1. **The Thing Hits Dr. Doom.** Dr. Doom is battling the Fantastic Four on top of the 250m tall Baxter Building. The Thing punches Dr. Doom, launching him at an angle of 30 degrees relative to the horizontal, at a speed of 25 m/s. How far away, in the horizontal x direction, does he land? What is the maximum height of Dr. Doom above the ground during his flight?

2. **Wonder Woman cleans up.** The Justice League is cleaning up after an alien invasion. Wonder Woman drags an alien spacecraft (50,000 kg) up out of a crater. The slope of the crater wall is 20 degrees. The coefficient of kinetic friction is 0.6. What force in Newtons must she apply to move the spacecraft at a constant velocity?

3. **Bullseye and Daredevil.** Bullseye is attacking Daredevil and throws a baseball (145 g) at 40 m/s at his head. Daredevil throws his club (0.5 kg) at 20 m/s back, hitting the ball just off center. If the club continues forward but is deflected up at an angle of 20 degrees, and slows to 15 m/s, what is the new trajectory of the baseball? What is its angle of deflection down and new speed just after the collision?

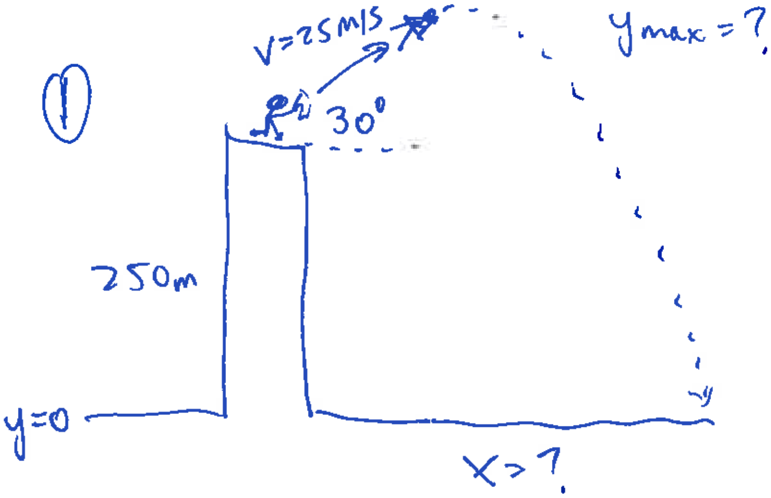
4. **Any icy slide ride.** Iceman has made a crazy slide ride with a loop. If the slide starts at a height of 50 meters, goes downhill, and then loops at the bottom, with a radius of 5 meters, what is the magnitude and direction of the acceleration at the top of the loop? Assume the ice slide is frictionless.

5. **Rolling Racers.** Elastigirl (50 kg) has challenged Mr. Fantastic (70 kg) to a race down a hill. The length of the ramp is 50 meters along the top. The initial height is 30 meters in the vertical direction. They start at zero velocity. She tuns herself into a hoop (treat as a hollow cylinder) with a radius of 0.2 meters. He turns himself into a ball (treat as a solid sphere) with a radius of 0.4 meters. Off they roll! How long does it take for each to cross the finish line, and who wins?

6. **Iron Man goes for a swim.**
   Iron Man is knocked into the ocean during a fight with Ultron. Assume his density is twice that of water ($1x10^3$ kg/m^3). What is his acceleration downward, ignoring water resistance? If his suit can handle a pressure of 5 atmospheres total (1 atmosphere is approximately 100,000 Newtons per square meter), how deep can he sink before his suit fails? Reminder: at the surface, the pressure is already one atmosphere.

7. **She-Hulk throws a Prius...on the Moon!**
   There's a crazy Prius-throwing contest on the blue area of the Moon. It's the She-Hulk's turn. How fast in m/s must she throw the Prius (mass 1300 kg) such that it never falls back down? Assume the mass of the Moon is $7.3x10^{22}$ kg, and the radius of the Moon is 1700 km.

①



Thing punches Dr. Doom!

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

$$X = X_0 + V_{x0} t + \frac{1}{2} a_x t^2 \quad (X_0 \to 0,\ a_x \to 0)$$

$$X = (25\,m/s)\cos 30°\, t = 21.6\,m\,t \quad (\cos 30° = 0.866)$$

$$y = y_0 + V_{0y} t + \frac{1}{2} a_y t^2 = 250m + 12.5\,m/s\, t - 5\,m/s^2\, t^2$$

$y_0 = 250m$, $V_{0y} = 25\,m/s \cdot \sin\theta = 12.5t$, $a_y = -10\,m/s^2$

$$V_y = V_{0y} + a_y t = 12.5\,m/s - 10\,m/s^2\, t = 0 \text{ for } y_{max}$$

$$t = \frac{12.5\,m/s}{10\,m/s^2} = 1.25\,sec.$$

$$y_{max} = y(t = 1.25\,sec) = 250m + 12.5\,m/s\, t - 5\,m/s^2\, t^2$$

$$y_{max} = 250m + 15.6m - 7.8m = \boxed{258\,m}$$

$$X_{max} \text{ at } y = 0 = 250m + 12.5\,m/s\, t - 5\,m/s^2\, t^2$$

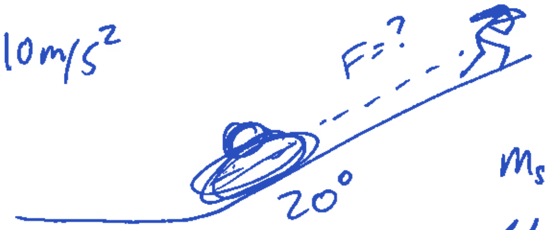
$c = 250m$, $b = 12.5\,m/s$, $a = -5\,m/s^2$

$t = -5.9\,s$ or $t = 8.43\,sec$

$$\Rightarrow X = 21.6m \cdot (t = 8.43) = \boxed{182\,m}$$

② Wonder Woman Cleans Up

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

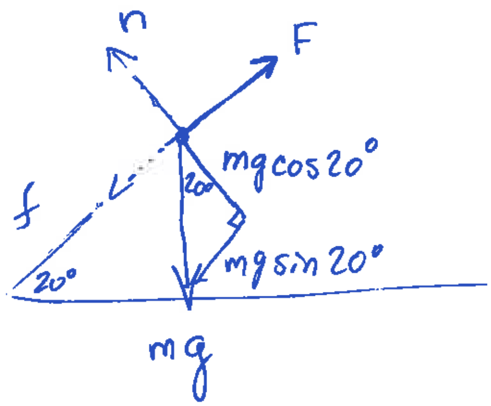


$m_s = 50{,}000\,kg$

$\mu_k = 0.6$

$a = 0$

What F needed?



$$\sum F_{\parallel} = 0$$

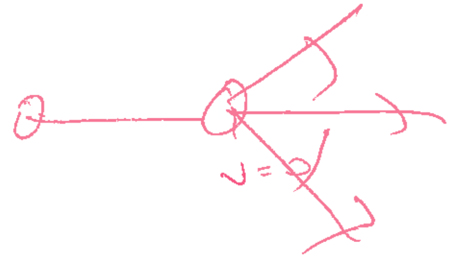
$$F - f - w_{\parallel} = 0$$

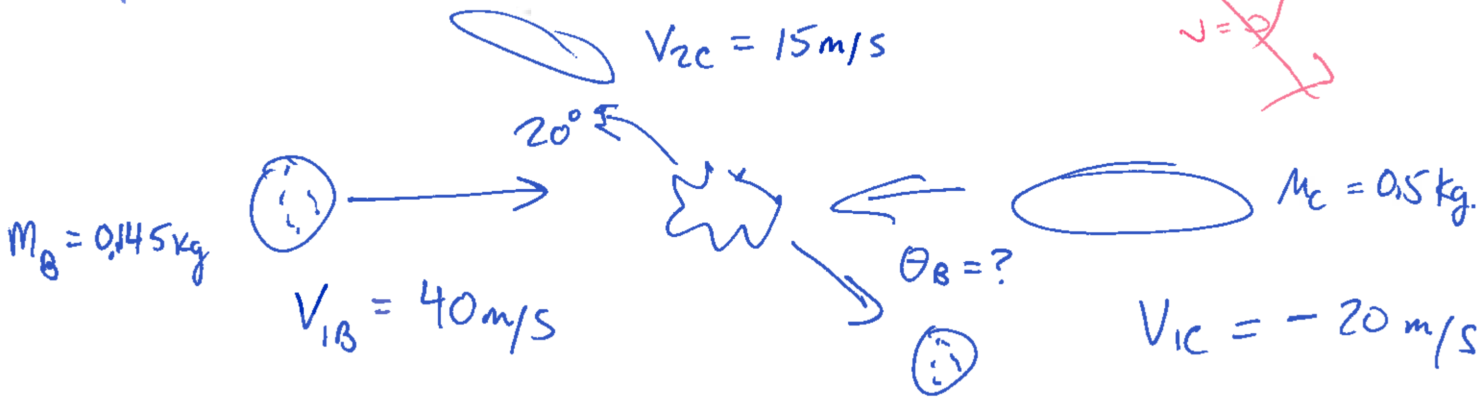
$$F - \underbrace{\mu_k n}_{\mu_k mg\cos 20^\circ} - mg\sin 20^\circ = 0$$

$$F = mg\,(\mu_k \cos 20^\circ + \sin 20^\circ)$$

$$F = (500{,}000\,N)\,(\underbrace{0.6(0.94) + 0.34}_{0.90}) \simeq \boxed{450{,}000\,N}$$

③ Bullseye vs. Daredevil





Conservation of momentum. $\vec{P}_1 = \vec{P}_2$ for system.

$$P_{1y} = 0$$

$$P_{1x} = m_B V_{1Bx} + m_c V_{1cx}$$

$$= (0.145\,kg)(40\,m/s) + (0.5\,kg)(-20\,m/s)$$

$$= 5.8 - 10 = -4.2\,kg\cdot m/s$$

$$P_{2y} = 0 = +V_{2c}\sin 20°_{\times m_c} + V_{2B}\sin\theta_B\,(0.145\,kg)$$

$$(0.5\,kg)(-15\,m/s \cdot 0.34) \Rightarrow V_{2B}\sin\theta_B =$$

$$V_{2B}\sin\theta_B = -17.7\,m/s$$

$$P_{2x} = -4.2\,kg\cdot m/s = -M_c\cos 20° \cdot 15\,m/s + M_B\cos\theta_B \cdot V_{B2}$$

M_c: 0.5 kg. M_B: 0.145 kg

$-M_c\cos 20° \cdot 15\,m/s$ = 7.0 kg·m/s

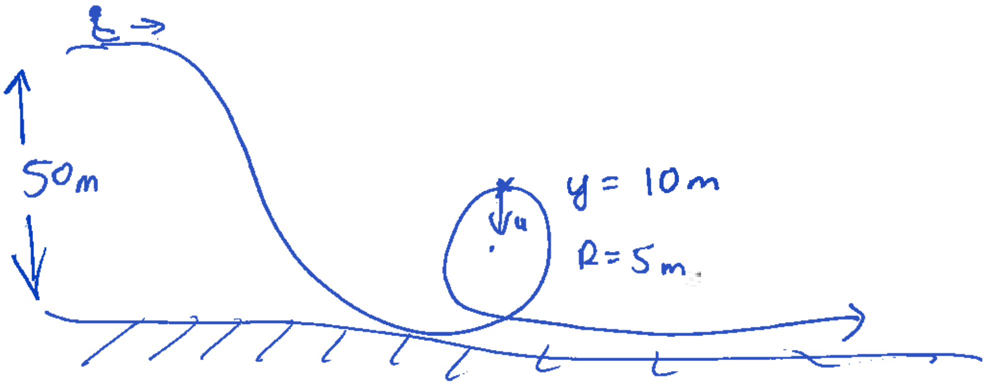
$$V_{B2}\cos\theta_B = \frac{2.8\,kg\cdot m/s}{0.145\,kg} = 19.3\,m/s$$

~~$V_{2B} = \sqrt{17.7^2 + 19.3^2}$~~

$$\frac{V_{2B}\sin\theta_B}{V_{2B}\cos\theta_B} = \frac{17.7}{19.3}$$

$$\Rightarrow \theta_B = \tan^{-1}(0.917) = \boxed{42.5°} \Rightarrow \boxed{V_{2B} = 26\,m/s}$$

④ Icy Slide Ride



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

$\mu_k = 0$

Conservation of Mech. Energy ($W_{other} = 0$)

$$mgh + \frac{1}{2}mv^2 = \text{const.} = mg\,50m.$$

$$\frac{1}{2}\cancel{m}v^2 + \cancel{m}g(10m) = \cancel{m}g\,50m.$$

$$\frac{1}{2}v^2 = 40m \cdot g$$

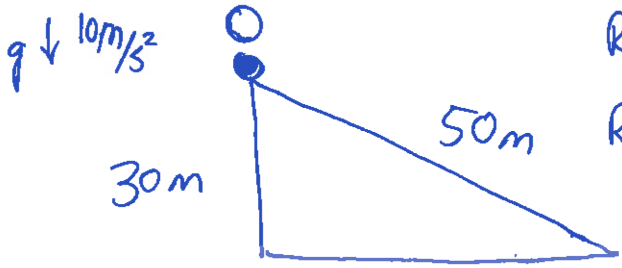
$$v^2 = 80m \cdot 10\,m/s^2 = 800\,m^2/s^2$$

$$v = 28.3\,m/s$$

Toward center

$$a = \frac{v^2}{R} = \frac{800\,m^2/s^2}{5m} = \boxed{160\,m/s^2}$$

(5) Elastigirl Races Mr. Fantastic!



$R_F = 0.4\,m$ $M_F = 70\,kg$ $I_F = \frac{2}{5}MR^2$

$R_E = 0.2\,m$ $M_E = 50\,kg$ $I_E = MR^2$ Hollow Cylinder

$$(mgh)_{Top} = \left(\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2\right)_{Bottom}$$

$V = r\omega$

$\omega = \frac{V}{R}$

F:

$$\cancel{m}gh = \frac{1}{2}\cancel{m_F}V_F^2 + \frac{1}{\cancel{2}}\cancel{M_F}\frac{\cancel{2}}{5}\cancel{R_F^2}\frac{V_F^2}{\cancel{R_F^2}}$$

$$gh = \frac{1}{2}V_F^2 + \frac{1}{5}V_F^2 = 0.7V_F^2 = 300\,m^2/s^2$$

$$V_F = 20.7\,m/s$$

$$\overset{50m}{X} - \overset{0}{X_0} = \frac{1}{2}(\overset{20.7}{V_x} + \overset{0}{V_{0x}})t$$

$$\boxed{t_F = 4.8\,sec}$$

E:

$$\cancel{m_E}gh_{Top} = \frac{1}{2}m_E V_E^2 + \frac{1}{2}M\cancel{R_E^2}\frac{V_E^2}{\cancel{R_E^2}} = \cancel{m_E}V_E^2 = 300\,m^2/s^2$$

$$V_E = 17.3\,m/s$$

$$50\,m = \frac{1}{2}(17.3\,m/s)t$$

$$\boxed{t = 5.8\,sec}$$

Mr. Fantastic wins! B/c he knows Physics!

⑥ Iron Man "Swims"

a) Acceleration?

$g = 10\ m/s^2$ ↓

↑ $F_B = \rho_{water} V_I g$

↓ $w = m_I g = \rho_I V_I g$ $\quad \rho_I = 2\rho_{water}$

$$\Sigma F = \rho_{water} \cancel{V_I} g - \rho_I \cancel{V_I} g = \rho_I \cancel{V_I} g$$

$$\cancel{\rho_{water}} (g - 2g) = 2 \cancel{\rho_{water}} a$$

$$\boxed{a = -\tfrac{1}{2} g = -5\ m/s^2 \text{ down.}}$$

b) $P = P_0 + \rho g h = 5\ Atm = 500{,}000\ N/m^2$ (ρ: water)

$1\ Atm = 100{,}000\ N/m^2$ (P_0)

$\rho g h = 400{,}000\ N/m^2$

$\rho = 1000\ kg/m^3$, $g = 10$, $h = ?$

$$\boxed{h = 40\ m}$$

(7) She-Hulk throws Prius on the Moon

Basically asking for V_{esc} here,

when $K_1 + U_1 = 0$

$$\frac{1}{2}\cancel{m}v^2 + -\frac{G\cancel{m}M_{moon}}{R_{moon}} = 0$$

$$\frac{1}{2}v^2 = \frac{G M_{moon}}{R_{moon}} \quad \text{mks units}$$

$$\frac{1}{2}v^2 = \frac{(6.67\times10^{-11})(7.3\times10^{22}\,kg)}{1700\cdot10^3\,m}$$

$$\frac{1}{2}v^2 = \frac{(6.67\times7.3\times10^{11})}{1700\,000}$$

$$\frac{1}{2}v^2 = 2.9\times10^6\ m^2/s^2$$

$$v^2 = 5.8\,10^6\ m^2/s^2$$

$$\boxed{V = 2400\ m/s}$$