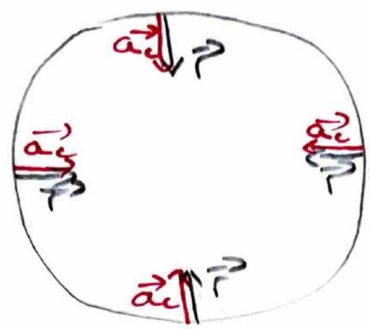
SN1 – PROBLEM SET # 3
NEWTON's LAWs (Friction & Gravitation)

CONCEPTUAL QUESTIONS

Answer - Question 1.

Constructing the FBD of the pilot at the top of the loop, bottom of the loop, and one of the two sides:



Top

$F_{net,r} = ma_c = \frac{mv_t^2}{r}$

$F_N + mg = \frac{mv_t^2}{r}$

$F_N = \frac{mv_t^2}{r} - mg$

Bottom

$F_{net,r} = \frac{mv_t^2}{r}$

$F_N - mg = \frac{mv_t^2}{r}$

$F_N = \frac{mv_t^2}{r} + mg$

Side

$F_{net,r} = \frac{mv_t^2}{r}$

$F_N = \frac{mv_t^2}{r}$

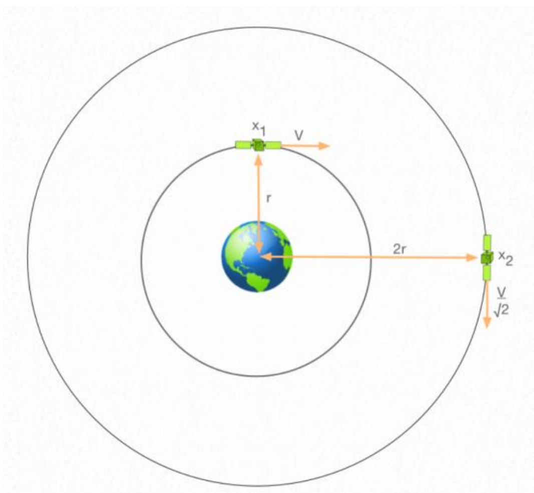
$$\frac{mv_t^2}{r} + mg > \frac{mv_t^2}{r} > \frac{mv_t^2}{r} - mg$$

Comparing the 3 different expressions for the normal force exerted by the seat on the pilot, we can see that for uniform circular motion at constant speed, the greatest normal force is at the bottom of the loop and the least normal force is at the top of the loop.

Answer - Question 2.

The gravity force is required to provide the radial acceleration of an orbit. If there were no gravity force on a spacecraft, the spacecraft would travel in a straight line at constant speed. An astronaut only feels weightless because the spacecraft and the astronaut have the same acceleration. Only at an infinite distance from the earth is its gravitational force zero according to Newton's Law of Universal Gravitation.

Answer - Question 3.



$$F_{c1} = \frac{mv_1^2}{r_1}$$

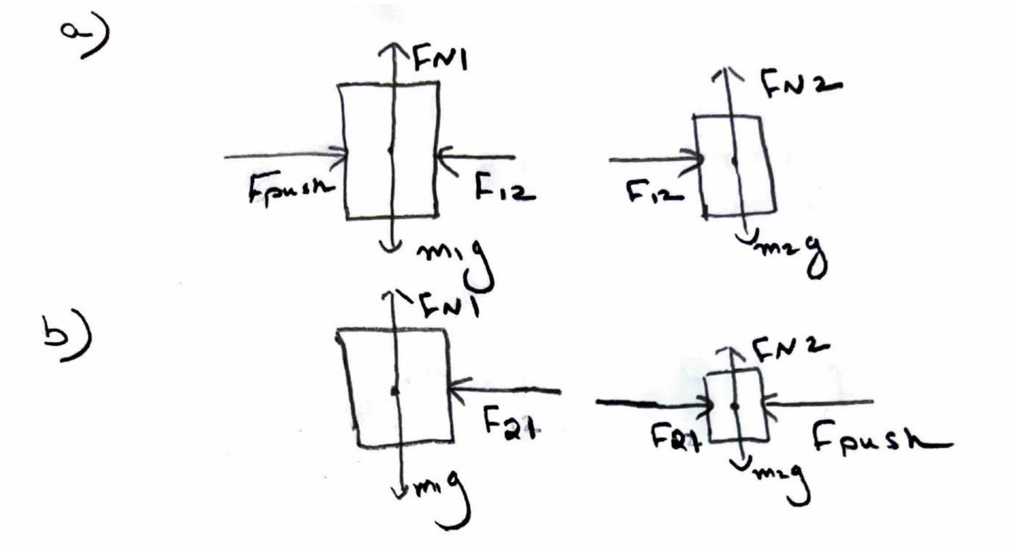
$$F_{c2} = \frac{mv_2^2}{r_2} = \frac{m(\frac{v_1}{\sqrt{2}})^2}{(2r_1)} = \frac{m\frac{v_1^2}{2}}{2r_1} = \frac{mv_1^2}{4r_1} = \frac{F_{c1}}{4}$$

$$Therefore, F_{c1} = 4F_{c2}$$

$$\frac{F_{c1}}{F_{c2}} = 4$$

Answer - Question 4.

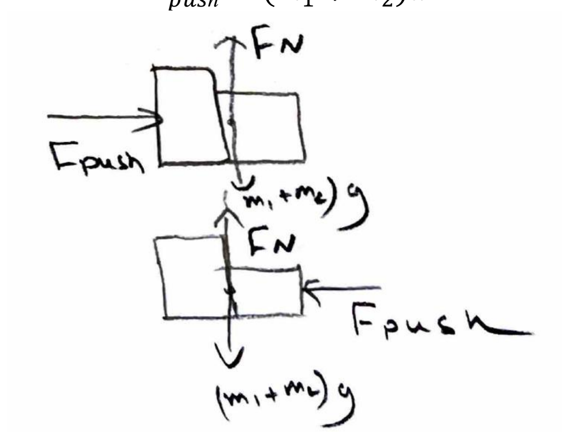
a and b)



c)
In situation a, the reaction force is determined by the smaller crate; however, in situation 2, the reaction force is determined by the larger crate. Therefore, the reaction force between the two crates is smaller in situation 1 than in situation 2. In the absence of friction (smooth surface), the same force is required to push the crates in both situation if the same acceleration is to be achieved.

d) Yes, my answer is consistent with the idea that you are pushing the same amount of mass, independent of the order of the creates as in this case the reaction force becomes an internal force.

$$F_{push} = (m_1 + m_2)a$$



e) Considering that the two crates move at the same acceleration as one object the sum of the forces exerted by crate 1 on crate 2 and by crate 2 on crate 1 is zero for both situations. The magnitudes of the force that one crate exerts on the other are equal; however, the forces are opposite in direction (Newton's Third Law). As discussed in part c, that force is smaller in magnitude in situation a compared to situation b.

Answer - Question 5.

According to Newton's Law of Universal Gravitation:

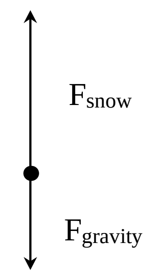
$$F_g = \frac{GmM_{earth}}{r^2}$$

This is the only force resulting in acceleration of objects in free fall in the absence of air resistance. Using Newton's Second Law to determine the acceleration of objects in free fall:

$$F_g = \frac{GmM_{earth}}{r^2} = ma$$
$$Therefore,$$
$$a = \frac{GM_{earth}}{r^2}$$

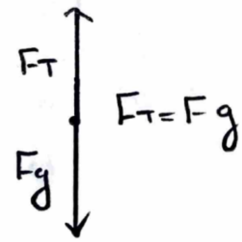
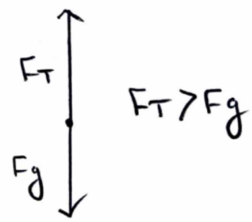
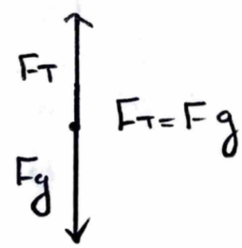
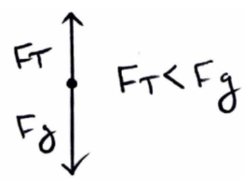
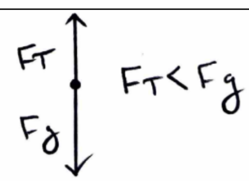
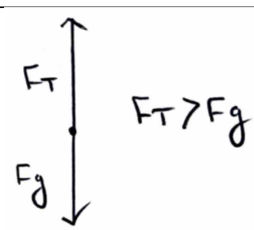
We can conclude that acceleration of falling objects is independent of the mass of the falling object in the absence of air resistance.

Answer - Question 6.



b) I agree with Amanda. I would agree with José in noticing that the net force is upward; however, I would remind José that the direction of the net force only determines the direction of acceleration and not the direction of motion. The paratrooper has been accelerating in free fall all the way until the paratrooper hits the snow. The paratrooper then has to decelerate in order to come to a stop within a certain distance. The is why the acceleration has to be upward opposite to the direction of motion. Therefore, according to Newton's second law the net force has to be upward. Therefore, the free body diagram is correct.

Answer - Question 7.

Motion diagram for the mass	Force diagram for the mass
Experiment 1. A mass is supported by a spring scale. The mass is at rest.	
$\vec{v} = \mathbf{0}$ $\vec{a} = \mathbf{0}$	
Experiment 2. The mass accelerates up (being pulled by the scale).	
$\overrightarrow{\Delta v}$ ↑ $\vec{a}$ ↑	
Experiment 3. The mass is moving up at constant speed.	
$\vec{v} = ct.$ $\vec{a} = \mathbf{0}$	
Experiment 4. The mass moves up slowing down to a stop.	
$\overrightarrow{\Delta v}$ ↑ $\vec{a}$ ↓	
Experiment 5. The mass accelerates down.	
$\overrightarrow{\Delta v}$ ↓ $\vec{a}$ ↓	
Experiment 6. The mass slows to a stop when moving down.	
$\overrightarrow{\Delta v}$ ↓ $\vec{a}$ ↑	

Patterns

The vector sum of the forces exerted on the mass has the same direction of the $\Delta\vec{v}$ arrow on the motion diagram which is the same as the acceleration vector because:

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

The spring scale reading (Tension) is greater than the actual weight of the mass in experiments 2 and 6 in which the acceleration vector is directed upward although the mass is slowing while moving down in experiment 6. The net force is upward for these two situations according to Newton's Second Law.

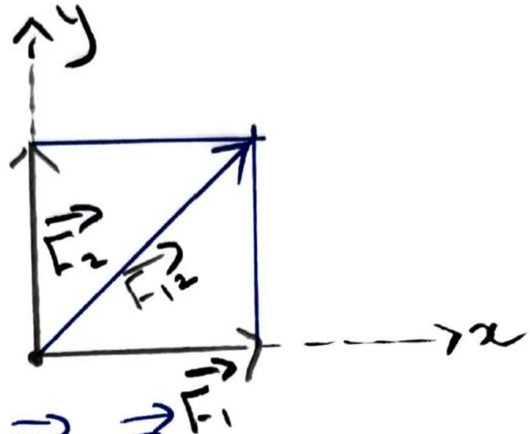
The spring scale reading (Tension) is smaller than the actual weight of the mass in experiments 4 and 5 in which the acceleration vector is directed downward although the mass is slowing while moving up in experiment 4. The net force is downward for these two situations according to Newton's Second Law.

The spring scale reading (Tension) corresponds to the actual weight of the mass in experiments 1 and 3 in which the acceleration is zero. The net force is zero for these two situations according to Newton's Second Law.

Answer - Question 8. A mass m in three-dimensional space is subjected to three forces $\vec{F}_1$, $\vec{F}_2$, and $\vec{F}_3$. $\vec{F}_1$ and $\vec{F}_2$ have the same magnitude, with $\vec{F}_1$ in the positive x direction, and $\vec{F}_2$ in the positive y direction. If the mass has an acceleration of 0, which of the following statements is false?

a) The magnitude of $\vec{F}_3$ is the same as that of $\vec{F}_1$.
b) The object is in equilibrium, and could be stationary.
c) $\vec{F}_3$ lies in the xy plane.
d) The object is in equilibrium, and could be moving.
e) The object experiences a net force of 0.

Statement (a) is false because:

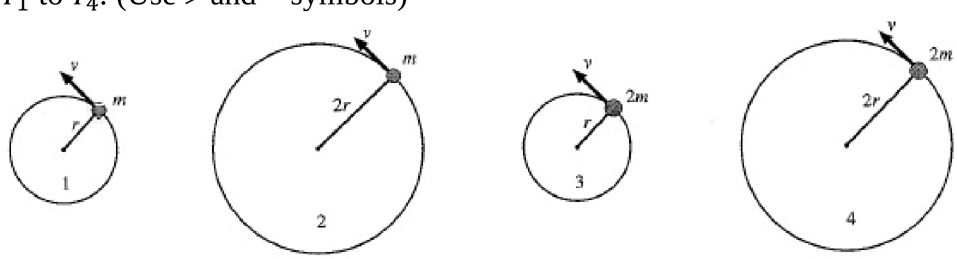


$\vec{F}_{12} = \vec{F}_1 + \vec{F}_2$

$|\vec{F}_{12}| = \sqrt{F_1^2 + F_2^2}$

In order for the acceleration to be 0 $|\vec{F}_3| = |\vec{F}_{12}|$, but $\vec{F}_3$ is opposite in direction to $\vec{F}_{12}$. $|\vec{F}_3|$ can be equal to $|\vec{F}_1|$ only if $|\vec{F}_2| = 0$, which is not the case here.

Answer - Question 9. The figures are a bird's-eye view of balls on a string moving in horizontal circles on a frictionless table top. All are moving at the same speed. Rank in order, from largest to smallest, the string tensions T_1 to T_4. (Use > and = symbols)



$$T_3 > T_1 = T_4 > T_2$$

$$T_1 = \frac{mv^2}{r}$$
$$T_2 = \frac{mv^2}{2r}$$
$$T_3 = \frac{2mv^2}{r}$$
$$T_4 = \frac{2mv^2}{2r} = \frac{mv^2}{r}$$

PROBLEMS

1.

a) $\Delta x = \frac{v_i+v_f}{2}t \rightarrow t = \frac{2\cdot\Delta x}{v_f+v_i} = \frac{2\cdot 0.10}{36} = \boxed{5.56\times10^{-3}s}$

b) $a = \frac{v_f-v_i}{t} = \frac{0-36}{5.56\times10^{-3}} = \boxed{-6480m/s^2}$

or $v_f^2 = v_i^2 + 2a(\Delta x) \rightarrow a = \frac{v_f^2-v_i^2}{2\Delta x} = \frac{0-36^2}{2(0.10)} = \boxed{-6480m/s^2}$

c) $\vec{F} = m\vec{a} = (2\times10^{-3})(-6480) = \boxed{-12.96N}$ (in the opposite direction of the velocity)

d) The force the bullet exerts on the block is the reaction of the force in c); that is, the force is $\boxed{+12.96N}$, in the same direction of velocity.

2.

$\Sigma F_y = F_N - mg = -ma \rightarrow F_N = m(g-a)$

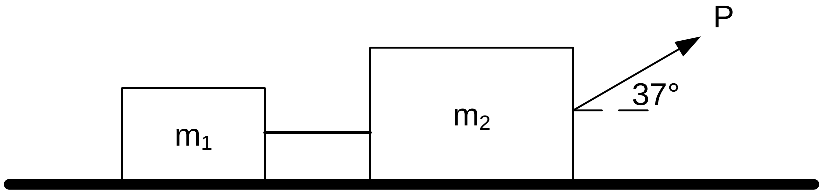
a) when the elevator is at rest, there is no acceleration, thus $F_N = mg = 491N$

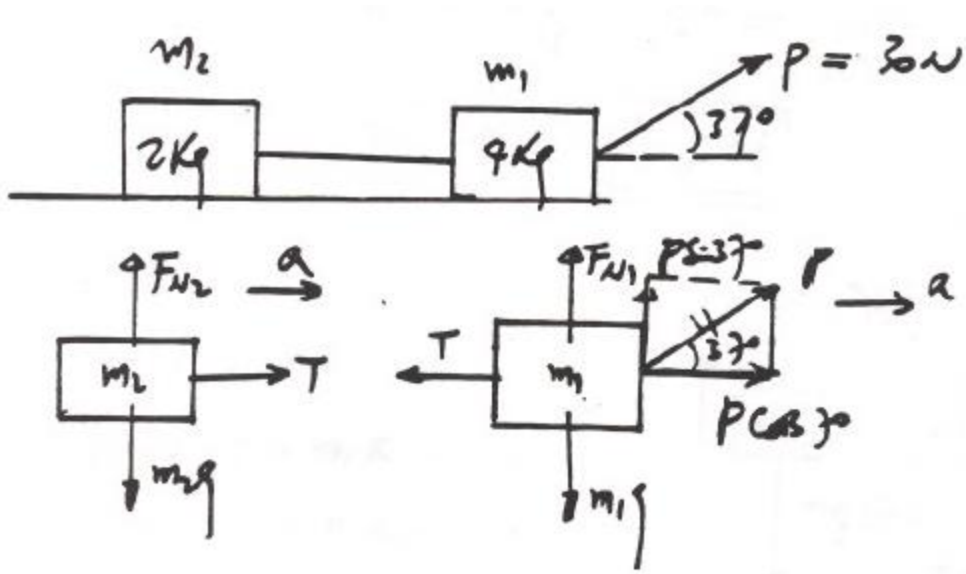
b) when the elevator is moving at constant speed, there is no acceleration, thus: $F_N = 491N$

c) when the elevator is accelerating upward:
$\Sigma F_y = F_N - mg = ma \rightarrow F_N = m(g+a) = 50(9.81+3) = \boxed{641N}$

d) when the elevator is accelerating downward:
$\Sigma F_y = F_N - mg = -ma \rightarrow F_N = m(g-a) = 50(9.81-3) = \boxed{341N}$

3. Construct Free Body Diagrams as shown below:





a) For this part, it is fastest to consider the combined FBD of the two blocs together. Working in the x and y direction separately is easiest. Note that we can solve the y-direction immediately but not the x. Why?

X-DIRECTION		**Y-DIRECTION**	
$\boldsymbol{\Sigma F_{xTotal} = (m_1 + m_2)a}$	$(\mathbf{1a})$	$\Sigma F_{yTotal} = 0$	$(2a)$
$\boldsymbol{Pcos\theta - f = (m_1 + m_2)a}$	$(\mathbf{1b})$	$N - (m_1 + m_2)g + Psin\theta = 0$	$(2b)$
$\boldsymbol{30cos37° - f = 6a}$	$(\mathbf{1c})$	$N = (m_1 + m_2)g - Psin\theta$	$(2c)$
$\boldsymbol{23.96 - f = 6a}$	$(\mathbf{1d})$	$N = 6g - 30sin37°$	$(2d)$
		$N = 40.81\ N$	$(2e)$

But how much friction is there? First, we need to know if it's static or kinetic friction. If the system was right at the point where it was about to start moving, then it would have zero horizontal acceleration. We can use this to solve Equation 1d and find the required amount of static friction to prevent it from accelerating:

$$23.96 - f_{s\,required} = 0 \qquad (3a)$$

$$f_{s\,required} = 23.96\ N \qquad (3b)$$

However, the maximum amount of static friction this system could experience is:

$$f_{smax} = \mu_s N = 0.24(40.81) = 9.79\ N \qquad (4)$$

Comparing the amount required to keep it static and the amount possible, we find:

$$23.96\ N > 9.79\ N \tag{5}$$

Therefore, static friction is not enough to prevent this system from accelerating, and the friction force must be kinetic. We can now solve equation 1 d to find the acceleration of the system:

$$23.96 - \mu_k N = 6a \tag{6a}$$

$$23.96 - 0.20(40.81) = 6a \tag{6b}$$

$$\boldsymbol{a = 2.63\ m/s^2} \tag{6c}$$

b) For b) and c), we need to consider each bloc independently.
e
$\Sigma F_{y1} = F_{N1} - m_1 g = 0$ (4)
$\Sigma F_{x2} = P\cos\theta - T - f_{k2} = m_2 a$ (5)
$\Sigma F_{y2} = F_{N2} - m_2 g + P\sin\theta = 0$ (6)

From (4): $F_{N1} = m_1 g = 2 \cdot 9.81 = 19.62\ N$
In (3): $T - f_{k1} = m_1 a \ \rightarrow T = \mu_k F_{N1} + m_1 a = 0.2 \cdot 19.62 + 2 \cdot 2.63 = 9.18\ N$

c) The force exerted on bloc 1 by the floor is:

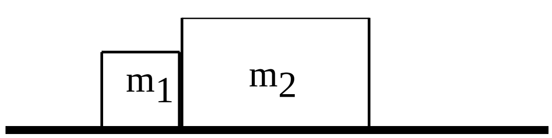
$\vec{F}_{Floor1} = -f_{k1}\hat{\imath} + F_{N1}\hat{\jmath} = (-3.92\hat{\imath} + 19.6\,\hat{\jmath})N$

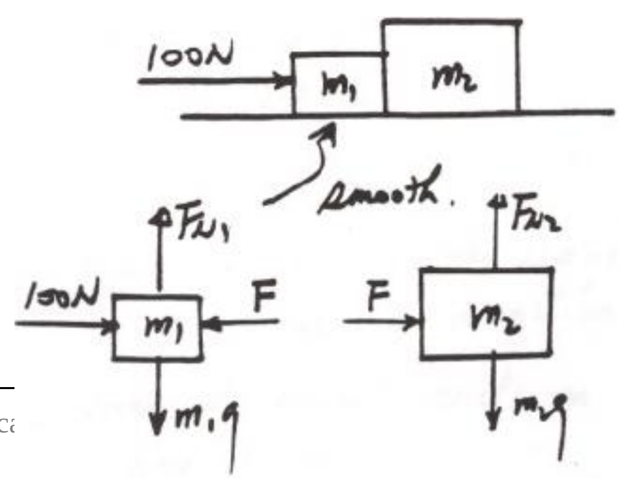
For bloc 2, from (6): $F_{N2} = m_2 g - P\sin\theta = 4 \cdot 9.81 - 30\sin 37 = 21.19\ N$
$f_{k2} = \mu_k F_{N2} = 0.2 \cdot 21.19 = 4.24N$

$\vec{F}_{Floor2} = -f_{k2}\hat{\imath} + F_{N2}\hat{\jmath} = (-4.24\hat{\imath} + 21.2\hat{\jmath})N$

We can verify our work with equation (5), to check whether $P\cos\theta - T - f_{k2} = m_e a$
$30\cos 37 - 9.18 - 4.24 = 4 \cdot 2.63 = 10.5N$, yay!

4.



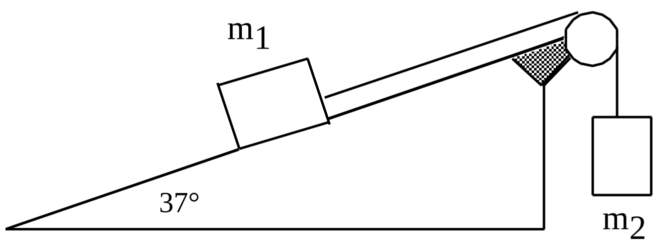


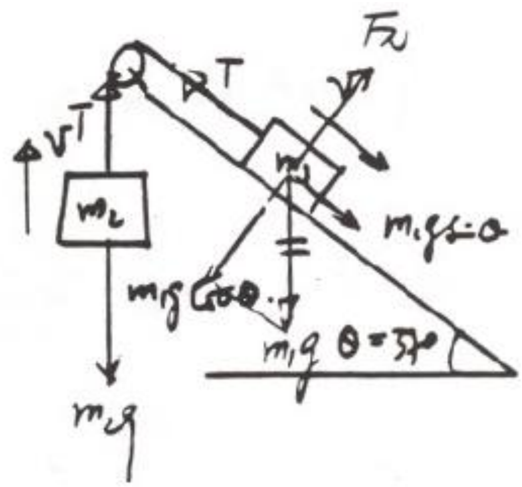
a) $\Sigma F_{x1} = 100 - F_{contact} = m_1 a$ (1)
$\Sigma F_{x2} = F_{contact} = m_2 a$ (2)

(1)+(2): $100 - m_2 a = m_1 a \rightarrow a = \frac{100}{m_2+m_1} = \frac{100}{10+5} = \boxed{6.67 m/s^2}$

b) from (2): $F_{contact} = m_2 a = \boxed{66.7N}$

5.



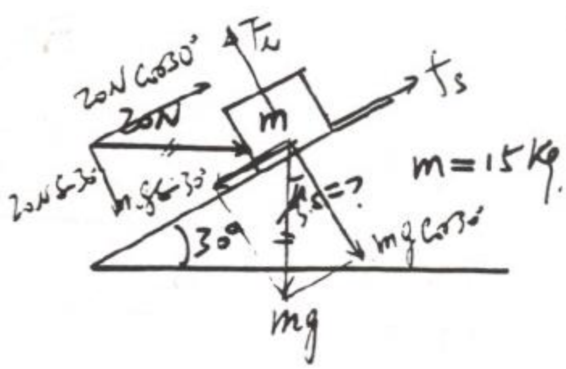


a) $\Sigma F_{x1} = -T + m_1 g \sin\theta = m_1 a$ (1)
$\Sigma F_{y1} = F_{N1} - m_1 g \cos\theta = 0$ (2)
$\Sigma F_{y2} = T - m_2 g = m_2 a$ (3)

from (1) + (3) :
$m_1 g \sin\theta - m_2 g = (m_1 + m_2)a \rightarrow a = \frac{m_1 g \sin\theta - m_2 g}{m_1+m_2} = \frac{3\cdot 9.81 \sin 37 - 10\cdot 9.81}{3+10} = \boxed{-6.2 m/s^2}$ the acceleration is the in opposite direction of the velocity

b) $v_f = v_i + a\Delta t \rightarrow \Delta t = t_f - t_i = t_f - 0 = \frac{v_f - v_i}{a} = \frac{0-3}{-6.2} = \boxed{0.485 s}$

6.



F_{ap} = 20N,
M = 15kg
θ = 30°

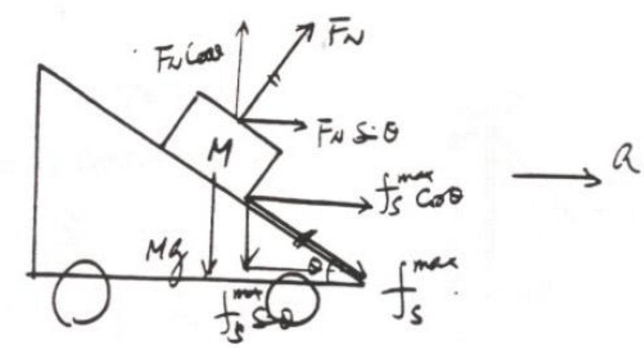
$$F_N = mg\cos\theta + F_{ap}\sin\theta$$
$$F_N = 15\cdot 9.81\cdot \cos 30 + 20 \sin 30 = 137.4N$$
$$F_{ap}\cos\theta + f_s = mg\sin\theta$$

$$f_s = mg\,sin\,\theta - F_{ap}\,cos\,\theta = 15 \cdot 9.81 \cdot sin\,3\,0 - 20\,cos\,3\,0$$
$$= 56.3N$$

$$56.3N = f_s \leq f_{s_{mac}} = \mu_s F_N \Rightarrow \mu_s \geq \frac{f_s}{F_N} = \frac{56.3}{137.4} = 0.409$$

the minimum of μ_s = 0.409

7.



a) $\Sigma F_y = F_N\,cos\,\theta - mg - f\,sin\,\theta_{smax}$ or $F_N\,cos\,\theta - \mu_s F_N\,sin\,\theta = mg$ (1)

$\Sigma F_x = f\,cos\,\theta_N\,sin\,\theta_{smax}$
or $\mu_s F_N\,cos\,\theta + F_N\,sin\,\theta = ma$ (2)

(2)/(1):

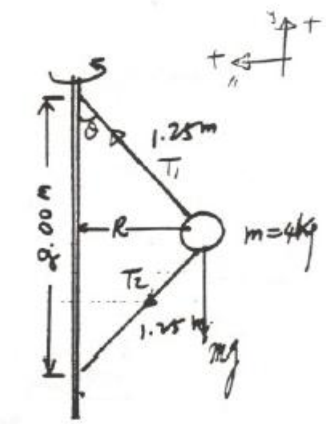
$$\frac{\mu_s\,cos\,\theta + sin\,\theta}{cos\,\theta - \mu_s\,sin\,\theta} = \frac{a}{g} \rightarrow a = \frac{\mu_s\,cos\,\theta + sin\,\theta}{cos\,\theta - \mu_s\,sin\,\theta} g$$
$$= \frac{0.5\,cos\,3\,0 + sin\,3\,0}{cos\,3\,0 - 0.5\,sin\,3\,0} 9.81 = 14.8m/s^2$$

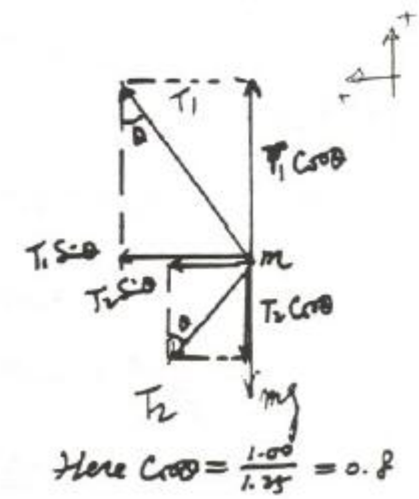
b) from (1): $F_N = \frac{mg}{cos\,\theta - \mu_s\,sin\,\theta} = \frac{49.1}{cos\,30 - 0.5\,sin\,30} = 79.6N$

8.

The radius of rotation is $R = \sqrt{1.25^2 - 1^2} = 0.75m$

$cos\,\theta = \frac{1}{1.25} = 0.8$ and $sin\,\theta = \frac{0.75}{1.25} = 0.6$





a) total vertical force should be zero

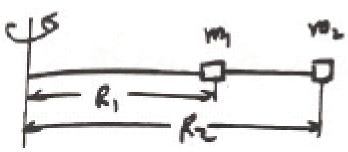
$$\Sigma F_y = T_1 \cos\theta - T_2 \cos\theta - mg = 0 \rightarrow T_2 = \frac{T_1 \cos\theta - mg}{\cos\theta} = \frac{60(0.8) - 4\cdot 9.81}{0.8} = \boxed{11N}$$

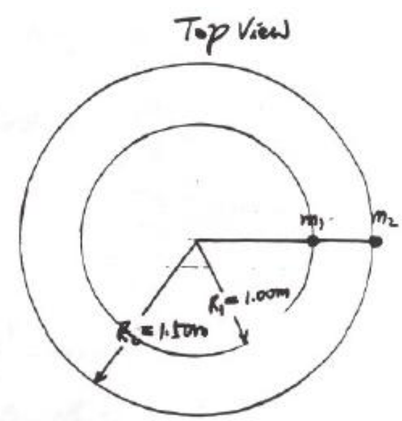
b) the magnitude of the centripetal force:

$$\Sigma F_x = T_1 \sin\theta + T_2 \sin\theta = ma_c = m\frac{v^2}{R}$$

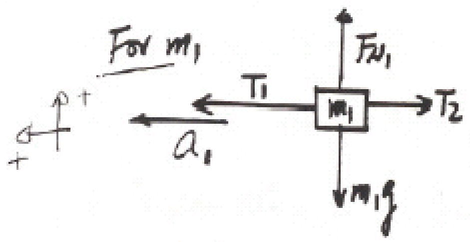
$$v = \sqrt{\frac{R(T_1 \sin\theta + T_2 \sin\theta)}{m}} = \sqrt{\frac{0.75(60(0.6) + 11(0.6))}{4}} = \boxed{2.83m/s}$$

9.





a) for m_1 :

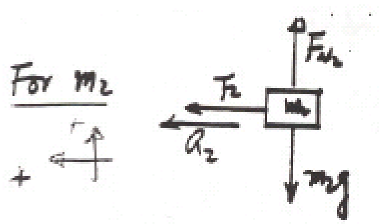


$\Sigma F_{x1} = T_1 - T_2 = m_1 a_{c1} = m_1 \frac{v_1^2}{R_1}$ (1)

$\Sigma F_{y1} = F_{N1} - m_1 g = 0$ (2)

for m2 :

$\Sigma F_{x2} = T_2 = m_2 a_{c2} = m_2 \frac{v_2^2}{R_2}$ (3)



$\Sigma F_{y2} = F_{N2} = m_2 g$ (4)

if v_2 = 3m/s then from (3):

$$T_2 = m_2 \frac{v_2^2}{R_2} = 3\frac{3^2}{1.5} = \boxed{18N}$$

b) $v_1 = \omega R_1$ and $v_2 = \omega R_2$ therefore:

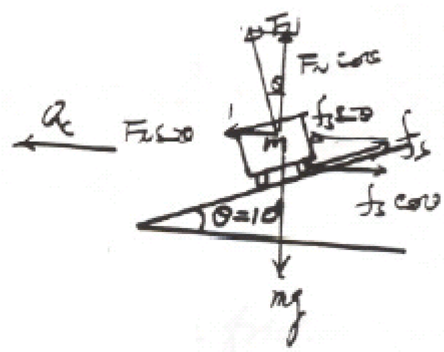
$\frac{v_1}{v_2} = \frac{R_1}{R_2} \rightarrow v_1 = \frac{v_2 R_1}{R_2} = \frac{3 \cdot 1}{1.5} = \boxed{2m/s}$

Or from (1) $v_1^2 = \frac{R_1(T_1 - T_2)}{m_1} = \frac{1.0(26-18)}{2.0} = 4m^2/s^2$

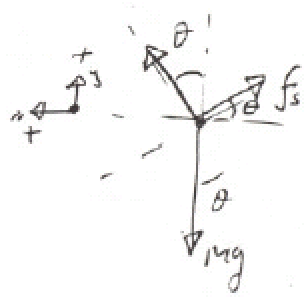
$$v_1 = \boxed{2m/s}$$

10.

a) If the speed is low, the car tends to slip down. The vertical force should be zero.



$\Sigma F_y =$
$f_{fs} \sin\theta -$
$\Sigma F_x =$
$f_{fs} \cos\theta =$



$F_N \cos\theta +$
$mg = 0$ (1)
$F_N \sin\theta -$
$ma_c = m\frac{v^2}{R}$ (2)

the larger
force (f_{fs}),
speed v. For

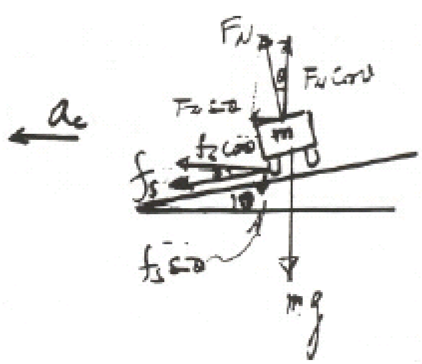
the static friction
the smaller the
maximum static

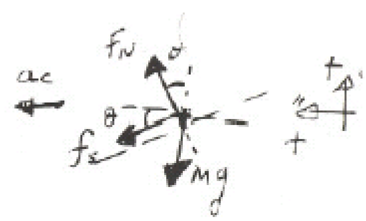
friction, v is minimum.

From (2) $F_N \sin\theta - \mu_s F_N \cos\theta = m\frac{v_{min}^2}{R}$ (3)
From (1) $F_N \cos\theta + \mu_s F_N \sin\theta = mg$ (4)

(3)/(4): $\frac{\sin\theta - \mu_s \cos\theta}{\cos\theta + \mu_s \sin\theta} = \frac{v_{min}^2}{R\frac{\sin 10 - 0.1\cos 10}{\cos 10 + 0.1 sn10}\;\frac{v_{min}^2}{10\cdot 100\,\boxed{8.66 m/s}}_{min}}$

b) If the speed is high, the car tends to slip up. The vertical force should be zero.





$\Sigma F_y = F_N \cos\theta - f_{fs} \sin\theta - mg = 0$ (1)
$\Sigma F_x = F_N \sin\theta + f_{fs} \cos\theta = ma_c = m\frac{v^2}{R}$ (2)

the larger the static friction force (f_{fs}), the larger the speed v. For maximum static friction, the speed is maximum.

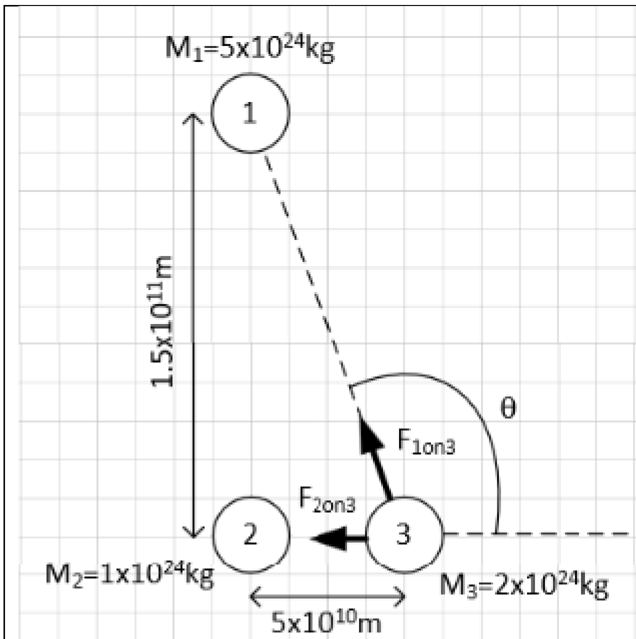
From (2) $F_N \sin\theta + \mu_s F_N \cos\theta = m\frac{v_{max}^2}{R}$ (3)
From (1) $F_N \cos\theta - \mu_s F_N \sin\theta = mg$ (4)

(3)/(4): $\frac{\sin\theta+\mu_s\cos\theta}{\cos\theta-\mu_s\sin\theta} = \frac{v_{min}^2}{R\frac{\sin 10+0.1\cos 10}{\cos 10-0.1sn10}\frac{v_{min}^2}{10\cdot 100\boxed{16.8m/s}_{min}}}$

the range of speeds the car can have without slipping up or down:

$$\boxed{8.66m/s \le v \le 16.8m/s}$$

11.



Solution

First let's draw the force that planet 2 exerts on planet 3 and the force that planet 1 exerts on planet 3.

We'll need to find the forces, split them into components and add them up.

Let's start with $\vec{F}_{2on3}$

$$|\vec{F}_{2on3}| = G\frac{m_2 m_3}{r_{23}^2}$$

$$|\vec{F}_{2on3}| = 6.67\cdot 10^{-11}\frac{1\cdot 10^{24}\cdot 2\cdot 10^{24}}{(5\cdot 10^{11})^2}$$

$$|\vec{F}_{2on3}| = 5.96\cdot 10^{15}N$$

$$\vec{F}_{2on3} = (-5.96\cdot 10^{15}\hat{\imath} + 0\hat{\jmath})N$$

Now let's find $\vec{F}_{1on3}$

$$|\vec{F}_{1on3}| = G\frac{m_1 m_3}{r_{13}^2}$$

$$|\vec{F}_{1on3}| = 6.67\cdot 10^{-11}\frac{5\cdot 10^{24}\cdot 2\cdot 10^{24}}{(1.5\cdot 10^{11})^2 + (1\cdot 10^{11})^2} = 2.68\cdot 10^{16}N$$

$$\vec{F}_{1on3} = |\vec{F}_{1on3}|cos\theta\hat{\imath} + |\vec{F}_{1on3}|sin\theta\hat{\jmath}$$

There are 2 methods for splitting this force into components

Method 1: Find the angle, and use the angle to split the force into components

$$\theta = 180° - tan^{-1}\left(\frac{1.5\cdot 10^{11}}{5\cdot 10^{10}}\right) = 180° - \tan^{-1}(3) = 108.4°$$

$$\vec{F}_{1on3} = 2.68\cdot 10^{16} cos108.4° + 2.68\cdot 10^{16} sin108.4°\hat{\jmath}$$

$$\vec{F}_{1on3} = (-8.46\cdot 10^{15}\hat{\imath} + 2.54\cdot 10^{16}\hat{\jmath})N$$

Method 2: calculate cosθ and sinθ directly

$$cos\theta = \frac{adjacent}{hypothenuse}$$

$$cos\theta = \frac{-5\cdot 10^{10}}{\sqrt{(1.5\cdot 10^{11})^2 + (5\cdot 10^{10})^2}} = -0.316$$

$$sin\theta = \frac{opposite}{hypothenuse}$$

$$sin\theta = \frac{1.5\cdot 10^{10}}{\sqrt{(1.5\cdot 10^{11})^2 + (5\cdot 10^{10})^2}} = 0.949$$

$$\vec{F}_{1on3} = 2.68\cdot 10^{16}\cdot(-0.316)\hat{\imath} + 2.68\cdot 10^{16}\cdot(0.949)\hat{\jmath}$$

$$\vec{F}_{1on3} = (-8.46\cdot 10^{15}\hat{\imath} + 2.54\cdot 10^{16}\hat{\jmath})N$$

Add the forces together by adding the components

$$\vec{F}_{1on3} + \vec{F}_{2on3} = (-8.46\cdot 10^{15}\hat{\imath} + 2.54\cdot 10^{16}\hat{\jmath}) + (-5.96\cdot 10^{15}\hat{\imath} + 0\hat{\jmath})N$$

$$\vec{F}_{1on3} + \vec{F}_{2on3} = (-1.44\cdot 10^{16}\hat{\imath} + 2.54\cdot 10^{16}\hat{\jmath})N$$

Calculate the vector in polar form, i.e. magnitude and direction

$$\left|\vec{F}_3\right| = \sqrt{(-1.44\cdot 10^{16})^2 + (2.54\cdot 10^{16})^2} = 2.92\cdot 10^{16}N$$

$$\theta_3 = 180° - tan^{-1}\left(\frac{2.54\cdot 10^{16}}{1.44\cdot 10^{16}}\right) = 120°$$

12.

Since the problem in problem set 1 was about a baseball, we will consider the force of gravity on a baseball on Mars (but obviously, the force on any object will do since the mass of the object on the surface cancels out in the calculation)

$$F_{gravity,Mars} = m_{ball}g_{Mars}$$

$$G\frac{m_{ball}m_{Mars}}{r_{Mars}^2} = m_{ball}g_{Mars}$$

$$G\frac{m_{Mars}}{r_{Mars}^2} = g_{Mars}$$

$$g_{Mars} = 6.67\cdot 10^{-11}\frac{6.42\cdot 10^{23}}{(3\,390\cdot 10^3)^2} = 3.73\frac{m}{s^2}$$