Physics 101 P
General Physics I

Problem Sessions – Week 4

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Dynamics

NI : if $\vec{F}_{net} = \vec{0} \Rightarrow \vec{v} = \text{constant}$

NII : $\vec{F}_{net} = m\vec{a}$

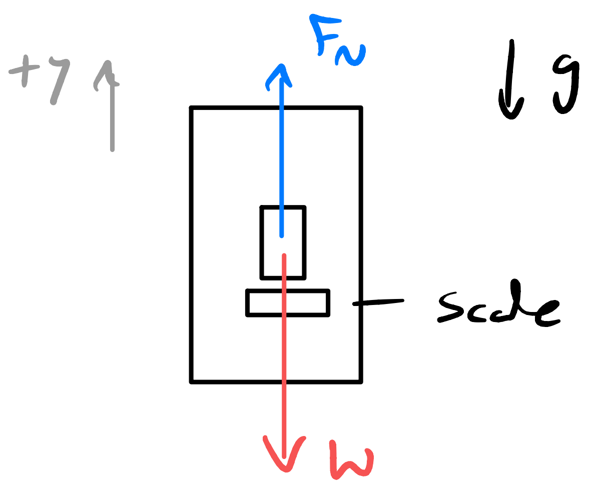
NIII : $\vec{F}_{A \to B} = -\vec{F}_{B \to A}$

Motion : $\vec{a} = \frac{d\vec{v}}{dt}$, $\vec{v} = \frac{d\vec{r}}{dt}$

Example

You are standing on a bathroom scale in an elevator. The elevator is moving upward at a constant speed of 3 m/s. If your mass is 70 kg, what does the scale read?

Solution



If v = constant, plays no role

$\Rightarrow \sum F = ma$

$y: \; F_N - W = 0$

$\Rightarrow F_N = mg$

$\simeq 700 \text{ N}$

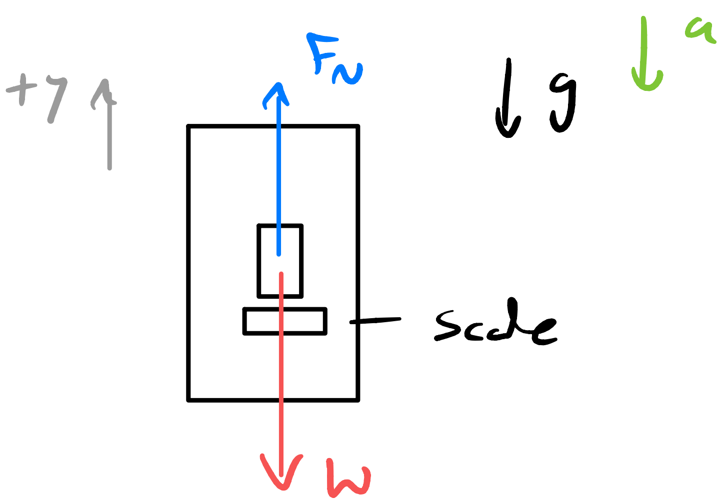
Example

You are standing on a bathroom scale in an elevator. The elevator is moving upward at a constant speed of 3 m/s.

Then, the elevator slows down at a rate of 1.5 m/s^2.

If your mass is 70 kg, what does the scale read?

Solution



$$\sum F = ma$$

$$F_N - mg = -ma$$

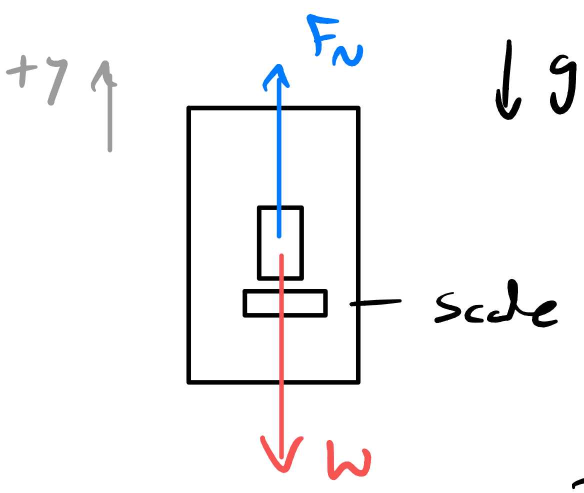
$$\Rightarrow F_N = m(g-a)$$

$$= 581 \text{ N}$$

Example

You are standing on a bathroom scale in an elevator. Suddenly, the elevator cable is cut & the safety devices fail, so that the elevator is in free fall. In your final moments, you look at the scale and see your weight. What would you read off the bathroom scale?

Solution



$$\sum F = ma$$

$$F_N - W = m(-g)$$

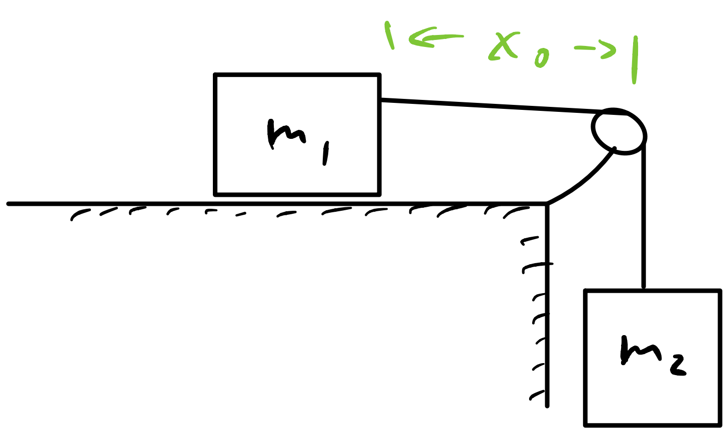
$$\Rightarrow F_N = W - mg$$

But, $W = mg$

$$\Rightarrow F_N = mg - mg$$
$$= 0 \qquad \blacksquare$$

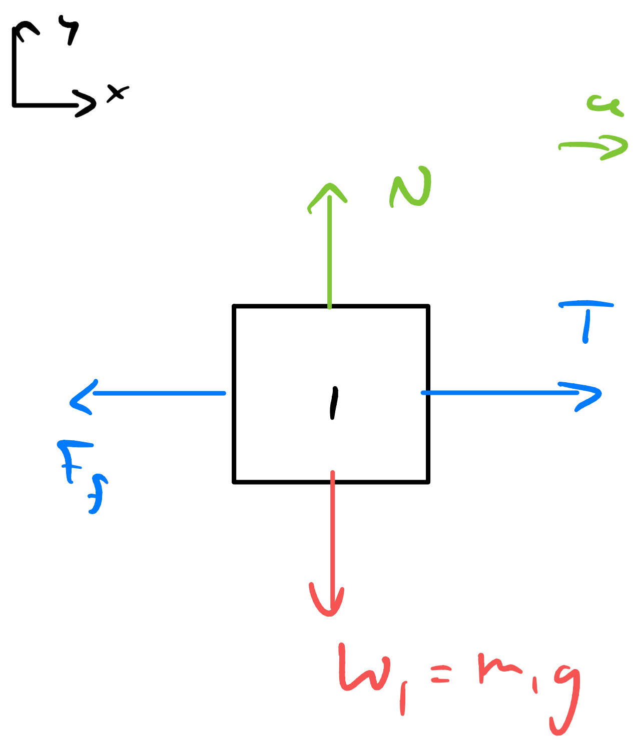
Example

A block w/ mass $m_1 = 6.0$ kg rests on a horizontal surface a distance $x_0 = 40$ cm from an ideal pulley. The coefficient of kinetic friction is $\mu_k = 0.22$. The block is connected by an ideal string passing over the pulley to a hanging mass w/ $m_2 = 3.0$ kg. When the system is released, the hanging mass begins falling to the ground. What is the acceleration of the hanging mass, & the tension in the rope. What speed does the block have when it reaches the pulley?



Solution

FBD's ①



$$\sum \vec{F} = m\vec{a}$$

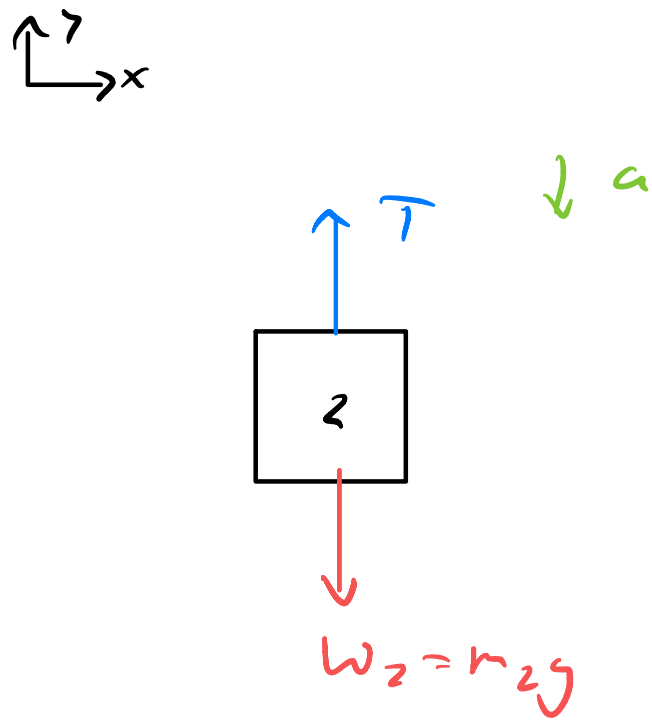
x: $T - F_f = m_1 a$ (1)

y: $N - m_1 g = 0$ (2)

also, $F_f = \mu_k N$

$= \mu_k m_1 g$ from (2)

②



$$\sum \vec{F} = m\vec{a}$$

y: $T - m_2 g = -m_2 a$ (3)

So,

$$\begin{cases} N = m_1 g \\ F_{f_k} = \mu_k N \\ \quad = \mu_k m_1 g \\ T - F_{f_k} = m_1 a \end{cases}$$

$$T - m_2 g = -m_2 a$$

Solve, $-f_{f_k} + m_2 g = m_1 a + m_2 a$

$$\Rightarrow a = \frac{1}{m_1 + m_2}(m_2 g - \mu_k m_1 g)$$

$$= g\frac{(m_2 - \mu_k m_1)}{m_1 + m_2}$$

$$\simeq 1.83 \ m/s^2$$

$$T = m_2 g - m_2 a$$

$$= \frac{m_1 m_2}{m_1 + m_2} g (1 + \mu_k)$$

$$\simeq 23.9 \text{ N} \blacksquare$$

Speed ?

$$v^2 = v_0^2 + 2a\Delta x,$$

$$= 2a x_0$$

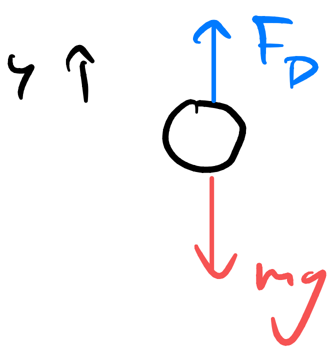
$$\Rightarrow v = \sqrt{2a x_0}$$

$$\simeq 1.2 \text{ m/s} \blacksquare$$

Example

A 560 g squirrel with surface area of 930 cm^2 falls from a 5.0 m tree to the ground. Estimate its terminal velocity, using a drag coefficient $C = 1.0$. What is the velocity of a 56-kg person hitting the ground from such a short distance, assuming no drag?

Solution



$$\sum F = ma$$

$$F_D - mg = 0$$

$$F_D = \frac{1}{2} C \rho A v^2$$

$$\Rightarrow \quad v = \sqrt{\frac{2mg}{C \rho A}}$$

Density of air,

$$\rho = 1.21 \ \frac{kg}{m^3}, \quad C = 1.0, \quad m = 0.560 \ kg$$

$$A = 930 \ cm^2 \left(\frac{1 \ m}{100 \ cm} \right)^2$$

$$= 0.0930 \ m^2$$

So, $v \simeq 9.87$ m/s $\blacksquare$

For person,

$$v^2 = 2gh$$

$$\Rightarrow \quad v = \sqrt{2gh}$$

$$\simeq 9.89 \text{ m/s} \quad \blacksquare$$

No mass, why?

$$\sum F = ma \quad \Rightarrow \quad mg = ma \quad \Rightarrow a = g \; !$$