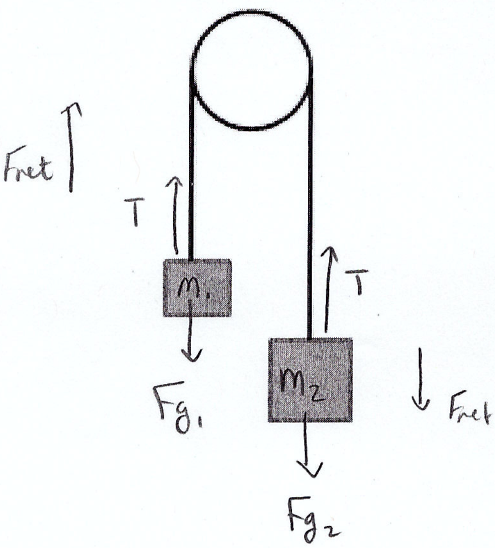
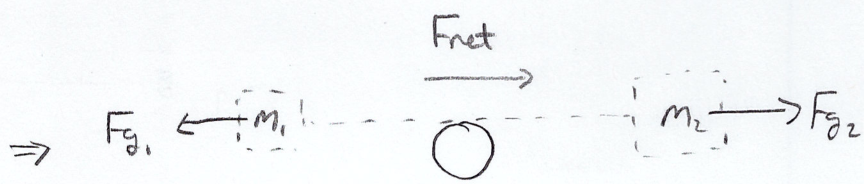
Systems and Pulleys

- A ***system*** is when two or more masses are all connected to each other
  - ✳ Applying a force to one object will cause all objects to accelerate in the same direction with the same magnitude

- For any system and any other force problem, it is necessary to draw a free-body diagram
- When creating a force net equation, imagine the problem to be horizontal by swinging out the masses and the forces attached to those masses.
  - This is just a strategy to solve the problems, it is not the actual free-body diagram

Atwood's Machine

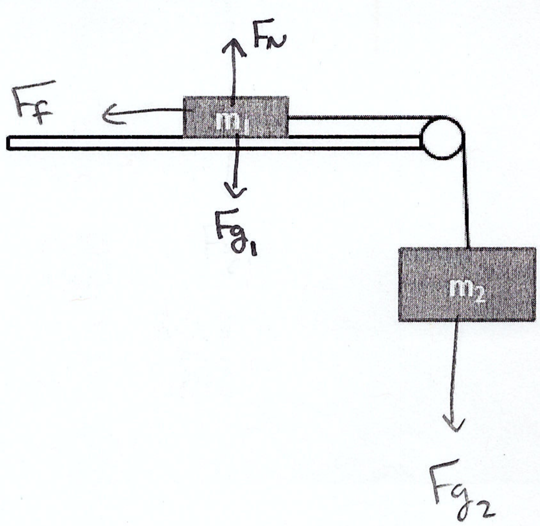


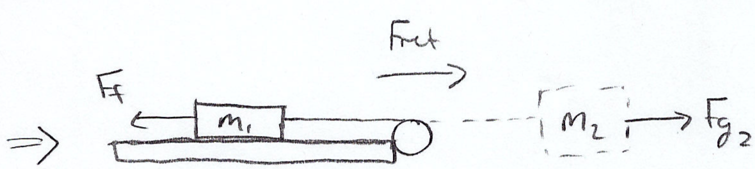


* Fnet always points toward heavier mass! *

$$F_{net} = F_{g2} + (-F_{g1})$$

Fletcher's Trolley



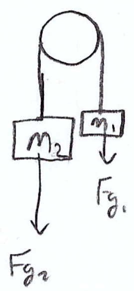


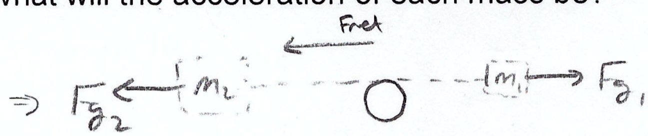
* Fnet always points toward overhanging mass * !

$$F_{net} = F_{g2} + (-F_f)$$

EXAMPLES:

1. Two spheres of masses 2.6 kg and 4.1 kg are tied together by a light string looped over a frictionless pulley.
   a. What will the acceleration of each mass be?





$\therefore \quad F_{net} = F_{g_2} + (-F_{g_1})$

$$m_{total}\, a = m_2 g - m_1 g$$

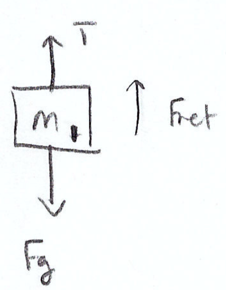
$$a = \frac{m_2 g - m_1 g}{m_{total}} = \frac{(4.1\,kg)(9.81\,m/s^2) - (2.6\,kg)(9.81\,m/s^2)}{(2.6\,kg + 4.1\,kg)}$$

$$a = 2.196\ldots\ m/s^2$$

$$\boxed{\begin{array}{l} m_1:\ a = 2.2\,m/s^2,\ \text{up} \\ m_2:\ a = 2.2\,m/s^2,\ \text{down} \end{array}}$$

   b. What is the magnitude tension in the string?

* only look at one mass * !



$$F_{net} = T + (-F_g)$$

$$F_{net} + F_g = T$$

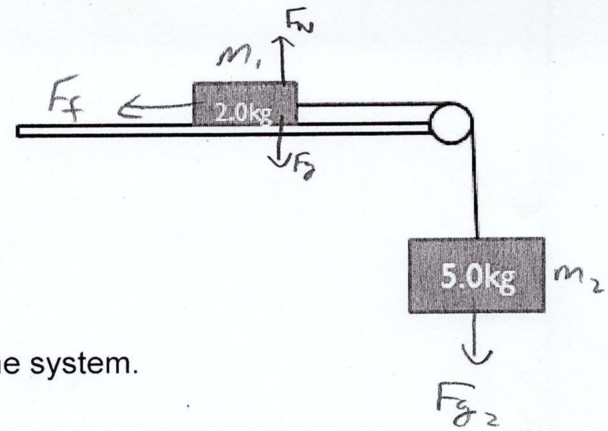
$$m_1 a + m_1 g = T$$

$$(2.6\,kg)(2.196\ldots\,m/s^2) + (2.6\,kg)(9.81\,m/s^2) = T$$

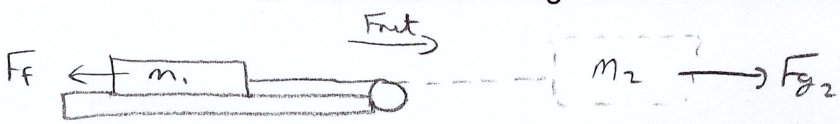
$$31.216\ldots\ N = T$$

$$\boxed{31\,N = T}$$

2. A 2.0 kg mass placed on a level table and is attached by a string passing over the edge of a table as illustrated in the diagram. The coefficient of friction between the 2.0kg mass and the table surface is 0.12.



a. Calculate the magnitude of acceleration of the system.



$\therefore F_{net} = F_{g2} + (-F_f)$

$m_t a = m_2 g - \mu F_N$

$a = \dfrac{m_2 g - \mu F_N}{m_t}$

$a = \dfrac{(5.0kg)(9.81 m/s^2) - (0.12)(19.62 N)}{(5.0kg + 2.0kg)}$

$a = 6.67\ldots m/s^2$

$\boxed{a = 6.7 m/s^2}$

Vertical on mass 1

$\underbrace{\cancel{F_{net}}}_{0.0N} = F_N + (-F_{g1})$

$F_{g1} = F_N$

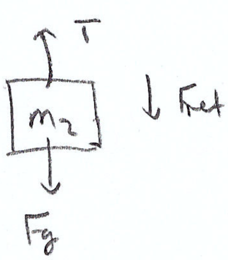
$m_1 g = F_N$

$(2.0kg)(9.81 m/s^2) = F_N$

$19.62 N = F_N$

b. Calculate the tension in the string.

* only look at one mass! *



$F_{net} = F_g + (-T)$

$T = F_g - F_{net}$

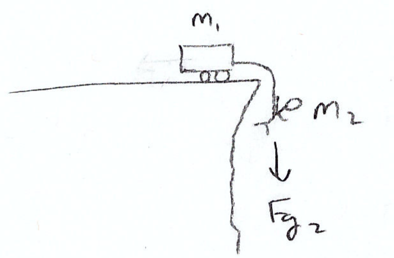
$T = m_2 g - m_2 a$

$T = (5.0kg)(9.81 m/s^2) - (5.0kg)(6.67\ldots m/s^2)$

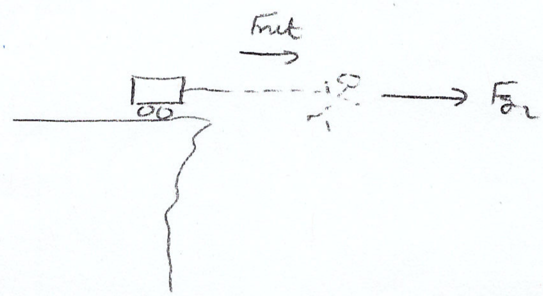
$T = 15.696 N$

$\boxed{T = 16 N}$

3. A 3000 kg truck is on a cliff and is tied with a rope to a 78.0 kg person hanging over the cliff. If the cliff is very icy (frictionless), what is the magnitude of acceleration of the system?



$\Rightarrow$



$\therefore F_{net} = F_{g_2}$

$m_t a = m_2 g$

$a = \dfrac{m_2 g}{m_t}$

$a = \dfrac{(78.0\,kg)(9.81\,m/s^2)}{(78.0\,kg + 3000\,kg)}$

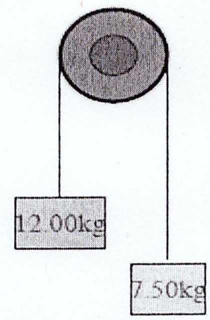
$a = 0.2485...\,m/s^2$

$\boxed{a = 0.249\ m/s^2}$

*****Now try pg. 94 #15 - 19 (#19 challenger) & worksheet*****

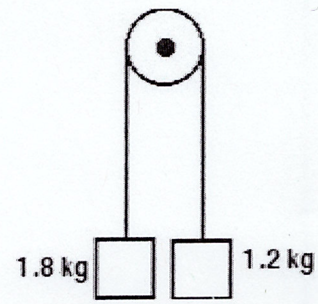
Pulley Systems: Worksheet

1.) Determine the magnitude of acceleration of each mass.
[2.26m/s^2]

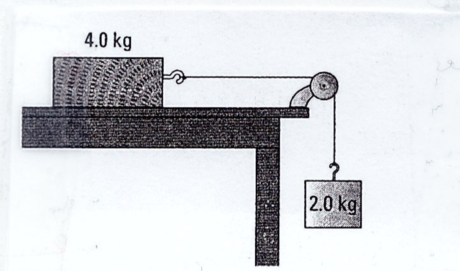


2.) The diagram shows a 1.8kg mass and a 1.2kg mass suspended by a vertical pulley.

a. Determine the magnitude of the acceleration of each mass. **[1.96m/s^2]**
b. Determine the tension in the rope. **[14.1 N]**



3.) A 4.0kg oak block on a horizontal, rough oak surface is attached by a light string that passes over a light, frictionless pulley to a hanging 2.0kg object. The magnitude of the force of friction on the 4.0kg block is 11.8N.



a. Calculate the magnitude of acceleration of the system. **[1.3 m/s^2]**
b. Calculate the tension in the string. **[17 N]**

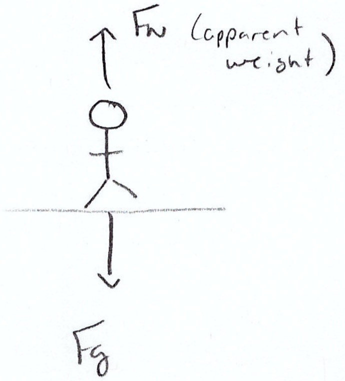
4.) A 6.70kg block on a horizontal, rough surface is attached by a light string that passes over a light, frictionless pulley to a hanging mass of 10.5kg. If the system is accelerating at 3.15m/s^2, what is the coefficient of friction between the block and the horizontal surface? **[0.743]**

Vertical Dynamics

- We can use dynamics and Newton's second law to solve vertical questions in addition to horizontal problems which we have seen up to now
- Recall that weight is the same or equal to F_g and $F_g=mg$
- When an object accelerates in the vertical direction, it experiences a change in *weight*
    - This is called "**apparent weight**"
    - Apparent weight can also be called tension, applied force, or force apparent   or F_N on a surface!
    - This change in weight is due to the fact that the acceleration of the object is no longer $9.81 m/s^2$, but either increased or decreased
- Remember, that dynamic/force problems usually always need a free-body diagram and a F_{net} equation

EXAMPLE: Draw a free body diagram and create a force net equation for

- an elevator that is stopped. This will be the same for an elevator that is moving up or down with uniform motion.



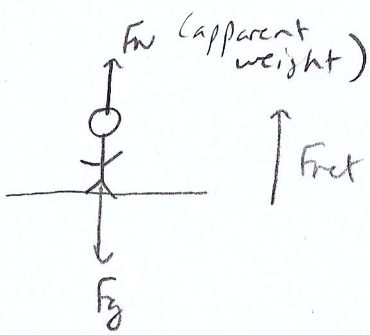
$$\underbrace{\cancel{F_{net}}}_{0.0_N} = F_N + (-F_g)$$

*no acceleration

$$F_g = F_N$$

$\therefore$ real weight = apparent weight.

- an elevator that is accelerating up.



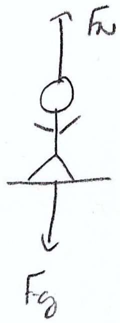
$$F_{net} = F_N + (-F_g)$$

F_N or T

EXAMPLES:

1. A 75.0kg person is in an elevator. What is the apparent weight of the student if the elevator is

   a. moving up at a constant velocity.



$m = 75.0\,kg$

$g = 9.81\,m/s^2$

$F_N = ?$

$$F_{net} = F_N + (-F_g)$$

0 b/c no acceleration

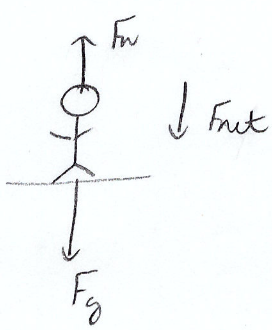
$$F_g = F_N$$

$$mg = F_N$$

$$(75.0\,kg)(9.81\,m/s^2) = F_N$$

$$\boxed{736\,N = F_N}$$

   b. accelerating down at 0.750m/s^2.



* let down be positive!

$$F_{net} = F_g + (-F_N)$$

$$ma = mg - F_N$$

$$F_N = mg - ma$$

$$F_N = (75.0\,kg)(9.81\,m/s^2) - (75.0\,kg)(0.750\,m/s^2)$$

$$\boxed{F_N = 680\,N}$$

$a = 0.750\,m/s^2$

$g = 9.81\,m/s^2$

$m = 75.0\,kg$

$F_N = ?$

* acceleration down $\Rightarrow$ apparent weight is <u>less</u>!

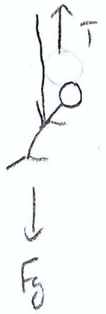
Great Test Question!

*

2. A person who is rock climbing and is tethered to a rope, has a weight of 600 N. At one point of the person's journey, she has an apparent weight of 585 N. What is the acceleration of the rock climber at this point on her journey?

$\nearrow F_g$

$\searrow T$



* down is positive! *

? $\downarrow F_{net}$

b/c $T < F_g$

$F_{net} = F_g - T$

$ma = F_g - T$

$a = \dfrac{F_g - T}{m}$

$F_g = 600\,N$

$T = 585\,N$

$a = ?$

$F_g = mg$

$\dfrac{F_g}{g} = m$

$\dfrac{600\,N}{9.81\,m/s^2} = m = 61.162...\,kg$

$a = \dfrac{600\,N - 585\,N}{(61.162...\,kg)}$

$a = 0.2452...\,m/s^2$

$\boxed{a = 0.245\,m/s^2\text{, down}}$

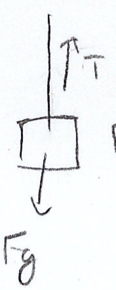
3. A crane is used to lift a car up into the air. The car has an apparent weight of 12000 N while it is accelerating up at 0.850m/s^2. What is the mass of the car?

$\swarrow T$

$T = 12000\,N$

$a = 0.850\,m/s^2$

$m = ?$



$F_{net} = T + (-F_g)$

$ma = T - mg$

$ma + mg = T$

$m(a + g) = T$

$m = \dfrac{T}{(a+g)}$

$m = \dfrac{12000\,N}{(0.850\,m/s^2 + 9.81\,m/s^2)}$

$m = 1125.7...\,kg$

$\boxed{m = 1.13 \times 10^3\,kg}$

*****Now try pg. 88 #3a,b,e,f, 4a-d, 5-9, 13*****