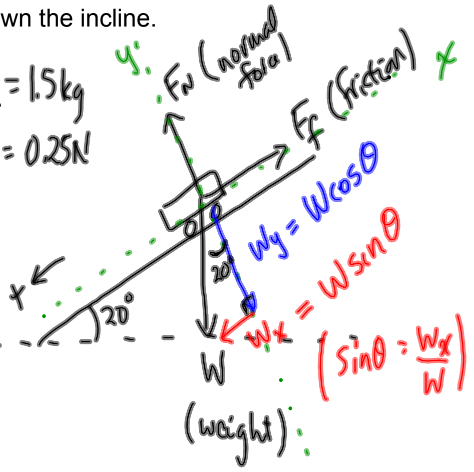
Newton's Second Law (continued)

Example
The diagram shows a dynamics trolley of mass 1.5 kg on a board which is inclined at 20°to the horizontal. A friction force of 0.25 N acts between the trolley and the board. Draw and label a FBD. Calculate the acceleration of the trolley down the incline.

$m = 1.5\,kg$

$F_f = 0.25\,N$



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

$$W_x - F_f = ma$$

$$a = \frac{W_x - F_f}{m}$$

$$a = \frac{W\sin\theta - F_f}{m}$$

$$a = \frac{mg\sin\theta - F_f}{m}$$

$$a = \frac{(1.5\,kg)(9.81\,ms^{-2})\sin 20^\circ - 0.25\,N}{1.5\,kg}$$

$$a = \frac{\underbrace{5.03\,N}_{W_x} - 0.25\,N}{1.5\,kg}$$ ← Friction (kinetic

$$a = 3.2\,m/s^2$$

$$\vec{a} = 3.2\,m/s^2 \text{ [down incline]}$$

What angle ($\theta > 0$), will give an acceleration of $0\,ms^{-2}$? (i.e. $\vec{F}_{net} = 0$)

i.e. $W_x = F_f$

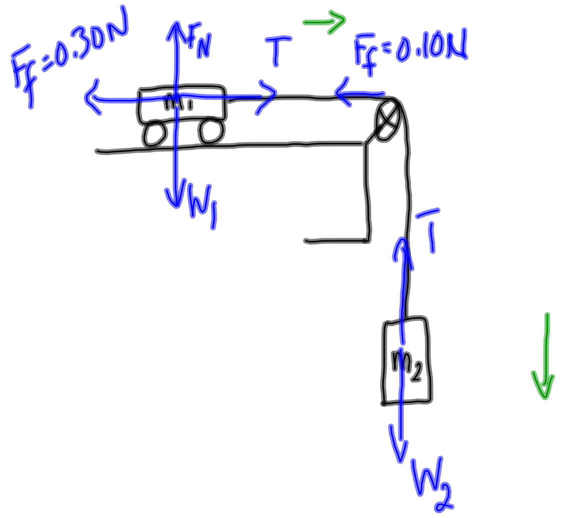
$$mg\sin\theta = F_f$$

$$\sin\theta = \frac{F_f}{mg}$$

$$\theta = \sin^{-1}\left(\frac{F_f}{mg}\right)$$

$$\theta = \sin^{-1}\left(\frac{0.25\,N}{(1.5\,kg)(9.81\,ms^{-2})}\right)$$

Example
A trolley of mass 0.20 kg is on a horizontal surface and is connected by a string to a mass of 0.10 kg. The string passes over a pulley such that the weight of the 0.10 kg mass causes the trolley to accelerate. There is a friction force of 0.10 N in the pulley and a friction force of 0.30 N in the wheels of the trolley. Calculate the acceleration of the trolley along the surface.

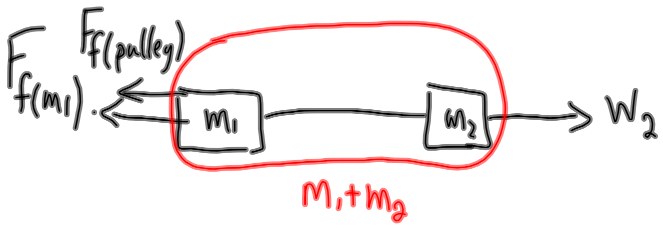


$m_1 = 0.20kg$

$m_2 = 0.10kg$

$F_{f(pulley)} = 0.10N$

$F_{f(m_1)} = 0.30N$



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

$$W_2 - F_{f(pulley)} - F_{f(m_1)} = (m_1 + m_2)a$$

$$a = \frac{m_2 g - F_{f(pulley)} - F_{f(m_1)}}{m_1 + m_2}$$

$$a = \frac{(0.10kg)(9.81ms^{-2}) - 0.10N - 0.30N}{0.20kg + 0.10kg}$$

$$a = \frac{0.981N - 0.10N - 0.30N}{0.30kg}$$

$$a \doteq 1.9\ ms^{-2}$$

$$\vec{a} \doteq 1.9ms^{-2}\ [\text{right}]$$

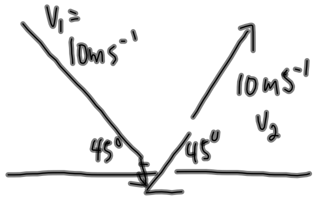
Example

A billiard ball of mass 0.15kg moving with a velocity of 10 m s^{-1} inclined at 45^{o} to the edge of the table bounces off the edge of the table at the same angle~~s~~ but with no change in speed. The ball is in contact with the edge of the table for 5.0 x 10^{-2} s. Determine the force acting on the ball during its collision with the edge of the table.

$m = 0.15kg$ $\quad \Delta t = 5.0 \times 10^{-2} s$

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

$F_{wall} = m a$ ← ??

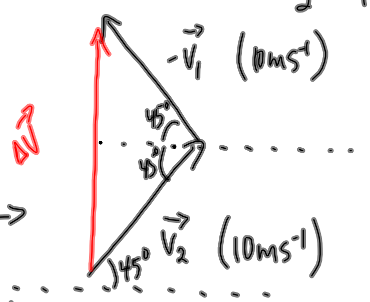


Recall $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$ ← need to do vector subtraction

Birds Eye View

Vector subtraction: $\vec{v}_2 - \vec{v}_1 = \vec{v}_2 + (-\vec{v}_1)$



due to symmetry we know that this is straight away from the wall

$c^2 = a^2 + b^2$

$c^2 = 10^2 + 10^2$

$c = (\sqrt{200})\, ms^{-1} = \Delta v$

$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

$\vec{a} = \frac{(\sqrt{200})ms^{-1}}{5.0 \times 10^{-2}s}$ (away from wall]

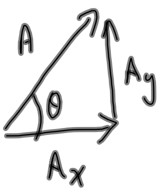
$\vec{a} \doteq 2.8 \times 10^{2}\, ms^{-2}$ [away from wall]

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

$\vec{F}_{wall} = m\vec{a}$

$\vec{F}_{wall} = (0.15kg)(2.8 \times 10^{2} ms^{-2})$ [away fr. wall]

$\vec{F}_{wall} \doteq 42N$ [away from the wall]



Revisiting Air Resistance

Air resistance is a friction force.

Properties of air resistance:

- acts in a direction opposite to the velocity of a moving object
- the magnitude depends on the speed of the object and is greater for an object moving at a greater speed.

$$\vec{F}_R \propto V^2$$

(doubling the speed increases F_{air} by a factor of 4)

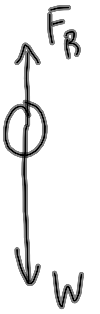
- the magnitude also depends on the size (mass) and shape of the object. There is less air resistance on a small streamlined object.

Terminal Speed

- At the instant the object starts to fall, the only force acting on the object is the force of gravity.

$\Rightarrow a = 9.81\,m/s^2$

- As the object falls, it accelerates and the force of air resistance will increase. The object will <u>NOT</u> have constant acceleration, the acceleration is decreasing.

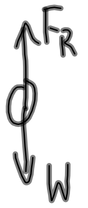


F_R (gradually increasing)

$W > F_R$, so $a \neq 0$

(the velocity is increasing but at a decreasing rate)

- Eventually the force of air resistance equals the the force of gravity (i.e. $F_{net} = 0$, $a = 0$) $\Rightarrow$ terminal velocity



$F_R = W \;\therefore F_{net} = 0,\; a = 0$