Exam 1 Spring 2015 P1210 Solutions

1. **Spider-man hanging around.**
Spider-man is hanging in equilibrium between two buildings, holding a webline in each hand. The first makes an angle to the horizontal of 60 degrees. The second makes an angle of 45 degrees. If Spider-man masses 60 kg, what are the tensions on each of the two lines in Newtons? Remember to approximate g = 10 m/s^2.

2. **Johnny Blaze jumps "Goalpost-to-Goalpost" in *Ghost Rider*.**
At the time of filming the first *Ghost Rider* movie, the world record distance for a motorcycle jump was 277.5 feet, set by Trigger Gumm in May, 2005. On Dec. 31, 2007, Robbie Madison essentially performed Johnny Blaze's "Goalpost-to-Goalpost" motorcycle jump in Las Vegas, setting a new world record distance of 322.625 feet (he has since beaten that record several times). If his take-off angle was 20 degrees, at about what speed was he going on launch? (Assume starting and ending altitude is the same and ignore air resistance. Give your answer to the nearest mph, keeping in mind that 1 foot is 0.3048 meters and 1 m/s = 2.24 mph.)

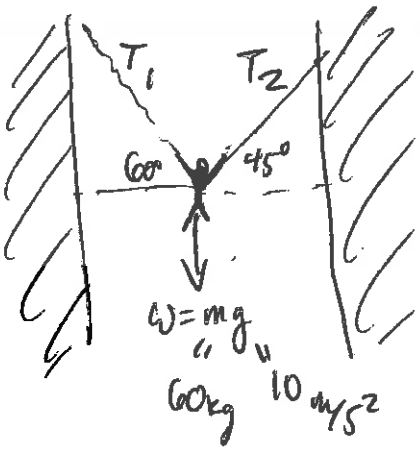
3. **Elastigirl turns herself into a boat!**
Following the explosion of their plane, Elastigirl has turned herself into a boat to carry Dash and Violet to a nearby island. If she can travel at 30 m/s relative to the water, but there is a fast cross current moving from left to right at 5 m/s, what direction should she aim for? That is, how many degrees to the left or right of the direction to the island?

4. **Ironman restarting the SHEILD Helicarrier turbine.**
The diameter of the turbines on the SHIELD Helicarrier are about 52 meters. The rotation rate of the blades is about 1.3 times per second when they are ramped up. If Ironman in his armor has a mass of 180 kg, what centripetal thrust must he supply to keep his flight path turning as he forces the blades to turn at full speed? Only consider the component of his thrust toward the center of the turbine, and ignore any other part. Remember you've been given a diameter, not a radius.

5. **Captain America chases an agent of Hydra.**
Captain America uses his shield to slide down the railing of a stairwell in pursuit of a bad guy. Assuming he starts at zero velocity, has a mass of 100 kg, the coefficient of kinetic friction is 0.2, the angle of the railing is 30 degrees, and the vertical change in height is 20 meters from top to bottom, how long does it take him to reach the bottom?

6. **Ms. Marvel flying.**
Ms. Marvel takes off, accelerating up according to the formula a= 2 m/s^2 + 10 m/s^4 t^2 for ten seconds. (This formula describes her observed acceleration and we need not add effects of gravity, since they are included already.) At the end of ten seconds, what is her velocity in m/s? How far has she traveled in meters?

0. Spider-man hanging around.



What are T_1 & T_2?

$$T_{1x} = -T_1 \cos 60^\circ$$
$$T_{2x} = T_2 \cos 45^\circ$$

$$T_{1y} = T_1 \sin 60^\circ$$
$$T_{2y} = T_2 \sin 45^\circ$$

Static $\Rightarrow \Sigma F_x = \Sigma F_y = 0$

$$x: \quad T_{1x} + T_{2x} = 0 = T_2 \cos 45^\circ - T_1 \cos 60^\circ$$

$$\frac{T_2}{T_1} = \frac{\cos 60^\circ}{\cos 45^\circ} = \frac{0.5}{0.707} = 0.707$$

$$y: \quad T_{1y} + T_{2y} - w = 0$$

$$600N = T_1 \underbrace{\sin 60^\circ}_{0.866} + T_2 \underbrace{\sin 45^\circ}_{0.707}$$

$$T_2 = 0.707\, T_1$$

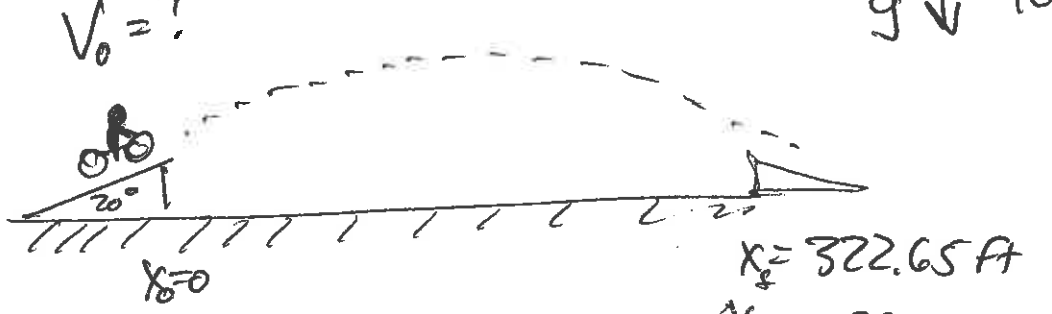
$$600N = 0.866\, T_1 + \underbrace{(0.707)^2}_{0.5} T_1$$

$$600N = 1.37\, T_1$$

$$\boxed{T_1 = 439\,N}$$

$$\boxed{T_2 = (0.707)(439N) = 310N}$$

(2) "Goal post-to-Goal post" (or is it "Ghoul post?")



$$\boxed{y} = y_0 + V_0 \underbrace{\sin 20^\circ}_{0.342} t + \frac{1}{2} \underbrace{g}_{10\ m/s^2} t^2$$

$y_0 = y_f = 0 \quad = (0.342) V_0 t - 5t^2$

$5t = (0.342) V_0$

Eq. 1 $\quad V_0 = \left(\frac{5}{0.342}\right) t = 14.6\ m/s^2\ t$

$$x = x_0 + V_0 \underbrace{\cos 20^\circ}_{0.94} t$$

$x = 98.3\ m \qquad x_0 = 0$

$(0.94) V_0 t = 98.3\ m$

$(0.94)(14.6\ m/s^2\ t^2) = 98.3\ m$

$t^2 = 7.16\ s^2$

$t = 2.68\ s$

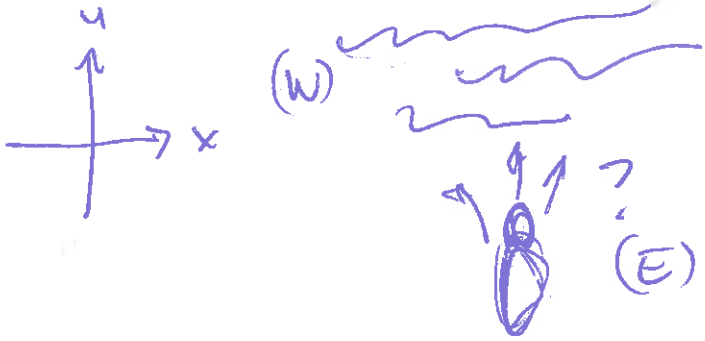
$V_0 = (14.6)(2.68)\ m/s$

$V_0 = 39\ m/s \quad (1\ m/s = 2.24\ mph)$

$V_0 = 39 \frac{m}{s} \times \frac{2.24\ mph}{1\ m/s} = \boxed{88\ mph}$

(3) Elastigirl turns into a boat

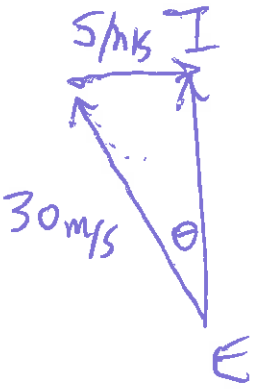
(I) Island



$V_{E|W} = 30$ m/s

$V_{W|I} = 5$ m/s

Relative velocities Vector Sum!



Elastigirl travels θ° to the left to make net velocity straight toward island.

$$\vec{V}_{E|I} = \vec{V}_{E|W} + \vec{V}_{W|I}$$

$$\rightarrow \quad \sin\theta = \frac{O}{H} = \frac{5}{30}$$

$\theta = 9.6^{\circ}$ to left

(4) Ironmen Restarting Helicarrier turbine

$d = 52\,m$
$r = 26\,m$

Rotation rate $= 1.3\ s^{-1} = T$

$m_I = 180\ kg$

$a = \frac{v^2}{r}$ $\quad F = ma = \frac{mv^2}{r}$ (190 kt = ?)

$r = 26\,m$

$v = \frac{2\pi r}{t} = \frac{2\pi r}{T^{-1}} = \frac{2\pi\, 26\,m}{(1.3)^{-1}}$

$= 212\ m/s$

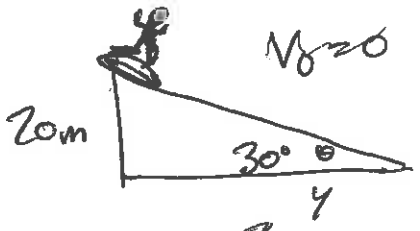
$F = \frac{(180\ kg)(212\ m/s)^2}{26\,m}$

$F = 312242 \approx 310{,}000\ N$

$\boxed{F \approx 310\ kN}$

Toward center.

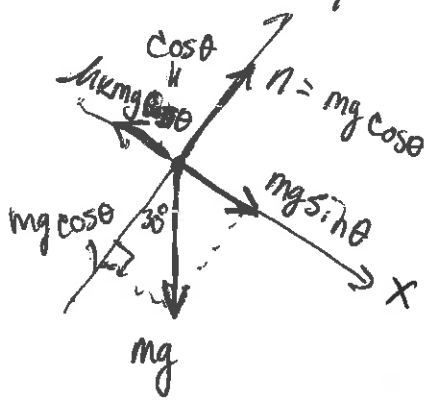
⑤. Capt. America chases Hydra agent.



$m_{CA} = 100\ kg$

$\mu_K = 0.2$

$g \downarrow 10\ m/s^2$



$\sum F_y = 0$, $w_y = n$

X: $\sum F_x = ma$

$mg\sin\theta - \mu_K mg\cos\theta = ma_x$

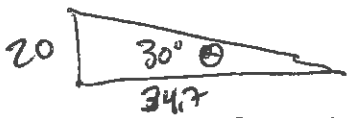
$10 \quad 10$

$0.5 \quad 0.2 \quad 0.866$

$a = 3.27\ m/s^2$ along rail

Rail = hypotenuse $= \sqrt{x^2 + y^2}$

$x = 34.7$, $y = 20m$



$\tan 30° = \frac{20}{Adj.}$

0.577

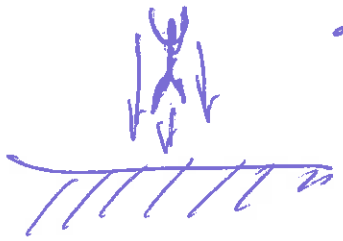
Rail = 40 m

3.27

$40\ m = \frac{1}{2} a t^2$

$t = 4.9\ s$

(6.) Ms. Marvel flying



$\uparrow a = 2 m/s^2 + 10 m/s^4 \, t^2$

$\Delta t = 10$ sec.

$t_0 = 0, \; y_0 = 0$

V & y at 10 sec?

$$a = \frac{dv}{dt} = 2 m/s^2 + 10 m/s^4 \, t^2$$

$$V = \int_0^{10s} (2 m/s^2 + 10 m/s^4) \, dt$$

$$V = (2 m/s^2) t \Big|_0^{10} + \frac{10}{3} \, m/s^4 \, t^3 \Big|_0^{10}$$

$$V = 20 m/s + 3333 m/s$$

$$\boxed{V = 3353 \, m/s}$$

$$y = \int_0^{10} v \, dt = \int_0^{10} (2 m/s^2 \, t) \, dt + \int_0^{10} \frac{10 t^3}{3} \, m/s^4 \, dt$$

$$y = \left(\frac{1}{2}\right)(2 m/s^2) t^2 \Big|_0^{10} + \frac{10}{3}\left(\frac{1}{4}\right) t^4 \, m/s^4 \Big|_0^{10}$$

$$y = \left[t^2 \Big|_0^{10} + \frac{10}{12} t^4 \Big|_0^{10} \right] m$$

$$\boxed{y = 100 m + 8333 m = 8433 m}$$