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AP Physics Class 3: Momentum & Energy

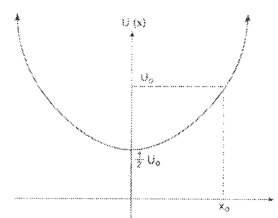
Multiple-Choice Questions

1. If a projectile thrown directly upward reaches a maximum height h and spends a total time in the air of T, the average power of the gravitational force during the trajectory is
   (a) $P = 2mgh/T$
   (b) $P = -2mgh/T$
   (c) 0
   (d) $P = mgh/T$
   (e) $P = -mgh/T$

   Constant force, no displacement.

2. Given that the constant net force on an object and the object's displacement, which of the following quantities can be calculated?
   (a) the net change in the object's velocity
   (b) the net change in the object's mechanical energy
   (c) the average acceleration
   (d) the net change in the object's kinetic energy
   (e) the net change in the object's potential energy

3. Consider the potential energy function shown below. Assuming that no non-conservative forces are present, if a particle of mass m is released from position x_0, what is the maximum speed it will achieve?
   (a) $\sqrt{4U_0/m}$
   (b) $\sqrt{2U_0/m}$
   (c) $\sqrt{U_0/m}$
   (d) $\sqrt{U_0/2m}$
   (e) The particle will achieve no maximum speed but instead will continue to accelerate indefinitely.



4. Which of the following is the most accurate description of the system introduced in the previous question?
   (a) stable equilibrium
   (b) unstable equilibrium
   (c) neutral equilibrium
   (d) a bound system
   (e) There is a linear restoring force

   → It would have been a stable equilibrium <u>if</u> the mass is stationary at the bottom, but it's not!

5. If the only force acting on an object is given by the equation $F(x) = 2 - 4x$ (where the force is measured in newtons and position in meters), what is the change in the object's kinetic energy as it moves from $x = 2$ to $x = 1$?
   (a) $+4$ J
   (b) -4 J
   (c) $+2$ J
   (d) -2 J
   (e) $+8$ J

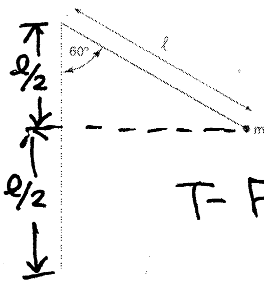
$$W = \Delta K = \int_2^1 F(x)\,dx = \int_2^1 (2-4x)\,dx = 4$$

6. A pendulum bob of mass m is released from rest as shown in the figure below. What is the tension in the string as the pendulum swings through the lowest point of its motion?

(a) $T = \frac{1}{2}mg$
(b) $T = mg$
(c) $T = \frac{3}{2}mg$
(d) $T = 2mg$
(e) None of the above

$\cancel{m}g\left(\frac{\ell}{2}\right) = \frac{1}{2}\cancel{m}v^2$

$v^2 = g\ell$



at lowest point:

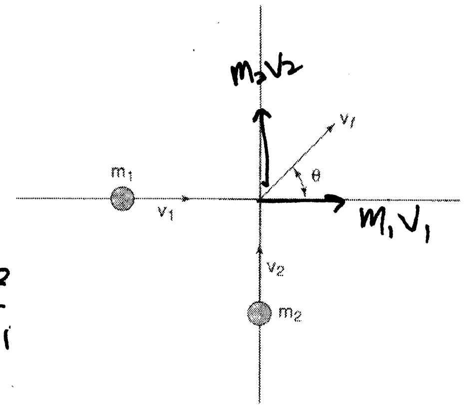
$F_c = \frac{mv^2}{\ell} = \frac{m(g\ell)}{\ell} = mg$

$T - F_g = F_c \Rightarrow T = F_g + F_c$ = 2mg

7. Two masses moving along the coordinates axes as shown collide at the origin and stick to each other. What is the angle θ that the final velocity that makes with the x-axis?

(a) $\tan^{-1}(v_2/v_1)$
(b) $\tan^{-1}[m_1v_1/(m_1+m_2)]$
(c) $\tan^{-1}(m_1v_2/m_2v_1)$
(d) $\tan^{-1}(m_2v_2^2/m_1v_1^1)$
(e) $\tan^{-1}(m_2v_2/m_1v_1)$

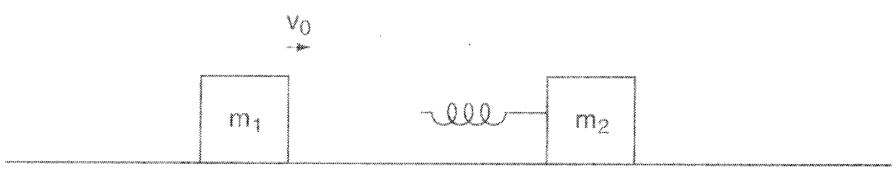
$\tan\theta = \frac{m_2 V_2}{m_1 V_1}$



8. A mass traveling in the $+x$ direction collides with a mass at rest. Which of the following statements is true?

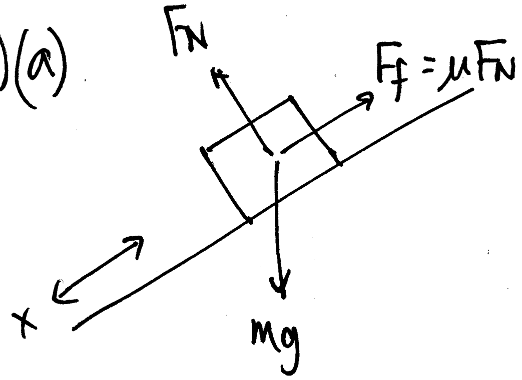
(a) After the collision, the two masses will move with parallel velocities
(b) After the collision, the masses will move with antiparallel velocities
(c) After the collision, the masses will both move along the x-axis
(d) After the collision, the y-components of the velocities of the two particles will sum to zero.
(e) None of the above

9. A mass m_1 initially moving at speed v_0 collides with and sticks to a spring attached to a second, initially stationary mass m_2. The two masses continue to move to the right on a frictionless surface as the length of the spring oscillates. At the instant that the spring is maximally extended, the velocity of the first mass is



(a) v_0
(b) $m_1^2v_0/(m_1+m_2)^2$
(c) m_2v_0/m_1
(d) m_1v_0/m_2
(e) $m_1v_0/(m_1+m_2)$

10(a)



$F_N = mg\cos\theta$

$F_f = \mu F_N = \mu mg\cos\theta$

$F_{net} = mg\sin\theta - \mu mg\cos\theta = mg(\sin\theta - \mu\cos\theta)$

$a = \frac{F_{net}}{m} = g(\sin\theta - \mu\cos\theta)$

$v_f^2 = \cancel{v_i^2} + 2ad = 2gd(\sin\theta - \mu\cos\theta) \rightarrow \boxed{v_f = \sqrt{2gd(\sin\theta - \mu\cos\theta)}}$

(b) only friction does work! ($mg\sin\theta$ is conservative)

$W = \vec{F_f}\cdot\vec{d} = -(\mu mg\cos\theta)(d)$

$\cancel{K_1} + U_1 + W_{F_f} = K_2 + \cancel{U_2}$

$mg(d\sin\theta) - \mu mg\cos\theta(d) = \frac{1}{2}mv^2$

$\boxed{v = \sqrt{2gd(\sin\theta - \mu\cos\theta)}}$ ← same as in part (a)

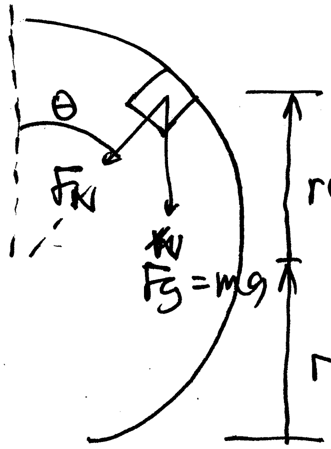
(c) maximum speed when $F_{net} = 0$

$mg\sin\theta - \mu mg\cos\theta - kx = 0.$

$\boxed{x = \frac{mg(\sin\theta - \mu\cos\theta)}{k}}$

11(a) $$\overbrace{2r\cancel{m}g}^{U_g} = \overbrace{\tfrac{1}{2}\cancel{m}v^2}^{K} \rightarrow v^2 = 4rg \rightarrow v = 2\sqrt{rg}.$$

(b)



(c) $$2r\cancel{m}g = \cancel{m}g(r + r\cos\theta) + \tfrac{1}{2}\cancel{m}v^2$$

$$\tfrac{1}{2}v^2 = rg - rg\cos\theta$$

$$\boxed{v = \sqrt{2rg(1-\cos\theta)}}$$

(d) $$a_c = \frac{v^2}{r} = \frac{2rg(1-\cos\theta)}{r} \rightarrow \boxed{a_c = 2g(1-\cos\theta)}$$

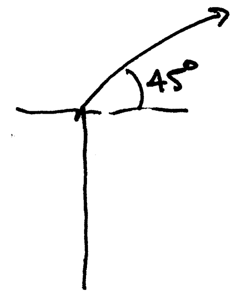
(e) $$F_{net,r} = mg\cos\theta + F_N = \frac{mv^2}{r}$$ when the mass falls off the track, $F_N = 0$.

$$mg\cos\theta = \frac{2mg(1-\cos\theta)}{\cancel{r}} \rightarrow \cancel{mg}\cos\theta = 2\cancel{mg} - 2\cancel{mg}\cos\theta$$

$$3\cos\theta = 2$$

$$\cos\theta = \frac{2}{3} \rightarrow \boxed{\theta = 48°}$$

12 (a) x → horizontal (+) is forward
y → vertical (+) is up)



$60\cos 45° = 60\sin 45° = 42.4$

– no acceleration in x-direction.

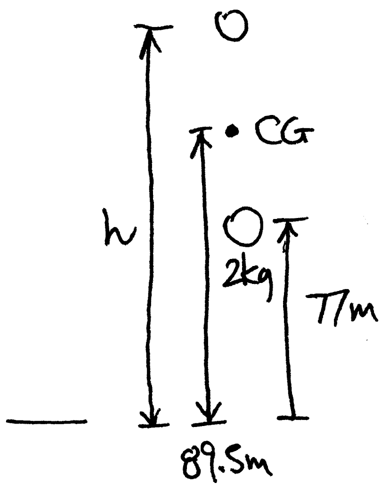
$\boxed{V_x = 60\cos 45° = 42.4\,m/s \text{ (constant)} \quad x(t) = V_x t = 42.4t \text{ m/s.}}$

– g in y-direction.

$\boxed{V_y = 42.4 - 9.81t \text{ (m)} \quad y(t) = 42.4t - 4.91t^2 \text{ (m/s)}}$

(b) at $t = 5$ → $\boxed{\vec{x} = 212\hat{i} + 89.5\hat{j} \quad \vec{v} = 42.4\hat{i} - 6.6\hat{j}}$

(c) at $t=5$ centre of mass should still be at the same location as (b) because no external force was applied



$89.5 = \frac{(2)(77) + 1(h)}{3kg}$ $\boxed{h = 115m}$

(d) conservation of momentum in vertical direction:

$(3kg)(-6.6) = (2)V_{y2} + (1)V_{y1}$

$= (2)(-17.8) + V_{y1}$

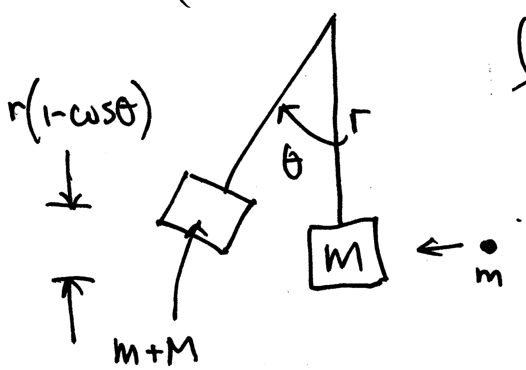
$\boxed{V_{y1} = 15.8\,m/s}$

$|V_{y2}| = \sqrt{V_{x2}^2 + V_{y2}^2}$

$46^2 = 42.4^2 + V_{y2}^2$

$V_{y2} = -17.8\,m/s.$

13 (a) work backwards! After the collision:



$$\cancel{(M+m)}\,g(1-\cos\theta)r = \frac{1}{2}\cancel{(M+m)}\,v^2$$

$$\boxed{v=\sqrt{2gr(1-\cos\theta)}}$$

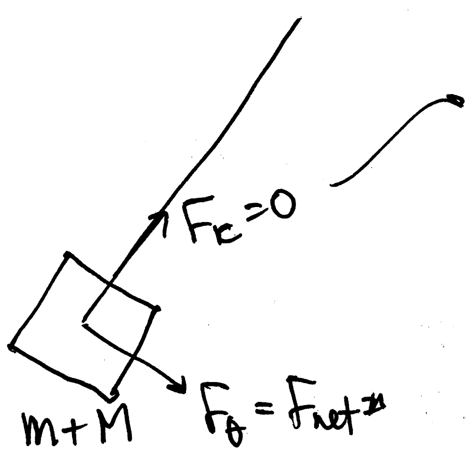
(b) Conservation of momentum:

$$v_m m + \cancel{v_M M} = v'(M+m) \rightarrow v_m = v'\frac{(M+m)}{m}$$

$$\boxed{v_M = \frac{M+m}{m}\sqrt{2gr(1-\cos\theta)}}$$

(c) at highest point, $v=0$, $\therefore a_c = 0$ $\therefore F_c = 0$.

F_{net} in tangential direction



$$T - \overset{(M+m)}{\cancel{m}}g\cos\theta = 0$$

$$\boxed{T=(M+m)g\cos\theta}$$

14 (a) all kinetic energy converted to elastic potential :

$K \to U_e \qquad \frac{1}{2}mv_0^2 = \frac{1}{2}kx^2 \to \boxed{x = \sqrt{\frac{mv_0^2}{k}}}$

(b) after they leave the wall, no external force in the system, ∴ no change in net momentum

$\boxed{\therefore \vec{P}_{total} = m\vec{v}_0}$

(c) no net force ∴ no work done ∴ $\boxed{K = \frac{1}{2}m_0v_0^2}$

(d) at maximum compression ~~or~~ $V_{rel} = 0$.

↑ or extension!

(e) momentum conserved! → at maximum compression. both masses are moving at v

energy conserved!

$\therefore mv_0 = 2mv$ ~~or~~ $\to v = \frac{v_0}{2}$

$\frac{1}{2}mv_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

$= mv^2 + \frac{1}{2}kx^2$

$\frac{1}{2}mv_0^2 = \underbrace{m\left(\frac{v_0}{2}\right)^2}_{\frac{1}{4}mv_0^2} + \frac{1}{2}kx^2$

$\frac{1}{4}mv_0^2 = \frac{1}{2}kx^2$

$\boxed{x = \sqrt{\frac{mv_0^2}{2k}}}$