Black 8   Red 8
Blue 3   Black + Blue 11
Total 19

1) $P = mv$ $v = 3\,m/s$

$E = \frac{1}{2}mv^2 = 4 \cdot \frac{1}{2} \cdot 2 = 9\,J$ (C) ✓

2) $J = F\Delta t = \Delta p$

$\frac{2\,kg \cdot m/s}{20N} = \Delta t$

$\Delta t = 0.1\,s$ (c) ✓

3) $J = F\Delta t$ $F = \frac{J}{\Delta t} = \frac{4(2)}{0.5} = 16N$ (e) ✓

4) $p_0 = -p_f$ $J = \Delta p = p_f - p_0$
$= 2mv$ (d) ✓

5) $m_1v_1 + m_2v_2 = m_1v_{1f} + m_2v_{2f}$

(e) B ×

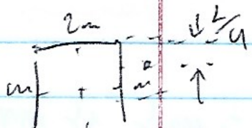
6) $m_1v_1 = (m_1 + m_2)v$

$v = \frac{m_1}{3m_1}v_1$ $v = \frac{1}{3}v$

$\frac{1}{9}(mv^2)$ ~~(B)~~ D ×

7) inelastic, momentum conserved (e) ✓

8) 2m, $\frac{L}{4}$ (B) ✓



9)

$mv \cancel{=} MV = (m+M)0$

$mv = MV$

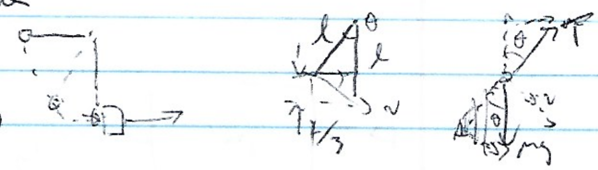
$v = \frac{MV}{m}$ (d) ✓

10) (E) (C) ×

FRQ

1)

A)



$v_{L/3}$: $mgL = \frac{1}{2}v^2 m + mg\frac{L}{3}$

$v^2 = 2gL - \frac{2gL}{3} = \frac{4}{3}gL$

$v = 2\sqrt{\frac{gL}{3}}$

$F_c = \frac{mv^2}{r} = \frac{m \cdot \frac{4}{3}gL}{L} = \frac{4}{3}mg$

$\theta = \cos^{-1}\left(\frac{2L}{3/L}\right) = \cos^{-1}\left(\frac{2}{3}\right)$

$T - mg\cos\theta = \frac{4}{3}mg$

$T = mg\left(\frac{4}{3} + \frac{2}{3}\right) = 2mg$ ~

B) $\frac{1}{2}v_f^2 = mgL$

$v_0 = \sqrt{2gL}$ & $mv_0 = mv_{f1} + 4mv_{f2}$

$v_0 = v_1 + 4v_2$ ~

C) ?

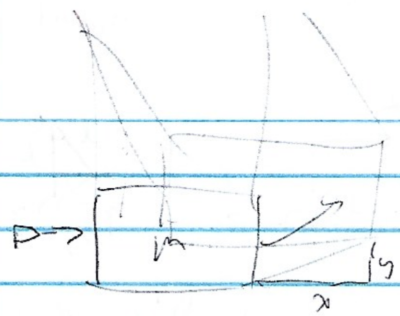
~~2) A) v B) same~~
~~B) v_h $mv = (m+M)v_f$~~
~~$v_f = \frac{mv}{m+M}$~~
~~fraction?~~

c)

7

3R

a)



$(m+M)v_f^2 = (m+M)gy$

$mv = (m+M)v_f$

$v_f^2 = gy \quad v_f = \sqrt{gy}$

$v = \frac{(m+M)\sqrt{gy}}{m}$ ~

b) ?

c) $mv = (m+M)v_f$

$v = \frac{v_f(m+M)}{m}$

$\cancel{v_f}^{0} = v_f + at$

$v_f = -at$

$x = v_f t + \frac{1}{2}at^2$

$v_f t = x - \frac{1}{2}at^2$

$v_f = \frac{x}{t} - \frac{1}{2}at$

$-at = \frac{x}{t} - \frac{1}{2}at$

$-\frac{1}{2}at = \frac{x}{t}$

$-at = 2v_f - \frac{2x}{t}$

$v_f = 2v_f - \frac{2x}{t}$

$v_f = \frac{2x}{t}$

$v = \frac{2x(m+M)}{mt}$

$t = \frac{1}{4}T = \frac{1}{4}\sqrt{\frac{g}{L}}$

$v = \frac{2x(m+M)4}{m\sqrt{\frac{g}{L}}}$

$= \frac{8x(m+M)}{m\sqrt{\frac{g}{L}}}$ ~

d) no, b/c the strings are external forces. ✓

3) a) θ_1, θ_2

$\frac{1}{2}mv^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$

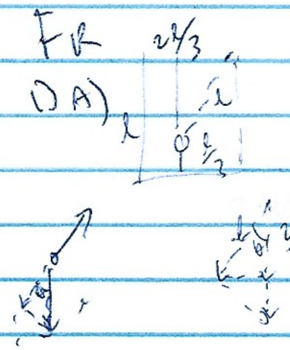
$v^2 = v_1^2 + v_2^2$ ~

b) ? c) $\theta_1 = \theta_2$?

$\theta_1 + \theta_2 = 90$ ✓, but no reasoning

FR

1) A)



$mgl = mg\frac{l}{3} + \frac{1}{2}mv^2$

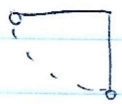
$\frac{2}{3}gl = \frac{1}{2}v^2$

$v = \sqrt{\frac{4}{3}gl}$

$T - mg\cos\theta = \frac{mv^2}{l} = \frac{m}{\cancel{l}} \cdot \frac{4}{3}g\cancel{l}$

$T - mg\left(\frac{2l}{3}/l\right) = \frac{4}{3}mg$

$T = mg\left(\frac{2}{3} + \frac{4}{3}\right) = 2mg$ ~

1) b)  $\cancel{m}gh = \frac{1}{2}\cancel{m}v_f^2$ $h = L$

$$v_f = \sqrt{2gL}$$

$$\frac{1}{2}mv_{b_0}^2 + \cancel{\frac{1}{2}Mv_{L_0}^2} = \frac{1}{2}mv_{b_f}^2 + \frac{1}{2}Mv_{L_f}^2$$

$$mv_{b_0} + \cancel{Mv_{L_0}} = mv_{b_f} + Mv_{L_f}$$

$$\cancel{v_{L_f} = \frac{m(v_{b_0} - v_{b_f})}{M}}$$

$$v_{b_f} = \frac{mv_{b_0} - Mv_{L_f}}{m}$$

$$= v_{b_0} - \frac{M}{m}v_{L_f}$$

$$\frac{1}{2}Mv_{L_f}^2 = \frac{1}{2}mv_{b_0}^2 - \frac{1}{2}mv_{b_f}^2$$

$$v_{L_f}^2 = \frac{m}{M}(v_{b_0}^2 - v_{b_f}^2)$$

$$= \frac{m}{M}\left(2gL - \left(\sqrt{2gL} - \frac{M}{m}v_{L_f}\right)^2\right)$$

$$\cancel{2\frac{m}{M}}$$

$$= \frac{m}{M}\left(2gL - \left(2gL - 2\sqrt{2gL}\frac{M}{m}v_{L_f} + \frac{M^2}{m^2}v_{L_f}^2\right)\right)$$

$$= \frac{m}{M}\left(2\sqrt{2gL}\frac{M}{m}v_{L_f} - \frac{M^2}{m^2}v_{L_f}^2\right)$$

$$\frac{M}{m}v_{L_f}^{\cancel{2}} = 2\sqrt{2gL}\frac{M}{m}\cancel{v_{L_f}} - \left(\frac{M}{m}\right)^{\cancel{2}}v_{L_f}^{\cancel{2}}$$

$$\cancel{v_{L_f}\left(1 - \frac{M}{m}\right) = 2\sqrt{2gL}}$$

$$\cancel{v_{L_f}\left(\frac{m-M}{m}\right) = 2\sqrt{2gL}}$$

$$\cancel{v_{L_f} = \frac{2m}{m-M}\sqrt{2gL}}$$

$$\cancel{M = 4m}$$

$$\cancel{v_{L_f}}$$

$$v_{L_f}\left(1 + \frac{M}{m}\right) = 2\sqrt{2gL}$$

$$v_{L_f}\left(\frac{m+M}{m}\right) = 2\sqrt{2gL}$$

$$v_{L_f} = 2\sqrt{2gL}\cdot\frac{m}{m+M} = 2\sqrt{2gL}\cdot\frac{m}{m+4m}$$

$$M = 4m$$

$$= \frac{2}{5}\sqrt{2gL}$$ ✓

c) $v_{b_f} = v_{b_0} - \frac{M}{m}v_{L_f}$

$$= \sqrt{2gL} - \frac{M}{m}\cdot\frac{2}{5}\sqrt{2gL}$$

$$= \sqrt{2gL} - \frac{8}{5}\sqrt{2gL}$$

$$= -\frac{3}{5}\sqrt{2gL}$$

$$\cancel{m}gh_f = \frac{1}{2}\cancel{m}v_0^2$$

$$h = \frac{\frac{1}{2}\left(\frac{9}{25}\cdot 2gL\right)}{g}$$

$$\boxed{h = \frac{9}{25}L}$$ ✓

2

2) a–c)

a) $mv = (m+M)v_f$

$\frac{1}{2}\cancel{(m+M)}v_f^2 = \cancel{(m+M)}gy$

$v = \frac{m+M}{m} v_f$

$v_f = \sqrt{2gy}$

$$\boxed{v = \frac{m+M}{m}\sqrt{2gy}}$$

✓

b) $\frac{1}{2}mv^2 \rightarrow KE_0 = \frac{1}{2}m\left(\frac{M+M}{m}\right)^2(2gy)$

$KE_{f\,extra} = \frac{1}{2}(m+M)(2gy)$

$= (m+M)gy$

$KE_{f\,bullet} = m+M\,gy \cdot \frac{m}{M}$

$= \frac{m(m+M)}{M}gy$

$KE_0 = m\left(\frac{m+M}{m}\right)^2 gy$

$= \frac{(m+M)^2}{m}gy$

$\frac{KE_0}{KE_f} = \frac{(m+m)^{\cancel{2}}\cancel{gy}}{m} \times \frac{M}{(m)\cancel{(m+M)gy}}$

$= \frac{M(M+m)}{m^2}$ ~

Lost in the collison – sound, heat, vibration, etc.

c) $v = \frac{m+M}{m}v_f$

pendulum w/ small ∠ approx

$T = \sqrt{\frac{g}{L}}$

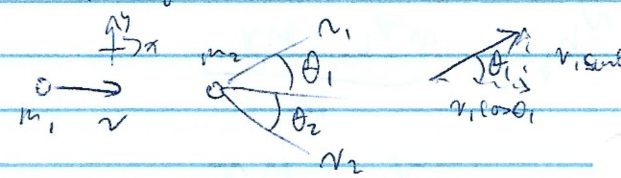
$x = v_0 t + \frac{1}{2}at^2$

$t = \frac{1}{4}T$

~~v_f~~ $v = v_0 + at$

$v_f^2 = v_0^2 + 2a\Delta x$??

3)



$m_1 v_x = m_1 v_{1x} + m_2 v_{2x}$

$m_1 v_{1y} = m_2 v_{2y}$

$m_1 v = m_1 v_1\cos\theta_1 + m_2 v_2\cos\theta_2$

$m_1 v_1\sin\theta_1 = m_2 v_2\sin\theta_2$

a) elastic – KE conserved

$KE_1 = \frac{1}{2}mv^2$

$KE_1 = KE_f = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

???

b) c)

2) b) $KE_f = \frac{1}{2}(m+M)v_f^2 = \frac{1}{2}\left(\frac{m^2}{m+M}\right)v^2$

$\Delta KE = KE_f - KE_0 = \frac{1}{2}\frac{m^2v^2}{m+M} - \frac{1}{2}mv^2$

$= -\frac{M}{m+M} KE_0$ ✓

$v^2 = v_{1a}^2 + 2v_{1a}v_{2a}\cos(\theta_1+\theta_2) + v_{2a}^2$

$v^2 = v_{1a}^2 + v_{2a}^2 \; ; \; \theta_1 + \theta_2 = 90°$ ✓

1) a) $T = \frac{3}{2}mg$ ✓

5

3) a) $mv = mv_{1a}\cos\theta_1 + mv_{2a}\cos\theta_2$

$mv_{1a}\sin\theta_1 = mv_{2a}\sin\theta_2$

$\frac{1}{2}mv^2 = \frac{1}{2}mv_{1a}^2 + \frac{1}{2}mv_{2a}^2$

$v_{2a}\cos\theta_2 = v - v_{1a}\cos\theta_1$

$v_{2a}\sin\theta_2 = v_{1a}\sin\theta_1$

$v_{2a}^2 = (v - v_{1a}\cos\theta_1)^2 + v_{1a}^2\sin^2\theta_{1a}$

$v_{2a}^2 = v^2 - 2vv_{1a}\cos\theta_1 + v_{1a}^2$

$v^2 - v_{1a}^2 = v_{2a}^2 = v^2 - 2vv_{1a}\cos\theta_1 + v_{1a}^2$ ✓

$2v_{1a}^2 = 2vv_{1a}\cos\theta_{1a}$

$v_{1a} = v\cos\theta_{1a}$

$KE_{1a} = \frac{1}{2}mv_{1a}^2 = \cos^2\theta_{1a}\frac{1}{2}mv^2 = \cos^2\theta_{1a}KE_1$ ✓

b) $KE_{2a} = \frac{1}{2}mv_{2a}^2 = \frac{1}{2}mv^2 - \frac{1}{2}mv_{1a}^2$

$= KE_1 - \cos^2\theta_{1a}KE_1 = KE_1(1-\cos^2\theta_{1a})$

$= \sin^2\theta_{1a}KE$ ✓

c) ~~MM~~ $v^2 = v_{1a}^2\cos^2\theta_{1a} + 2v_{1a}v_{2a}\cos\theta_{1a}\cos\theta_{2a}$

$+ v_{2a}^2\cos^2\theta_2$

$0 = v_{1a}^2\sin^2\theta_{1a} - 2v_{1a}v_{2a}\sin\theta_{1a}\sin\theta_{2a}$

$+ v_{2a}^2\sin^2\theta_{2a}$