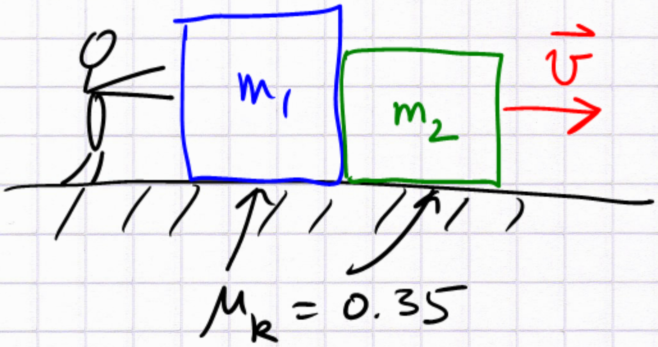
3.39

$m_1 = 45$ kg

$m_2 = 22$ kg

v = const



What is the normal force between the crates?

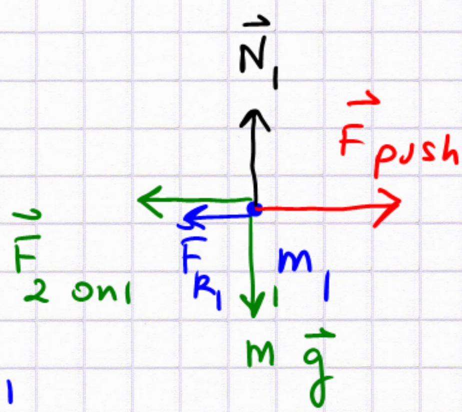
Solution.

The kinetic friction force (against $\vec{v}$) is overcome by pushing the combined system.

$$\vec{F}_{push} + \vec{F}_{k_1} + \vec{F}_{k_2} = 0 \quad \text{(no acceleration)}$$

$$\therefore \quad F_{push} = \mu_k (m_1 + m_2) g \quad \text{(magnitude)}$$

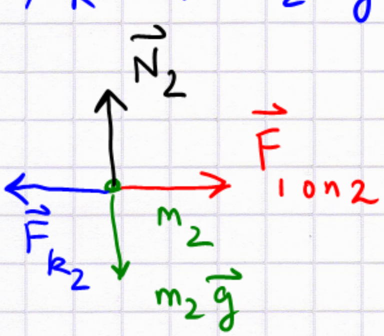
Free-body diagram for m_1:



$$\vec{F}_{k_1} + \vec{F}_{2\,on\,1} + \vec{F}_{push} = 0$$

$\therefore$ magnitudes: $F_{push} = F_{k_1} + F_{2\,on\,1}$

$$\mu_k (m_1 + m_2) g = \mu_k m_1 g + F_{2\,on\,1} \quad \therefore \quad F_{2\,on\,1} = \mu_k m_2 g$$



m_2 is also acceleration-free. It is pushed by $\vec{F}_{1\,on\,2}$ and accelerated back by $\vec{F}_{k_2}$. $F_{1\,on\,2} = F_{k_2} = \mu_k m_2 g$

Note: $F_{1\,on\,2} = F_{2\,on\,1}$ (magnitudes) $\quad \mu_k m_2 g = 75$ N

3.48 A Rock is dropped from a tower. It took 4.5 s to reach the ground. How high is the tower?

Solution.

$$y(t) = y_0 - \frac{1}{2} g t^2$$

$$y(t_f) = 0 = y_0 - \frac{1}{2} g t_f^2$$

$$y_0 = \frac{1}{2} g t_f^2$$

$$\underline{\underline{y_0 = 99 \quad m}}$$

3.54 A Bridge is 150 m tall

Kid 1 drops rock @ $t=0$

Kid 2 throws rock @ $t = 1$ s with $v_0 = ?$ (down)

Both rocks hit ground simultaneously.

Solution.

① $y_1 = y_0 - \frac{1}{2} g t^2$ $\qquad y_0 = 150\text{m}$

② $y_2 = y_0 - v_0 (t-1) - \frac{1}{2} g (t-1)^2$ $\qquad$ for $t \geq 1$

why? ② uses the time of ①, so uses not $t_0 = 0$, but $t_0 = 1$ s

When $t = t_0$, i.e., $t = 1$s, Eq. ② agrees with the free-fall eqs (from then on)

From ①: $t_f = \sqrt{\frac{2y_0}{g}} = 5.53$ s

using $0 = y_1 - \frac{1}{2} g t_f^2$

From ②: $v_0 (t_f - 1) = y_0 - \frac{1}{2} g (t_f - 1)^2$

$$v_0 = \frac{y_0}{t_f - 1} - \frac{1}{2} g (t_f - 1)$$

$$= \frac{150}{4.53} - 0.5 \cdot 9.8 \cdot 4.53$$

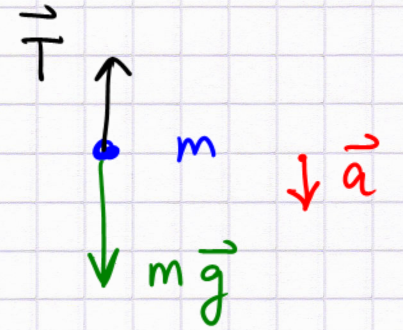
$$= 10.9 \text{ m/s}$$

Thus, $v_0 = 11 \frac{m}{s}$ (initial speed) or $v_0 = -11 \frac{m}{s}$ (velocity), downward

3.62 $m_{car} = 1200\ kg$ lowered by crane with $a = 0.2\ \frac{m}{s^2}$ down

Cable tension $T = ?$

Solution $\longrightarrow$ free-body diagram



$\therefore$ Newton's 2nd law:

$$m\vec{a} = \vec{F}_{net}, \quad \text{using } \hat{j} \uparrow$$

$$= \vec{T} + m\vec{g}$$

$$\therefore \quad ma_y = T - mg$$

$$T = m(g + a_y) \qquad \text{but } a_y = -0.2\ \frac{m}{s^2}$$

$$= 1200\ (9.8 - 0.2)\ N$$

$$= 11520\ N$$

$$= 12 \times 10^3\ N$$

3.68 requires some guessing

Airplane @ take-off accelerates from rest up until lift-off ($a = const$)

What could a be?

Solution. What can we estimate?

length of runway (few km, but use ~ 2 km)

lift-off speed? 250 km/h

(sports cars require spoilers to remain on ground ...)

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

$v_0 = 0$

$v_f = 250\ km/h$

$\Delta x = 2\ km$

$$a = \frac{v_f^2}{2\Delta x}$$

$$v_f = 250 \frac{10^3}{3.6 \times 10^3} \frac{m}{s} \simeq 70 \frac{m}{s}$$

$$\Delta x = 2 \times 10^3\ m$$

$$a = 1.2 \frac{m}{s^2}$$

Reasonable?

$\tilde{\approx} 0.1\,g$, we are pressed into the seats a bit, seems OK.

3.76 styrofoam ball, $R = 28$ cm,

terminal speed under free fall $v_{term} = 5.0 \, \frac{m}{s}$. What is its mass?

Solution. Free body diagram

No acceleration $\therefore$ $v = $ const.

Magnitudes: $F_{drag} = Mg$

$$M = \frac{F_{drag}}{g}, \quad F_{drag} = \frac{1}{2} \rho A v^2$$

Note: Eq. (3.22) is NOT on the formula sheet

$$M = \frac{\frac{1}{2} \rho A v^2}{g}$$ where $\rho = 1.3 \, \frac{kg}{m^3}$ = mass density of air

A = cross section $= \pi R^2 = 3.14 \times 0.28^2 \; m^2$

$= 0.246 \; m^2$

$$M = \frac{0.5 \times 1.3 \times 0.246 \times 25.}{9.8} \; kg$$

$= 0.41$ kg

Heavier than expected? (almost a pound, but the diameter is 0.56 m!)