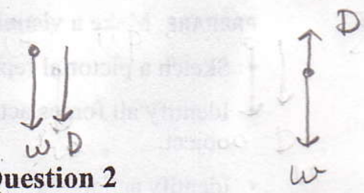
Questions and Example Problems from Chapter 5

Question 1

A ball is thrown straight up. Taking the drag force of air into account, does it take longer for the ball to travel to the top of its motion or for it to fall back down again.

note: air resistance (drag) always acts in opposite direction of motion

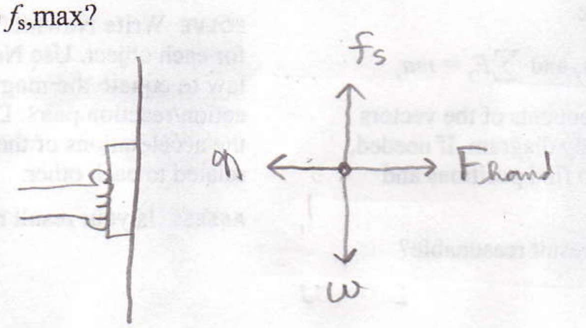
way up: way down:



Since $\sum F_y$ is smaller on the way down, the acceleration is smaller on the way down so it will take longer to fall back down.

Question 2

If you press an apple crate against a wall so hard that the crate cannot slide down the wall, what is the direction of (a) the static frictional force $\vec{f}_s$ on the crate from the wall and (b) the normal force $\vec{N}$ on the crate from the wall? If you increase your push, what happens to (c) f_s, (d) N, and (e) $f_{s,max}$?



(a) up the wall

(b) perpendicular away from wall

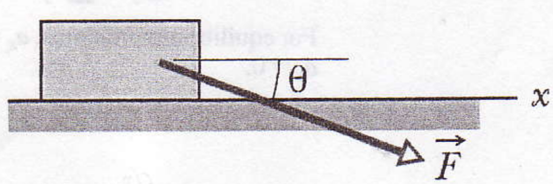
(c) remains constant ($f_s = w$)

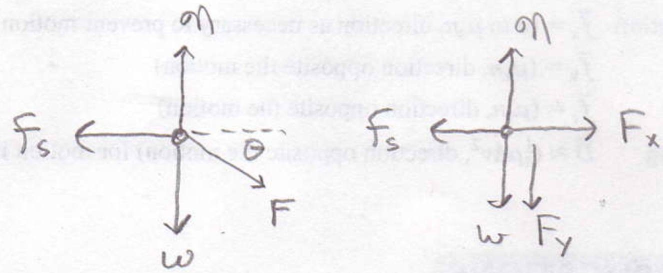
(d) increases

(e) increases ($f_{s,max} = \mu_s N$)

Question 3

In the figure below, if the box is stationary and the angle θ of force $\vec{F}$ is increased, do the following quantities increase, decrease, or remain the same: (a) F_x; (b) f_s; (c) N; (d) $f_{s,max}$? (e) If, instead, the box is sliding and θ is increased, does the magnitude of the frictional force on the box increase, decrease, or remain the same?





(a) decrease

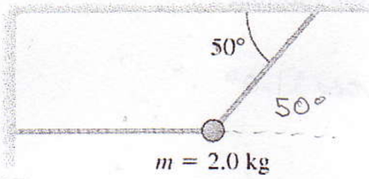
(b) decrease (as $a_x = 0$, then $f_s = F_x$)

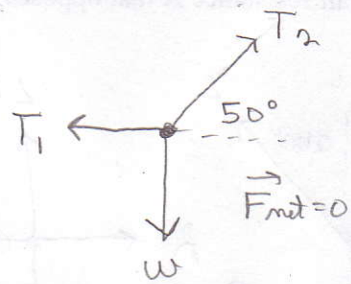
(c) increase (because F_y increases)

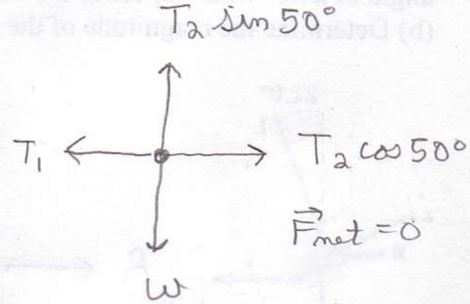
(d) increase (because N increases and $f_{s,max} = \mu_s N$)

(e) increase (because N increases and $f_k = \mu_k N$)

Problem 1
A 2.0 kg ball is suspended by two light strings as shown in the figure below. What is the tension in each string?







$$\sum F_y = ma_y = 0$$

$$T_2 \sin 50° - w = 0$$

$$T_2 = w / \sin 50° = \frac{mg}{\sin 50°}$$

$$T_2 = \frac{(2.0\,kg)(9.80\,m/s^2)}{\sin 50°} = 25.6\,N$$

$$\boxed{T_2 = 26\,N}$$

$$\sum F_x = ma_x = 0$$

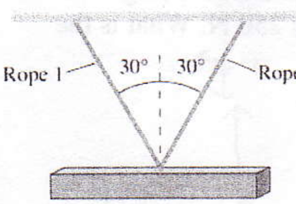
$$T_2 \cos 50° - T_1 = 0$$

$$T_1 = T_2 \cos 50°$$

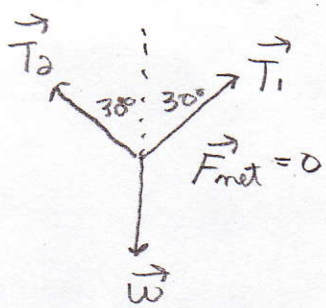
$$= (25.6\,N) \cos 50°$$

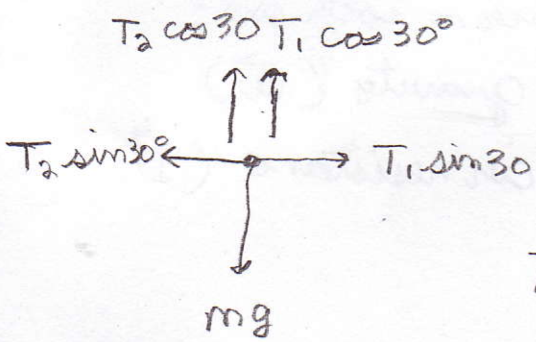
$$\boxed{T_1 = 16\,N}$$

Problem 2
A 1000 kg steel beam is supported by the ropes shown in the figure below. Each rope can support a maximum sustained tension of 5600 N. Do the ropes break?



forces on beam: gravity (weight)
tension in ropes 1 + 2





$$\sum F_x = ma_x = 0$$

$$T_1 \sin 30° - T_2 \sin 30° = 0$$

$$T_1 = T_2$$

$$\sum F_y = ma_y = 0$$

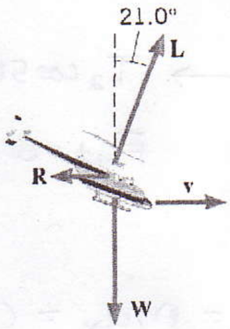
$$T_2 \cos 30° + T_1 \cos 30° - mg = 0$$

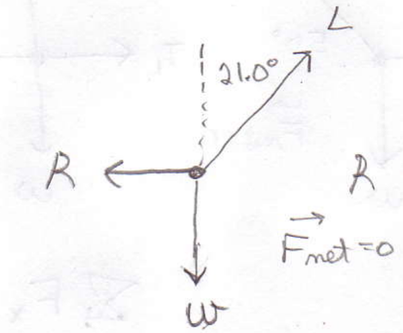
$$2 T_1 \cos 30° - mg = 0 \rightarrow T_1 = \frac{mg}{2 \cos 30°}$$

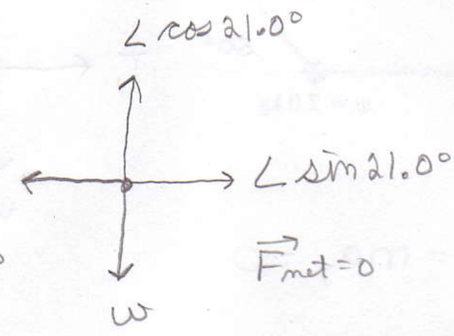
$$T_1 = \frac{(1000\,kg)(9.80\,m/s^2)}{2 \cos 30°} = 5658\,N \rightarrow \text{the ropes break}$$

Problem 3

The helicopter in the drawing is moving horizontally to the right at a constant velocity. The weight of the helicopter is 53,800 N. The lift force **L** generated by the rotating blade makes an angle of 21.0° with respect to the vertical. (a) What is the magnitude of the lift force?
(b) Determine the magnitude of the air resistance **R** that opposes the motion.







$$\sum F_y = ma_y = 0$$

$$L\cos 21.0° - w = 0$$

$$L = w / \cos 21.0°$$

$$L = \frac{53{,}800\,N}{\cos 21.0°} = 5.76 \times 10^4\,N$$

$$\sum F_x = ma_x = 0$$

$$L\sin 21.0° - R = 0$$

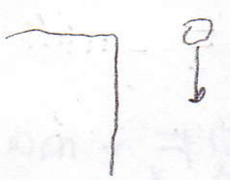
$$R = L\sin 21.0°$$

$$= (5.76\times10^4\,N)\sin 21.0°$$

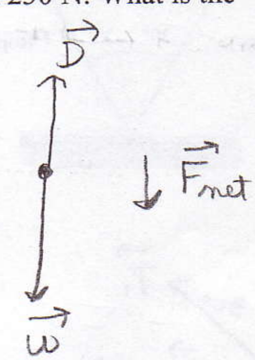
$$\boxed{R = 2.07\times10^4\,N}$$

Problem 4

A rock of mass 45 kg accidentally breaks loose from the edge of a cliff and falls straight down. The magnitude of the air resistance that opposes its downward motion is 250 N. What is the magnitude of the acceleration of the rock?



forces on rock are:
gravity ($\vec{w}$)
air resistance ($\vec{D}$)



$$\sum F_y = ma_y$$

$$a_y = \sum F / m = \frac{(D - mg)}{m}$$

$$a_y = D/m - g = \frac{(250\,N)}{9.80\,m/s^2} - 9.80\,m/s^2 = -4.2\,m/s^2$$

$$\vec{a} = 4.2\,m/s^2 \text{ downward}$$

Problem 5

A 95.0 kg person stands on a scale in an elevator. What is the apparent weight when the elevator is (a) accelerating upward with an acceleration of 1.80 m/s², (b) moving upward at a constant speed, and (c) accelerating downward with an acceleration of 1.40 m/s²?

$\sum F_y = ma_y$

$n - w = ma_y \rightarrow n = w + ma_y = mg + ma_y$

$n = m(g + a_y) \rightarrow$ apparent weight is defined as the magnitude of the contact force that supports a person

$w_{app} = m(g + a_y)$

a) $a = +1.80\,m/s^2 \rightarrow w_{app} = (95.0\,kg)(9.80\,m/s^2 + 1.80\,m/s^2) = 1.10 \times 10^3\,N$

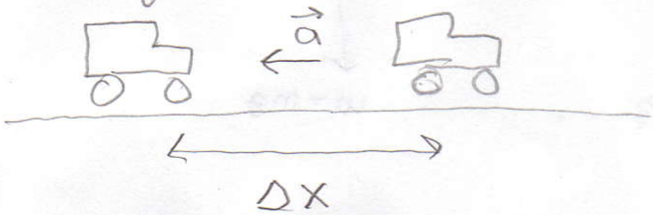
b) $a = 0\,m/s^2 \rightarrow w_{app} = (95.0\,kg)(9.80\,m/s^2 + 0) = 931\,N$

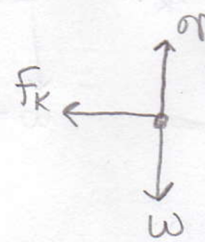
c) $a = -1.40\,m/s^2 \rightarrow w_{app} = (95.0\,kg)(9.80\,m/s^2 - 1.40\,m/s^2) = 798\,N$

Problem 6

A 1000 kg car is traveling at a speed of 40 m/s skids to a halt on wet concrete where $\mu_k = 0.60$. How long are the skid marks?

⇒ first find the acceleration from $\sum \vec{F} = m\vec{a}$, then use equations of constant acceleration to find Δx





$\sum F_y = ma_y = 0$

$n - w = 0$

$n = w = mg$

$n = (1000\,kg)(9.80\,m/s^2)$

$n = 9.80 \times 10^3\,N$

$\sum F_x = ma_x$

$-f_k = ma_x$

$-\mu_k n = ma_x$

$a_x = -\frac{\mu_k n}{m} = -\frac{(0.60)(9.80 \times 10^3\,N)}{(1000\,kg)} \rightarrow a_x = -5.9\,m/s^2$

$(v_x)_i = 40\,m/s$

$(v_x)_f = 0\,m/s$

$a_x = -5.90\,m/s^2$

$\Delta x = ?$

$(v_x)_f^2 = (v_x)_i^2 + 2a_x\Delta x \rightarrow 0 = (v_x)_i^2 + 2a_x\Delta x$

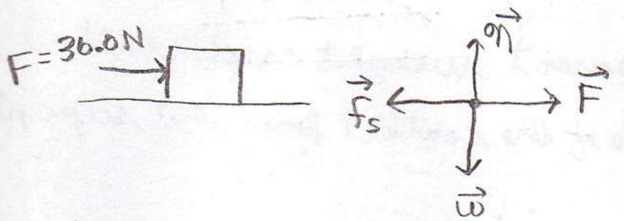
$\Delta x = -(v_x)_i^2 / 2a_x = -(40\,m/s)^2 / 2(-5.9\,m/s^2)$

$\Delta x = 136\,m \rightarrow \boxed{\Delta x = 1.4 \times 10^2\,m}$

$$m = w/g = \frac{45.0\,N}{9.80\,m/s^2} = 4.59\,Kg$$

Problem 7
A block whose weight is 45.0 N rests on a horizontal table. A horizontal force of 36.0 N is applied to the block. The coefficients of static and kinetic friction are 0.650 and 0.420, respectively. Will the block move under the influence of the force, and, if so, what will be the block's acceleration? Explain your reasoning.

⇒ if $36.0\,N > \vec{f}_{s,max}$, then block will move; otherwise $f_s = 36.0\,N$ and block will remain at rest



$\sum F_y = ma_y = 0$ $\vec{n} - \vec{w} = 0$

$n = w = 45.0\,N$

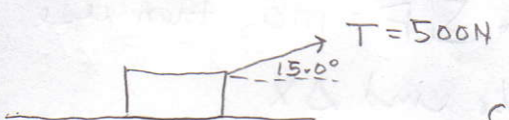
$f_{s,max} = \mu_s n = (0.650)(45.0\,N) = 29.25\,N$

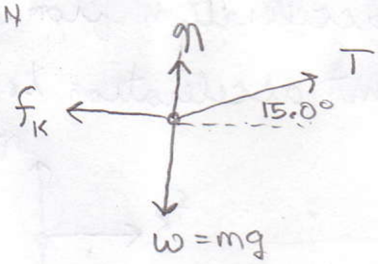
⇒ since $36.0\,N > f_{s,max}$, block moves + friction is kinetic

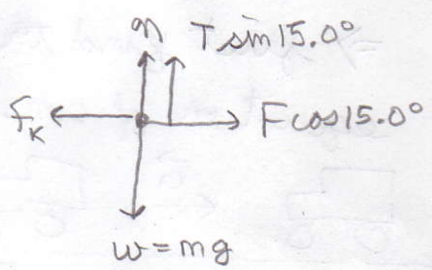
$\sum F_x = ma_x \rightarrow a_x = \frac{\sum F_x}{m} = \frac{F - f_k}{m}$

$$a_x = \frac{(36.0\,N) - (0.420)(45.0\,N)}{(4.59\,Kg)} \rightarrow a_x = 3.73\,m/s^2$$

Problem 8
A 70.0 kg crate is dragged across a floor by pulling on a rope with a force of 500.0 N at an angle of 15.0° above the horizontal. If $\mu_k = 0.35$, what is the acceleration of the crate?







$\sum F_y = ma_y = 0$

$n + T\sin 15.0° - mg = 0$

$n = mg - T\sin 15.0°$

$n = (70.0\,Kg)(9.80\,m/s^2) - (500.0\,N)\sin 15.0°$

$n = 557\,N$

$\sum F_x = ma_x$

$F\cos 15.0° - f_k = ma_x$

$F\cos 15.0° - \mu_k n = ma_x$

$a_x = \frac{F\cos 15.0° - \mu_k n}{m}$

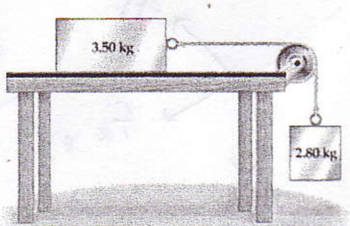
$$a_x = \frac{(500.0\,N)\cos 15.0° - (0.35)(557\,N)}{(70.0\,Kg)} = \boxed{4.1\,m/s^2}$$

$m_1 = 3.50\text{ Kg}$

$m_2 = 2.80\text{ Kg}$

Problem 9

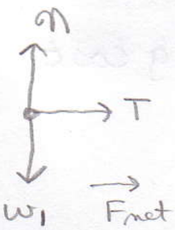
A 3.50 kg block on a frictionless tabletop is attached by a string to a hanging block of mass 2.8 kg, as shown in the figure below. The blocks are released from rest and allowed to move freely. (a) Is the tension in the string greater than, less than, or equal to the weight of the hanging mass? (b) Find the acceleration of the blocks and the tension in the string.



(a) If the 2.80 Kg block is to accelerate downwards, we must have $T < w$.

(b) note: the tension is the same in all parts of the string + the magnitude of the acceleration is the same (since they are connected)

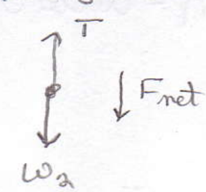
3.50 Kg block:



$\sum F_x = m a_x$

$T = m_1 a$ ↓ put into eqn. 1

2.80 Kg block:



$\sum F_y = m a_y$

$T - w_2 = m_2(-a)$

$T - m_2 g = -m_2 a$ eqn. 1

$m_1 a - m_2 g = -m_2 a$

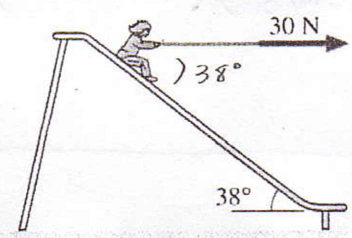
$m_1 a + m_2 a = m_2 g$

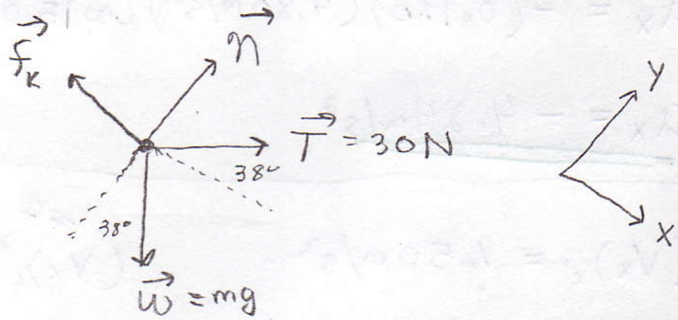
$a = m_2 g / (m_1 + m_2)$

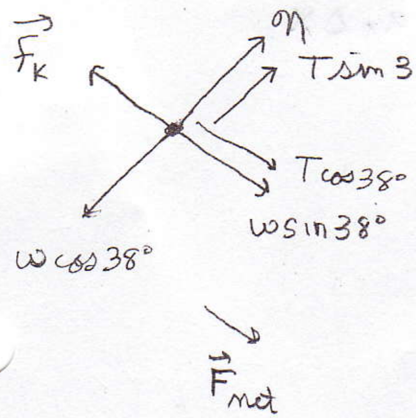
$a = \frac{(2.80\text{ Kg})(9.80\text{ m/s}^2)}{(3.50\text{ Kg} + 2.80\text{ Kg})} = 4.4\text{ m/s}^2$

Problem 10

A 23 kg child goes down a straight slide inclined 38° above the horizontal. The child is acted on by his weight, the normal force from the slide, kinetic friction, and a horizontal rope exerting a 30 N force as shown in the figure below. How large is the normal force of the slide on the child?







$\sum F_y = m a_y = 0$

$n + T\sin 38° - w\cos 38° = 0$

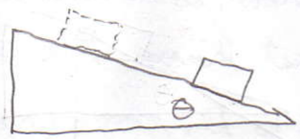
$n = w\cos 38° - T\sin 38°$

$n = (23\text{ Kg})(9.80\text{ m/s}^2)\cos 38° - (30\text{ N})\sin 38°$

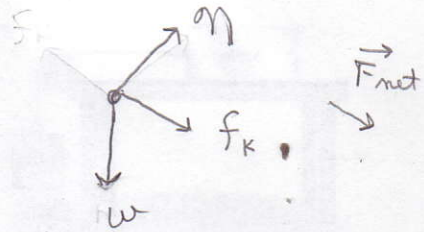
$n = 159\text{ N} \longrightarrow n = 1.6 \times 10^2\text{ N}$

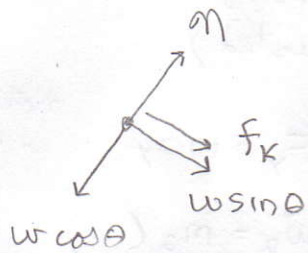
Problem 11

A box is sliding up an incline that makes an angle of 15.0° with respect to the horizontal. The coefficient of kinetic friction between the box and the surface of the incline is 0.180. The initial speed of the box at the bottom of the incline is 1.50 m/s. How far does the box travel along the incline before coming to rest?



define axes as:





$\sum F_y = ma_y = 0$

$n - w\cos\theta = 0 \rightarrow n = w\cos\theta = mg\cos\theta$

$\sum F_x = ma_x$

$-f_K - w\sin\theta = ma_x$ $\quad f_K = \mu_K n = \mu_K(mg\cos\theta)$

$-\mu_K mg\cos\theta - mg\sin\theta = ma_x \rightarrow a_x = -\mu_K g\cos\theta - g\sin\theta$

$a_x = -(0.180)(9.80\,m/s^2)\cos 15.0° - (9.80\,m/s^2)(\sin 15.0°)$

$a_x = -4.24\,m/s^2$

$(V_x)_i = 1.50\,m/s^2$

$(V_x)_f = 0\,m/s$

$a_x = -4.24\,m/s^2$

$\Delta X = ?$

$(V_x)_f^2 = (V_x)_i^2 + 2a_x\Delta X$ (with $(V_x)_f^2 = 0$)

$0 = (V_x)_i^2 + 2a_x\Delta X$

$\Delta X = -\frac{(V_x)_i^2}{2a_x}$

$\Delta X = -\frac{(1.50\,m/s)^2}{2(-4.24\,m/s^2)}$

$\Delta X = 0.265\,m$