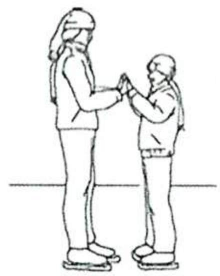
Energy & Momentum Exam Review

Directions – Complete the following problems to help prepare you for the upcoming test.

2008 AP® PHYSICS B FREE-RESPONSE QUESTIONS (Form B)



1. (10 points)

m_1 m_2

A 70 kg woman and her 35 kg son are standing at rest on an ice rink, as shown above. They push against each other for a time of 0.60 s, causing them to glide apart. The speed of the woman immediately after they separate is 0.55 m/s. Assume that during the push, friction is negligible compared with the forces the people exert on each other. v_1 t

(a) Calculate the initial speed of the son after the push.

$$p_o = p_f$$
$$0\ \text{kgm/s} = m_1 v_1 + m_2 v_2$$
$$v_2 = \frac{-m_1 v_1}{m_2} = -\frac{(70\ \text{kg})(.55\ \text{m/s})}{35\ \text{kg}} = 1.1\ \text{m/s}$$

(b) Calculate the magnitude of the average force exerted on the son by the mother during the push.

$$Ft = m\Delta v$$
$$F = \frac{m\Delta v}{t} = \frac{35\ \text{kg}(1.1\ \text{m/s})}{.60\ \text{s}} = 64\ \text{N}$$

OR

$$a = \frac{\Delta v}{t} = 1.83\ \text{m/s}^2$$
$$F = ma = 64\ \text{N}$$

(c) How do the magnitude and direction of the average force exerted on the mother by the son during the push compare with those of the average force exerted on the son by the mother? Justify your answer.

The average force exerted on the mother by the son is equal + opposite to the force of the mother on the son due to Newton's 3rd law.

(d) After the initial push, the friction that the ice exerts cannot be considered negligible, and the mother comes to rest after moving a distance of 7.0 m across the ice. If their coefficients of friction are the same, how far does the son move after the push?

mom

$$\cancel{v^2} = v_o^2 + 2ax$$
$$a = \frac{v_o^2}{2x} = \frac{(.55\ \text{m/s})^2}{2(7.0\ \text{m})}$$
$$= .022\ \text{m/s}^2$$

$$\Sigma F = ma$$
$$F_f = ma$$
$$\mu F_N = ma \quad \mu \cancel{m} g = \cancel{m} a$$
$$a = \mu g \text{ (same for both)}$$

son

$$x = \frac{v_o^2}{2a} = \frac{(1.1\ \text{m/s})^2}{2(.022\ \text{m/s}^2)} = 28\ \text{m}$$

① $E_o + W = E_f$

$\frac{1}{2} m_{mom} V_{10}^2 + F_f \cdot d = 0J$

$\frac{1}{2} \cancel{m_1} V_1^2 + \mu \cancel{m_1} g d = 0J$ $\quad$ m_{mom} cancels

$\frac{1}{2} V_1^2 = \mu g d$

$\mu = \frac{V_1^2}{2gd} = \frac{(.55 m/s)^2}{2(9.81 m/s^2)(7m)} = .0022$

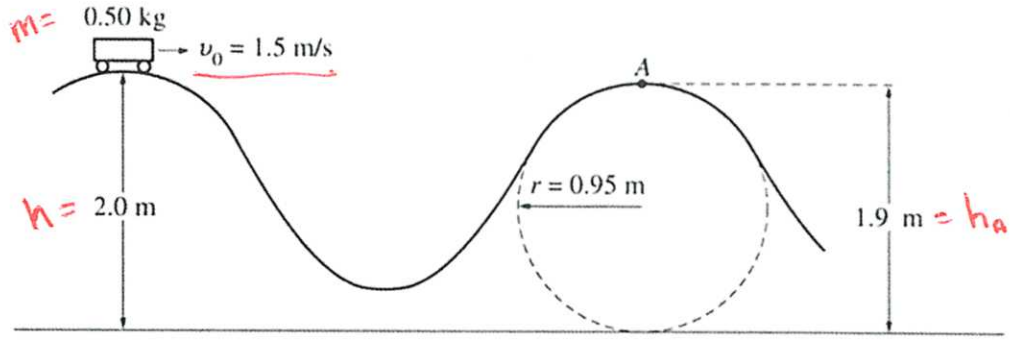
② $\mu_{son} = \mu_{mom} = .0022$

③ $E_o + W = E_f$

$\frac{1}{2} m_{son} V_2^2 = F_f \cdot d$

$\frac{1}{2} \cancel{m_2} V_2^2 = \mu \cancel{m_2} g d$ $\quad$ m_{son} cancels

$d = \frac{V_2^2}{2\mu g} = \frac{(1.1 m/s)^2}{2(.0022)(9.81 m/s^2)} = 28m$



1. (15 points)

A designer is working on a new roller coaster, and she begins by making a scale model. On this model, a car of total mass 0.50 kg moves with negligible friction along the track shown in the figure above. The car is given an initial speed v_0 = 1.5 m/s at the top of the first hill of height 2.0 m. Point A is located at a height of 1.9 m at the top of the second hill, the upper part of which is a circular arc of radius 0.95 m.

(a) Calculate the speed of the car at point A.

$E_0 = E_f$

$K_0 + U_{g0} = K + U_g$

$\frac{1}{2} \cancel{m} v_0^2 + \cancel{m} g h = \frac{1}{2} \cancel{m} v_A^2 + \cancel{m} g h_A$

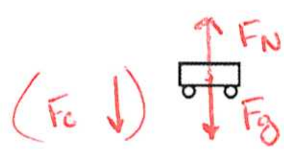
$v_A^2 = \cancel{\tfrac{2}{2}} v_0^2 + 2g(h - h_A)$

$v_A^2 = \sqrt{v_0^2 + 2g(h - h_A)}$

$= \sqrt{(1.5\,m/s)^2 + 2(9.81\,m/s^2)(2.0\,m - 1.9\,m)}$

$= 2.1\,m/s$

(b) On the figure of the car below, draw and label vectors to represent the forces on the car at point A.



(c) Calculate the magnitude of the force of the track on the car at point A. $F_N = ?$

$\Sigma F = F_c$

$F_N - F_g = -\frac{mv^2}{r}$

$F_N = -\frac{mv^2}{r} + mg$

$= -\frac{(.50\,kg)(2.1\,m/s)^2}{.95\,m} + .50\,kg(9.81\,m/s^2)$

$= 2.6\,N$

(d) In order to stop the car at point A, some friction must be introduced. Calculate the work that must be done by the friction force in order to stop the car at point A.

to no K

$W = \Delta K$

$= -K$

$= -\frac{1}{2} m v^2 = -\frac{1}{2}(.50\,kg)(2.1\,m/s)^2 = -1.1\,J$

(e) Explain how to modify the track design to cause the car to lose contact with the track at point A before descending down the track. Justify your answer.

• losing contact would mean no F_N

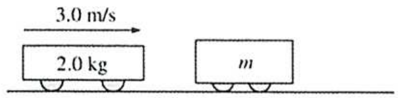
$\cancel{F_N}^{\,0} - F_g = -\frac{mv^2}{r}$ ↓

• decrease radius of 2nd hill curve

OR

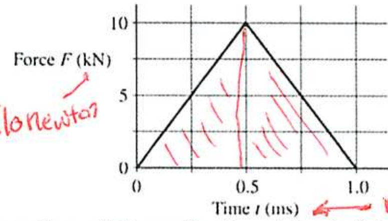
• Increase height of 1st hill or lower 2nd hill to increase speed

$\cancel{F_N}^{\,0} - F_g = -\frac{mv^2}{r}$ ↑



1. (15 points) m_1

A 2.0 kg frictionless cart is moving at a constant speed of 3.0 m/s (v_1) to the right on a horizontal surface, as shown above, when it collides with a second cart of undetermined mass m that is initially at rest. The force F of the collision as a function of time t is shown in the graph below, where $t = 0$ is the instant of initial contact. As a result of the collision, the second cart acquires a speed of 1.6 m/s to the right. Assume that friction is negligible before, during, and after the collision.



kilonewton $\times 10^3$ N

millisecond $\times 10^{-3}$ s

(a) Calculate the magnitude and direction of the velocity of the 2.0 kg cart after the collision.

① $\Delta p = F\Delta t = \text{area}$

$\Delta p = 2(\frac{1}{2}bh)$

$= (.5\times10^{-3}s)(10\times10^3 N)$

$\Delta p = 5\,Ns$

② $\Delta v = \frac{\Delta p}{m_1}$

$v_f - v_i$

$v_f = \frac{\Delta p}{m} + v_i = \frac{-5Ns}{2.0kg} + 3.0 m/s$

$= .5 m/s$ right

(b) Calculate the mass m of the second cart.

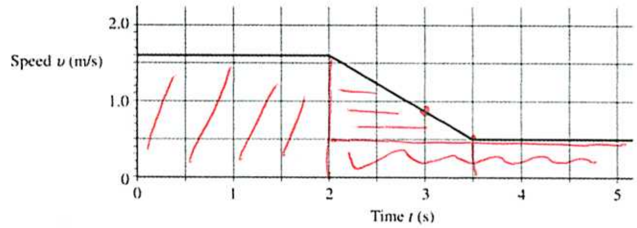
$p_0 = p_f$

$m_1v_1 + \cancel{m_2v_2} = m_1v_1 + m_2v_2$

$m_2 = \frac{m_1v_{1i} - m_1v_{1f}}{v_2}$

$= \frac{(2.0kg)(3.0m/s - .5m/s)}{1.6m/s} = 3.1kg$

After the collision, the second cart eventually experiences a ramp, which it traverses with no frictional losses. The graph below shows the speed v of the second cart as a function of time t for the next 5.0 s, where $t = 0$ is now the instant at which the carts separate.



(c) Calculate the acceleration of the cart at $t = 3.0$ s.

$a = \frac{\Delta v}{t} = \frac{1.6m/s - .5m/s}{2s - 3.5s} = -.73 m/s^2$

(d) Calculate the distance traveled by the second cart during the 5.0 s interval after the collision (0 s < t < 5.0 s).

d = Area under curve

$d = bh + \frac{1}{2}bh + bh = (2s)(1.6m/s) + \frac{1}{2}(1.5s)(1.1m/s) + (3s)(.5m/s)$

$= 5.5m$

(e) State whether the ramp goes up or down and calculate the maximum elevation (above or below the initial height) reached by the second cart on the ramp during the 5.0 s interval after the collision (0 s < t < 5.0 s).

• The ramp must be going up because the acceleration is negative

$E_0 = E_f$

$K_0 = U_g + K$

$\frac{1}{2}\cancel{m}v_i^2 = \cancel{m}gh + \frac{1}{2}\cancel{m}v$

$h = \frac{(v_i^2 - v_f^2)}{2g}$

$\frac{(1.6m/s)^2 - (.5m/s)^2}{2(9.81m/s^2)}$

$= .12m$