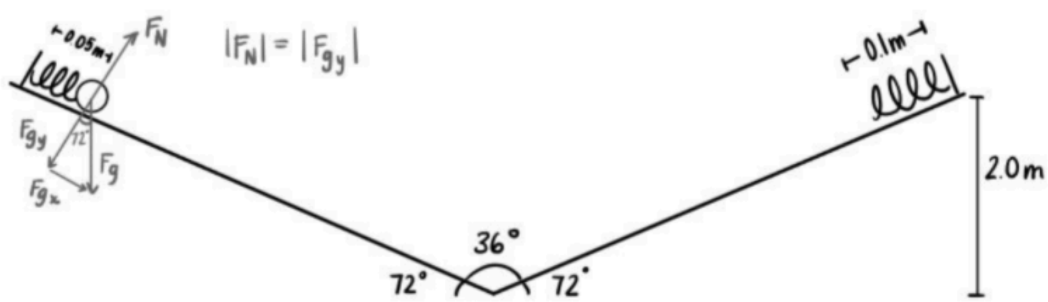
C39. **Given:** $v_1 = 25\,m/s$
$\theta = 50^\circ$
$h = 30\,m$
$V_2 = ?$



$$E_{T_1} = E_{T_2}$$
$$E_{K_1} + \cancel{E_{g_1}}^{0} = E_{K_2} + E_{g_2}$$
$$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2 + mgh$$
$$\frac{1}{2}(25\,m/s)^2 = \frac{1}{2}V_2^2 + (9.8\,m/s^2)(30\,m)$$
$$312.5\,m^2/s^2 = \frac{1}{2}V_2^2 + 294\,m^2/s^2$$
$$18.5\,m^2/s^2 = \frac{1}{2}V_2^2$$
$$37\,m^2/s^2 = V_2^2$$
$$V_2 = \sqrt{37\,m^2/s^2}$$
$$\boxed{V_2 = 6.1\,m/s}$$

∴ The shirt is traveling at 6.1 m/s.

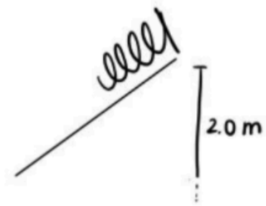
41.



Given: $K = 100\,N/m$ $\mu_f = 0.30$ $m = 0.030\,kg$
$x = 0.050\,m$ $h = 2.0\,m$
$l_{sp} = 0.100\,m$ $\theta = 36^\circ$

Basic expressions:

length of ramp: $\Delta d = \dfrac{2.0\,m}{\sin 72°}$



Starting height of ball: $h_1 = 2.0\,m - 0.05 \sin 72°$

Ending height of ball: $h_2 = 2.0\,m - (0.1m - x)\sin 72°$

① $$E_{T_1} - W_f = E_{T_2}$$
$$E_{e_1} + E_{g_1} - F_f \cdot \Delta d = E_{e_2} + E_{g_2}$$
$$\frac{1}{2} k x_1^2 + mgh_1 - \mu_f \cdot mg\cos 72 \cdot \Delta d = \frac{1}{2} k x_2^2 + mgh_2$$
$$\frac{1}{2} k x_1^2 + mgh_1 - \mu_f \cdot mg\cos 72 \cdot \Delta d = \frac{1}{2} k x_2^2 + mg(2 - (0.1m - x)\sin 72°)$$

$$\text{LEFT SIDE} = \frac{1}{2}(100\tfrac{N}{m})(0.05m)^2 + (0.03\,kg)(9.8\tfrac{N}{kg})(2.0m - 0.5\sin 72°) - 0.3\,(0.03kg)(9.8\tfrac{N}{kg})(\cos 72°)\left(\frac{2.0}{\sin 72}\right)$$
$$= 0.516\,J$$

$$0.516J = \frac{1}{2}(100\tfrac{N}{m})(x_2^2) + (0.03\,kg)(9.8\tfrac{N}{kg})(2 - 0.1\sin 72 - x\sin 72)$$
$$0.516 = 50x^2 + (0.294)(1.90 - 0.951x)$$
$$0.516 = 50x^2 + 0.559 - 0.280x$$
$$0 = 50x^2 - 0.280x + 0.043$$
$$0 = 50x^2 - 0.280x + 0.043$$

$$x = \frac{0.280 \pm \sqrt{(-0.280)^2 - 4(50)(0.043)}}{2(50)}$$

$$x = \frac{0.280 \pm \sqrt{-8.5216}}{100}$$

therefore, the ball does not make it to the spring.

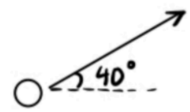
we must reconsider our initial conservation of energy statement, because we proved that $E_{e_2} = 0$.

② $$E_{T_1} - W_f = E_{T_2}$$
$$E_{e_1} + E_{g_1} - F_f \cdot \Delta d = \cancel{E_{e_2}}^{0} + E_{g_2}$$
$$\frac{1}{2} k x_1^2 + mgh_1 - \mu_f \cdot mg\cos 72 \cdot \Delta d = mgh_2$$
$$0.516\,J = (0.030\,kg)(9.8\tfrac{N}{kg})(h_2)$$
$$0.516\,J = (0.294\,N)(h_2)$$
$$\boxed{h_2 = 1.8\,m}$$

∴ The steel ball will not reach the spring on the other side of the ramp. It will only reach a height of 1.8 m up the other side of the ramp.

C43. $m = 0.250\ \text{kg}$ $\quad \theta = 40^\circ$

$F = 15\ \text{N}$ $\quad \Delta t = 0.285\ \text{s}$



① $F_y = ma_y$

$$15\text{N}(\sin 40^\circ) = (0.250\ \text{kg})(a_y)$$

$$a_y = 38.57\ \text{m/s}^2$$

② $a_y = \dfrac{V_{1y} - V_{0y}}{\Delta t}$

$$38.57\ \text{m/s}^2 = \frac{V_{1y} - 0\ \text{m/s}}{0.285\ \text{s}}$$

$$V_{1y} = 10.99\ \text{m/s}$$

③ ignore motion in x-dimension, since change in gravitational potential energy is unaffected by it. Horizontal velocity remains constant, therefore so does E_{Kx}.

<u>in y-dimension:</u>

$$E_{K1} + E_{g1} = \cancelto{0}{E_{K2}} + E_{g2}$$

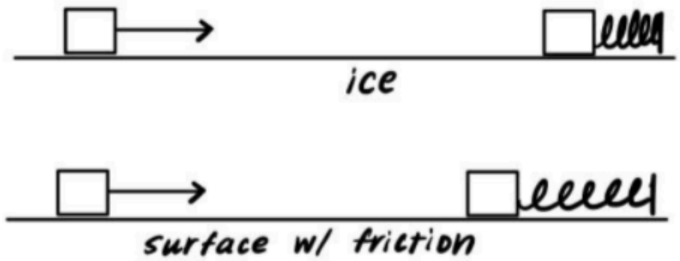
$$\frac{1}{2}mv^2 = E_{g2} - \cancelto{0}{E_{g1}}$$

$$\frac{1}{2}(0.250\ \text{kg})(10.99\ \text{m/s})^2 = \Delta E_g$$

$$\boxed{\Delta E_g = 15\ \text{J}}$$

Therefore, the projectile's increase in gravitational potential energy is 15 J.

C45.



Both the boxes began with 70J of kinetic energy, but the box that slid on a surface with friction compresses a spring by a smaller amount than the box that slid on ice (a surface with a nearly negligible coefficient of friction). In the action of compressing the spring, the two boxes slow down and come to a stop at a point of maximum compression. This point of maximum compression represents the moment where all the initial kinetic energy held in the sliding boxes converts to a stored elastic potential energy.

In order to determine how much energy was lost due to friction, a comparison of the stored elastic potential energy must be made. The formula for elastic potential energy is as follows:

$$E_e = \frac{1}{2} K x^2$$

where K is the spring constant.

Assuming that no energy is lost in the case when the box is slid over ice, the spring constant can be calculated as:

$$E_{e\ ice} = 70\,J = \frac{1}{2} K x^2$$
$$70\,J = \frac{1}{2} K\ (0.30\,m)^2$$
$$70\,J = 0.045\,m^2 \cdot K$$
$$K = 1.56 \times 10^3\ N/m$$

Using the spring constant, the elastic potential energy in the spring compressed by a box slid over a surface with friction is:

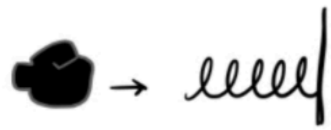
$$E_{e\ friction} = \frac{1}{2} K x^2$$
$$= \frac{1}{2}\left(1.56 \times 10^3\ N/m\right)(0.10\,m)^2$$
$$= 7.8\ J$$

$$\therefore\ E_{lost\ due\ to\ friction} = E_{T_1} - E_{T_2}$$
$$E_{lost\ due\ to\ friction} = 70\,J - 7.8\ J$$
$$\boxed{E_{lost\ due\ to\ friction} \doteq 62\ J}$$

Therefore, the energy lost due to friction is 62 J.

C47.

$m = 20 \text{ kg}$
$V = 30 \text{ km/h}$
$K = 500 \text{ N/m}$



① km/h → m/s conversion

$$30 \frac{km}{h} \cdot \frac{1000 \, m}{km} \cdot \frac{1 \, h}{3600 \, s} = 8.33 \, m/s$$

② all E_K is converted into stored E_e.

$$E_K = E_e$$
$$\frac{1}{2} m v^2 = \frac{1}{2} K x^2$$
$$\frac{1}{2} (20 \, kg)(8.33 \, m/s)^2 = \frac{1}{2} (200 \, N/m) x^2$$
$$693.9 \, \frac{kg \cdot m^2}{s^2} = (100 \, N/m) x^2$$
$$x^2 = 6.939 \, m$$
$$\boxed{x = 2.6 \, m}$$

∴ The spring at the amusement park will be compressed by 2.6 m.

C49.

$$E_K = \frac{1}{2} m v^2$$

$$E_K \propto v^2$$

Kinetic energy is proportional to the square of velocity.

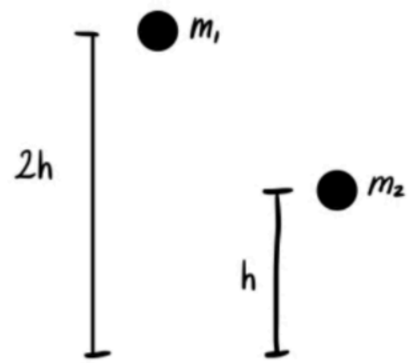
Assume v is quadrupled :

$$E_{K_2} = \frac{1}{2} m (4v)^2$$
$$E_{K_2} = \frac{1}{2} m (16 v^2)$$
$$E_{K_2} = 16 \left(\frac{1}{2} m v^2\right)$$
$$E_{K_2} = 16 \, E_{K_1}$$

If v is quadrupled, kinetic energy will increase by a factor of 16.

However, a four-fold increase in velocity will not affect an object's potential energy at all. This is because velocity is not a determining factor of potential energy, for which the formula reads mgh.

C51.



E_{k_2} of mass 1 = E_{k_2} of mass 2

If both objects have the same final kinetic energy (just as they are about to hit the floor), they must also have the same initial potential energy.

$$E_{g_1} \text{ of mass } 1 = E_{g_1} \text{ of mass } 2$$

$$m_1 \cdot g \cdot 2h = m_2 \cdot g \cdot h$$

$$m_1 = \frac{m_2 \cdot \cancel{g} \cdot \cancel{h}}{\cancel{g} \cdot 2\cancel{h}}$$

$$\boxed{m_1 = \frac{1}{2} m_2}$$

Since the objects' final kinetic energy is determined only by their initial potential energy (by conservation of energy) and both objects have the same initial gravitational potential energy, it must be that the object raised to double the height of the second object has half the mass.

C53. Power is a measure of the rate at which energy is converted, expended or consumed per unit time. The common SI unit for power is the watt (W), which is equivalent to one joule per second.

$$P = \frac{W}{\Delta t}$$

The kWh (kilowatt hour) unit can be better understood if each part of the unit is broken down. The *watt* is the root of the unit– equivalent to one joule per second (J/s). The *kilo* prefix indicates 100 watts (1000 W). The *hour* adds the unit of time. The unit analysis below demonstrates how the unit of the kilowatt hour is equivalent to 3.6×10^6 J.

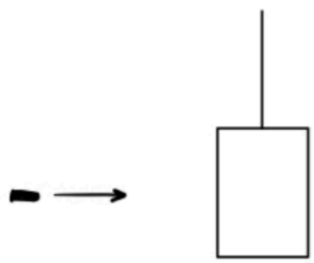
$$1\ \text{kWh} = 1000\ \text{W} \cdot \text{h} = 1000\ \tfrac{\text{J}}{\text{s}} \cdot \text{h} = 1000\ \tfrac{\text{J}}{\text{s}} \cdot 3600\ \text{s} = 3{,}600{,}000\ \text{J}$$

C55. $m_b = 0.005$ kg

$V_1 = 100$ m/s

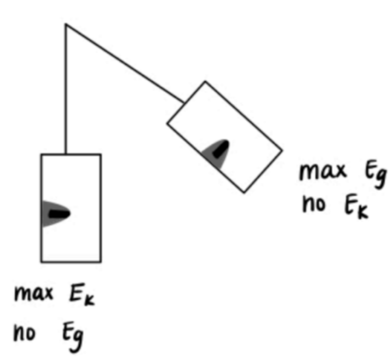
$\ell = 1.5$ m

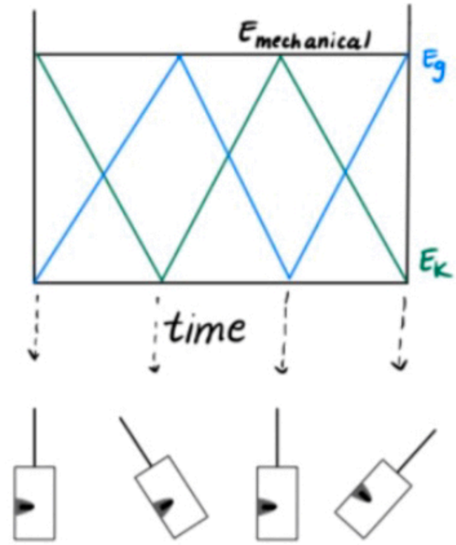
$m_{bl} = 5$ kg



We are analzying the system only once the bullet is embedded in the block. Assuming the bullet/block system is not affected by air resistance, only mechanical energy is conserved. Option (b) is correct.

The bullet/block system will act like a pendulum, swinging from side to side. If energy is perfectly conserved, all the initial kinetic energy added into the system by the embeded bullet will remain constant and simply oscillate in conversions between kinetic and gravitational potential energy.



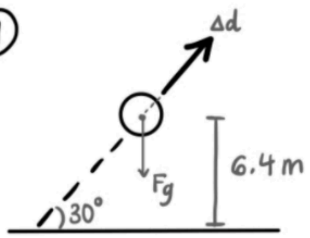


Linear momentum will not be conserved since the velocity of the bullet/block system does not stay constant.

C57. $m = 0.068$ kg

$h = 12.8$ m

①



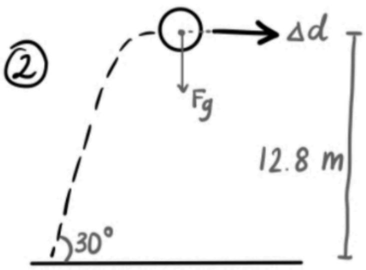
$$\Delta d = \frac{6.4\text{m}}{\sin 30°}$$

$$F_g = mg$$
$$= (0.068\text{ kg})(9.8\text{ N/kg})$$
$$= 0.666\text{ N}$$

$$W = F \cdot \cos\theta \cdot \Delta d$$
$$W = (0.666\text{N})(\cos 120°)\left(\frac{6.4\text{ m}}{\sin 30°}\right)$$
$$\boxed{W = -4.3\text{ J}}$$

-4.3 J of work is done by gravity on the golf ball when it is halfway up.

②



$$\Delta d = \frac{12.8\text{m}}{\sin 30°}$$

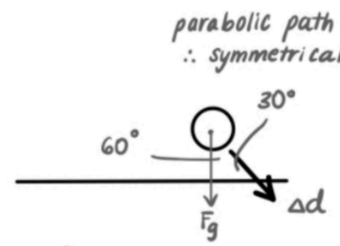
$$F_g = 0.666\text{ N}$$

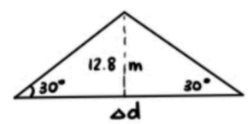
$$W = F \cdot \cos\theta \cdot \Delta d$$
$$\cos\theta = \cos 90° = 0$$

$$\boxed{W = 0\text{ J}}$$

∴ no work is done by gravity on the golf ball when it is at its maximum height.

③





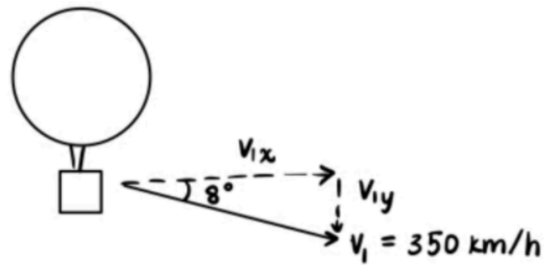
$$\Delta d = 2\left(\frac{12.8\text{ m}}{\tan 30°}\right)$$

$$F_g = 0.666\text{ N}$$

$$W = F \cdot \cos\theta \cdot \Delta d$$
$$W = (0.666\text{N})(\cos 60°)\left(\frac{25.6}{\tan 30}\right)$$
$$\boxed{W = 15\text{ J}}$$

∴ 15 J of work is done by gravity on the golf ball when it is about to hit the ground again.

C59.



$$v_1 = 350\ \frac{km}{h} \cdot \frac{1000\ m}{km} \cdot \frac{1\ h}{3600\ s} = 97.2\ m/s$$

$$v_2 = 800\ \frac{km}{h} \cdot \frac{1000\ m}{km} \cdot \frac{1\ h}{3600\ s} = 222\ m/s$$

$$E_{T_1} = E_{T2}$$

$$E_{K_1} + E_{g_1} = E_{K2} + \cancel{E_{g2}} \rightarrow 0$$

$$\frac{1}{2}\cancel{m}v_1^2 + \cancel{m}gh = \frac{1}{2}\cancel{m}v_2^2$$

$$\frac{1}{2}(97.2\ m/s)^2 + (9.8\ N/m)h = \frac{1}{2}(222\ m/s)^2$$

$$4724\ m^2/s^2 + (9.8\ N/m)h = 24\,642\ m^2/s^2$$

$$(9.8\ N/m)h = 19\,918\ m^2/s^2$$

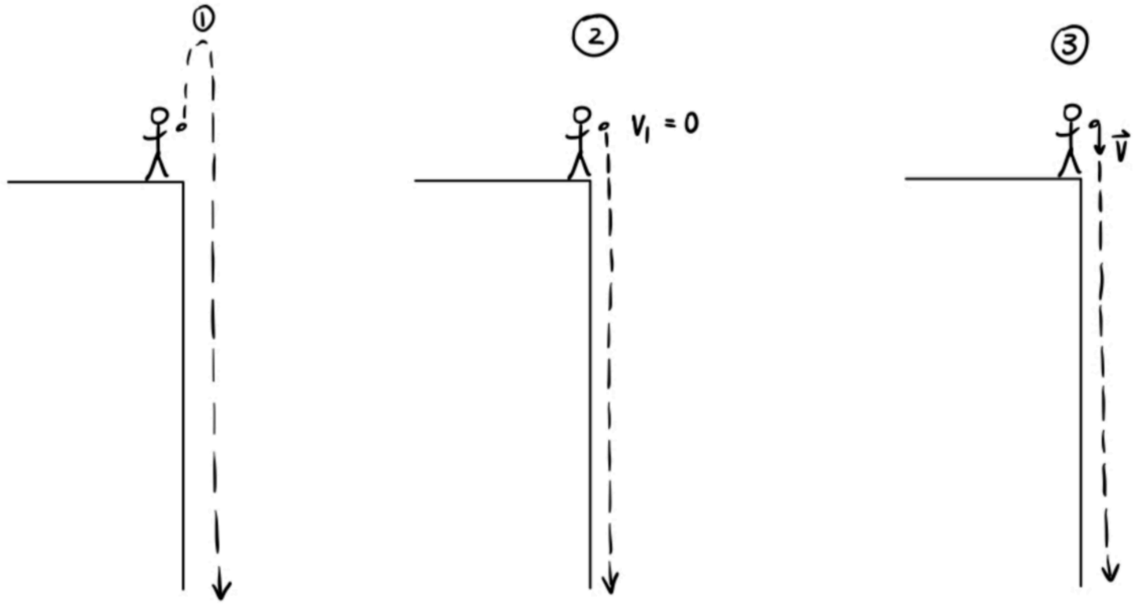
$$\boxed{h = 2.0 \times 10^3\ m}$$

∴ Mr. Fluffle was dropped from a height of 2.0×10^3 m.

C61. $W = F \cdot \cos\theta \cdot \Delta d$

Work has no dependence on time, but work is dependent on displacement. The question specifically states that the boulder does not move, therefore neither person does any work.

C63.

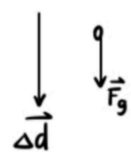


$$W = \vec{F}_{\parallel} \cdot \Delta \vec{d}$$

$$W = F_g \cdot \cos\theta \cdot \Delta d$$

$$W = mg\ (\cos 0^\circ)\, \Delta d$$

$$W = mg\Delta d$$



equivalent for all 3 scenarios

equivalent for all 3 scenarios

equivalent for all 3 scenarios

The displacement of the eggs does not change depending on how the eggs are thrown. All eggs begin at the top of the school and end at the bottom of the school. With mass m and acceleration due to gravity g constant in all 3 scenarios, the work done by gravity must be equivalent for all 3 thrown eggs.