Honors Physics

T07P : Practice for Energy Test

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Multiple Choice

M01 A rocket in deep space explodes, splitting into exactly two pieces of unequal masses. Which has the higher kinetic energy?

(A) The less massive piece.
(B) The more massive piece
(C) They have the same kinetic energy.
(D) It cannot be determined without more information.

M02 If you push an object twice as far while applying the same force, you do

(A) twice as much work.
(B) the same amount of work.
(C) half as much work.
(D) no work.

M03 A clerk can lift containers a vertical distance of 1 meter or can roll them up a 2 meter-long ramp to the same elevation.

With the ramp, the applied force required is about
(A) twice as much.
(B) the same.
(C) half as much.
(D) impossible to compute.

M04 After rolling halfway down an incline a marble's kinetic energy is

(A) less than its potential energy there.
(B) greater than its potential energy there.
(C) the same as its potential energy there.
(D) impossible to determine.

M05 What task requires the most work; lifting a 50-kg sack 2 meters or lifting a 25-kg sack 4 meters?

(A) The 50-kg sack.
(B) The 25-kg sack.
(C) They require the same work.
(D) It depends on the path used in moving them.

M06 It takes 40 J to push a large box 4 m across a floor. Assuming the push is in the same direction as the move, what is the magnitude of the force on the box?

(A) 4 N
(B) 10 N
(C) 40 N
(D) 160 N

M07 Two identical arrows, one with twice the kinetic energy of the other, are fired into a hay bale. The faster arrow will penetrate

(A) the same distance as the slower arrow.
(B) twice as deeply as the slower arrow
(C) four times as deeply as the slower arrow.
(D) More than four times as deeply as the slower arrow.

M08 Car A and Car B are identical. Car A passes Car B moving at four times Car B's speed. How does Car A's kinetic energy compare to Car B?

(A) It is 1/16 as much.
(B) It is ¼ as much.
(C) It is four times as great.
(D) It is sixteen times as great.

Short Answer

S01 How much work is done on a box massing 20 kg by moving it 13 m with a force of 22 N?

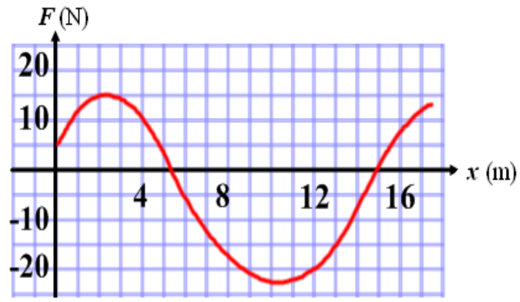
S02 A 1100-kg car moving 20 m/s slows suddenly to 5 m/s. How much work was done on it?

S03 A box (m = 12 kg) slides across a frictionless floor at a speed of 5.4 m/s. It then slides up a frictionless ramp inclined at 32°.

(a) What is the maximum <u>height</u> h reached by the box? (Assume that the ramp is so long that the box can not possibly slide off the end.)
(b) How would your answer to (a) change if the mass of the box was 1000 kg (but everything else was the same)? Explain briefly.

S04 A force F is applied to a 2-kg block, as shown to the right.

If the block was moving at 5 m/s when located at $x = 4$ m, how fast is it moving at $x = 8$ m?

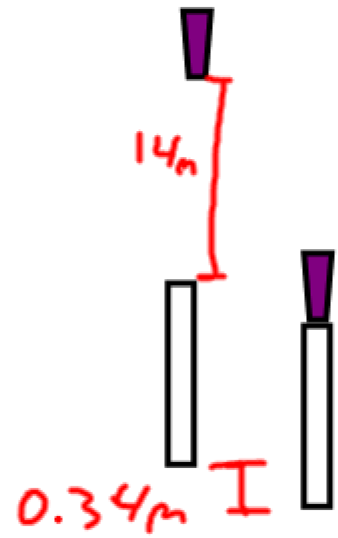


S05 How much energy is lost to air resistance if an egg (0.150 kg) dropped from the roof of Russell Hall (15 m) hits the ground with a speed of 12.2 m/s?

S06 The words "energy conservation" mean different things in ordinary language and in physics. Explain the difference.

Problems

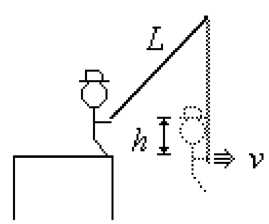
P01. Note that **new information** has been added to this problem. A pile driver is a device used to drive posts into the ground for use in foundations. Consider a particular pile driver which masses 1500 kg and is raised 14 m above an I-beam which masses 11500 kg **and is 2 m long**. The driver is released from rest and, after hitting the post, drives it 0.34 m into the ground.



(a) Assuming that the ground is the zero point for gravitational energy, how much energy does the pile driver have at the moment of release?
(b) How fast is it moving when it hits the post?
(c) What is the average force exerted **by the driver** on the post?

P02.
Clay ball A (mass 0.200 kg) moving at 2.7 m/s strikes clay ball B at rest; the two stick and move off together. In the process, 0.62 J of heat is released.
(a) What is the speed of the combined clay after collision?
(b) What was the mass of ball B?

P03: ***PALO ALTO SMITH AND THE SPY FROM ENGLAND***



Palo Alto Smith (mass 70 kg) stands on the edge of a cliff. A rope (length L = 2.6 m) is fixed to a pipe and he is preparing to swing across a gap. The rope makes an angle of 55° with the vertical.
(a) How far below his original position does he swing? (That is, find h. HINT: This is trig, not Physics.)
(b) What is his speed v as he passes through the lowest point?
(c) Pally lets go just as he swings through the lowest point. Sketch the trajectory he tracks out.
(c) In an alternate reality, it's superspy James Stock swinging. At the lowest point, he fires his jet-pack, which doubles his speed instantaneously and then turns off. If Stock remains swinging, what is the new maximum height H that he reaches? (HINT: There's an easy way to do this, and a slightly-harder one.)

M01: A

We can do this formally. Assume $m_2 > m_1$. What we want is

$$\frac{K_2}{K_1} = \frac{\frac{1}{2}m_2 v_2^2}{\frac{1}{2}m_1 v_1^2} = \frac{m_2}{m_1}\left(\frac{v_2}{v_1}\right)^2$$

But since the total momentum before was 0, we also have

$$0 = m_1 v_1 + m_2\left(-v_2\right)$$

$$\frac{v_2}{v_1} = \frac{m_1}{m_2}$$

Plugging in, we see

$$\frac{K_2}{K_1} = \frac{m_2}{m_1}\left(\frac{m_1}{m_2}\right)^2 = \frac{m_1}{m_2}$$

which tells us that $K_2 < K_1$

M02: A

This is relatively simple: $W = F\Delta x$, so doubling Δx doubles *W*.

M03: C

The change in potential energy is the same, since the change in height is the same. That implies that the work is the same. But the incline path is twice as long. Since $W = F\Delta x$, we see that *F* would be half as large.

M04: C

The <u>total</u> energy $E = U + K$ doesn't change. Set the zero point at the bottom of the incline. At the start, the marble's energy is all potential. But after rolling halfway, half of that energy has been converted to kinetic.

M05: C

The work done will be the potential energy given to the sack. So here, $W = F\Delta y = mg\Delta y$. The 50-kg sack receives $\left(50\text{ kg}\right)9.8\frac{\text{m}}{\text{s}^2}2\text{ m} = 980\text{ J}$ whereas the other receives $\left(25\text{ kg}\right)9.8\frac{\text{m}}{\text{s}^2}4\text{ m} = 980\text{ J}$.

M06: B

Working from $W = F\Delta x$, we have $F = \frac{W}{\Delta x} = \frac{40\text{ J}}{4\text{ m}} = 10\text{ N}$.

M07: B

Assuming that the stopping force is the same regardless of arrow speed (which is defensible if not necessarily true), and recalling that the work done is equation to the change in kinetic energy, we have

$$\Delta x = \frac{W}{F} = \frac{\Delta K}{F}$$

M08: D

We can just find the ratio:

$$\frac{K_A}{K_B} = \frac{\frac{1}{2}mv_A^2}{\frac{1}{2}mv_B^2} = \left(\frac{v_A}{v_B}\right)^2 = 4^2 = 16$$

S01

$$W = F\Delta x = 22\text{ N}\left(13\text{ m}\right) = 286\text{ J}$$

Note that the mass is not relevant.

S02:

$$\begin{aligned} W &= \Delta K = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_0^2 \\ &= \tfrac{1}{2}\left(1100\text{ kg}\right)\left(\left(5\,\tfrac{\text{m}}{\text{s}}\right)^2 - \left(20\,\tfrac{\text{m}}{\text{s}}\right)^2\right) = \boxed{-206\,250\text{ J}} \end{aligned}$$

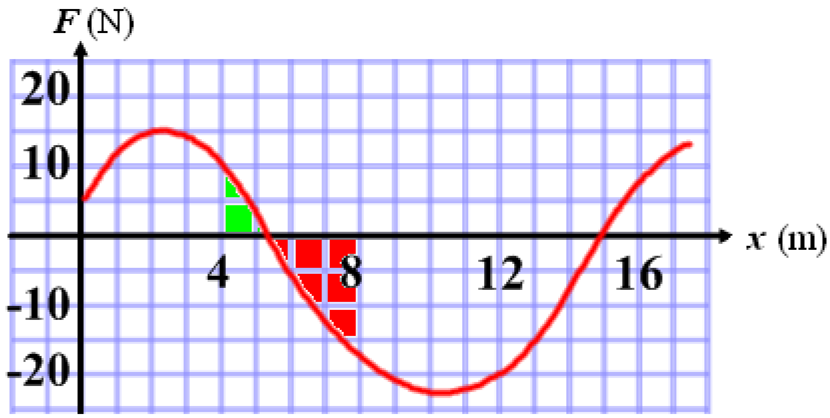
S03:

(a) This is simple energy conservation:

$$\begin{aligned} E &= E \\ K_0 + U_0 &= K + U \\ \tfrac{1}{2}mv_0^2 + 0 &= 0 + mgh \\ h &= \frac{v_0^2}{2g} = \frac{\left(5.4\,\tfrac{\text{m}}{\text{s}}\right)^2}{2\left(9.8\,\tfrac{\text{m}}{\text{s}^2}\right)} = \boxed{1.49\text{ m}} \end{aligned}$$

(b) It would not change at all, as the mass has dropped out. It starts with more kinetic energy, but requires more at any given height.

S04:
The change in kinetic energy is the work done, and the work done is the area on a force-position graph. (We can recall that because $W = F\Delta x$ for constant forces, analogously to $d = v\Delta t$ for constant velocities.) So first we must estimate the area:



There are approximately 1.5 boxes above the axis (green), and somewhat fewer than 5 boxes below (red), so the net is about -3.5 boxes. Each box is worth $5\text{ N}\times 1\text{ s} = 5\text{ J}$ of work. So the total work done is -17.5 J.

Then we use

$$\Delta K = W_{tot}$$
$$\tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_0^2 = W_{tot}$$
$$v_f = \sqrt{\frac{2\left(W_{tot} + \tfrac{1}{2}mv_0^2\right)}{m}}$$
$$= \sqrt{\frac{2\left(-17.5\text{ J} + \tfrac{1}{2}(2\text{ kg})(5\,\tfrac{\text{m}}{\text{s}})^2\right)}{2\text{ kg}}}$$
$$= \boxed{2.74\,\tfrac{\text{m}}{\text{s}}}$$

S05: Call the energy lost Q. Clearly,

$$E = E$$
$$U_0 + K_0 = U_f + K_f + Q$$
$$mgH + 0 = 0 + \tfrac{1}{2}mv_f^2 + Q$$
$$Q = mgH - \tfrac{1}{2}mv_f^2$$
$$= 0.150\text{ kg}\left(9.8\,\tfrac{\text{m}}{\text{s}^2}\right)15\text{ m} - \tfrac{1}{2}(0.150\text{ kg})\left(12.2\,\tfrac{\text{m}}{\text{s}}\right)^2$$
$$= \boxed{10.9\text{ J}}$$

S06: Used in conversation, “energy conservation” refers to minimizing the amount of (generally) electric energy consumed, by (for example) turning off lights when a room is empty or by not running an air conditioner. The goal is to reduce the energy “lost” to waste (particularly heat) so that less fuel needs to be consumed. To a physicist, all energy is conserved. Energy is never really "lost"; it's just transformed into a form we can't use or don't account for (such as heat energy or sonic energy).

P01:

(a) There is a subtlety here: The driver is 14 m above the beam, but that point is 2 m above the ground, so the total height is really 16 m. The potential energy thus is

$$U_0 = m_D g H = 1500\text{ kg}\left(9.8\tfrac{\text{m}}{\text{s}^2}\right)16\text{ m} = \boxed{235\,200\text{ J}}$$

(b) This is simple energy conservation. Note that the driver does <u>not</u> end on the ground.

$$E_0 = E_1$$

$$U_0 + 0 = U_1 + K_1$$

$$U_0 = m_D g h + \tfrac{1}{2} m_D v_1^2$$

$$v_1 = \sqrt{\frac{U_0 - m_D g h}{\tfrac{1}{2} m_D}} = \sqrt{\frac{235\,200\text{ J} - 1500\text{ kg}\left(9.8\tfrac{\text{m}}{\text{s}^2}\right)2\text{ m}}{\tfrac{1}{2}(1500\text{ kg})}}$$

$$= \boxed{16.57\tfrac{\text{m}}{\text{s}}}$$

(c) This too can be subtle. There are <u>three</u> forces on the post – the driver pushing it, the Earth's gravity pulling it down, and the ground resisting its motion. That last force is extremely hard to incorporate, as we have no idea what it looks like or how it acts. However, the force by the driver on the post is numerically equal (but opposite in direction) to the force by the post on the driver (by Newton's III). And only <u>two</u> forces act on the driver, gravity and the post. So we'll go that route.

The <u>total</u> work done on the driver is the change in its kinetic energy from the moment it hits the post to the moment it comes to rest a distance *l* lower. That is to say,

$$W_{total} = \Delta K$$

But the total work comes from two places, the work done by gravity as the post slips and the work done on the driver via the force *F* from the post:

$$W_{tot} = W_{by\ grav} + W_{by\ post} = m_D g l + (-1) F_D l$$

The -1 comes from the fact that this force <u>opposes</u> the actual motion (where as gravity augments it).

We can now substitute in:

$$\Delta K = m_D g l - F l$$

$$F = \frac{m_D g l - \Delta K}{l} = m_D g - \frac{\Delta K}{l}$$

$$= 1500\text{ kg}\left(9.8\tfrac{\text{m}}{\text{s}^2}\right) - \frac{\tfrac{1}{2}1500\text{ kg}\left(0\tfrac{\text{m}}{\text{s}}\right)^2 - \tfrac{1}{2}1500\text{ kg}\left(16.57\tfrac{\text{m}}{\text{s}}\right)^2}{0.34\text{ m}}$$

$$= 6.20\times10^5\text{ N}$$

So the force <u>on</u> the post is 6.20×10^5 N directed <u>downward</u>.

P02:

(a) If the heat produced is Q, we can say

$$K_0 = K_1 + Q$$

which can be written as

$$\tfrac{1}{2} m_A v_0^2 = \tfrac{1}{2}\left(m_A + m_B\right) v_f^2 + Q$$

which looks awful. <u>But</u> we can also conserve momentum, so

$$m_A v_0 = \left(m_A + m_B\right) v_f$$

or

$$m_A + m_B = \frac{m_A v_0}{v_f}$$

or, solving for the combined mass and substituting into the equation above,

$$\tfrac{1}{2} m_A v_0^2 = \tfrac{1}{2}\left(\frac{m_A v_0}{v_F}\right) v_f^2 + Q$$

$$\tfrac{1}{2} m_A v_0^2 = \tfrac{1}{2} m_A v_0 v_f + Q$$

$$v_f = \frac{\tfrac{1}{2} m_A v_0^2 - Q}{\tfrac{1}{2} m_A v_0} = \frac{\tfrac{1}{2}\left(0.200\text{ kg}\right)\left(2.7\,\tfrac{\text{m}}{\text{s}}\right)^2 - 0.62\text{ J}}{\tfrac{1}{2}\left(0.200\text{ kg}\right) 2.7\,\tfrac{\text{m}}{\text{s}}}$$

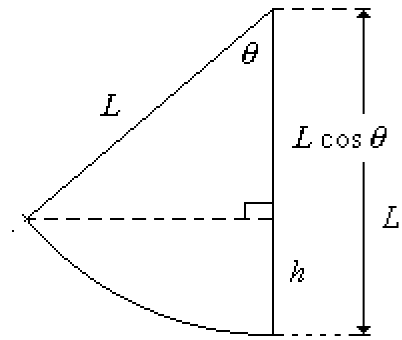
$$= \boxed{0.404\,\tfrac{\text{m}}{\text{s}}}$$

(b) Now we can use the momentum equation directly:

$$m_B = \frac{m_A v_0}{v_f} - m_A = m_A\left(\frac{v_0}{v_f} - 1\right)$$

$$= 0.200\text{ kg}\left(\frac{2.7\,\tfrac{\text{m}}{\text{s}}}{0.404\,\tfrac{\text{m}}{\text{s}}} - 1\right) = \boxed{1.14\text{ kg}}$$

P03: **PALO ALTO SMITH AND THE SPY FROM ENGLAND** -- solution



(a) From the diagram, we see that

$$L\cos\theta + h = L$$

$$\boxed{h = L(1-\cos\theta)}$$

(b) We can conserve energy:

$$E_{top} = E_{bottom}$$

$$U_{top} + K_{top} = U_{bottom} + K_{bottom}$$

$$mgh + 0 = 0 + \tfrac{1}{2}mv^2$$

$$v = \sqrt{2gh} = \sqrt{2gL(1-\cos\theta)}$$

$$= \sqrt{2\times 9.81\tfrac{\text{m}}{\text{s}^2}\times 2.6\,\text{m}\left(1-\cos 55^\circ\right)} = \boxed{4.66\tfrac{\text{m}}{\text{s}}}$$

(c) Once Pally lets go, he's just a projectile: His trajectory will be half of a parabola, opening downwards.

(d) The problem doesn't say if Stock masses the same as Pally, but it doesn't really matter, since *m* dropped out. The hard way to do this problem is double the speed found in (b), then re-conserve energy and find the height. The easy way is to note that doubling the speed quadruples the energy. Now all of that energy has to go into potential energy, and since the energy is directly proportional to the height, the spy goes four times as high as he descended. Thus, the final height of James Stock is $4h = 4L(1-\cos\theta) \approx 1.70L$. Note that this is less than $2L$, as required by the statement that he continues swinging.