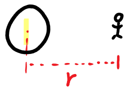
Dynamics Note Part 2

November 16, 2016 8:39 AM

$F_g = mg$ (near the surface of a planet)



Unit 2 Part 2: Forces

Note 1: **Newton`s Universal Law of Gravitation**

Gravity... attracts any two objects depending on their
1. masses
2. distance apart.

Newton`s Law of Universal Gravitation states:

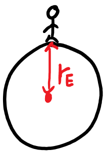
$$F_g = \frac{GMm}{r^2}$$

Where:
G = gravitational constant.
= $6.67 \times 10^{-11}\ Nm^2/kg^2$
M = mass (kg) of 1st obj.
m = mass of 2nd obj.
r = distance between centres of mass (m)

Ex 1: What is the force of gravity exerted on a 70.0 kg astronaut that is standing on Earth's surface?

Radius of Earth = 6.38×10^6 m

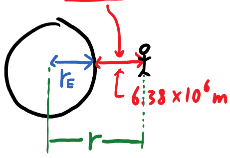
Mass of Earth = 5.98×10^{24} kg



$$F_g = \frac{GMm}{r^2} = \frac{6.67\times10^{-11}(5.98\times10^{24}kg)(70)}{(6.38\times10^6)^2}$$

$= 686\ N$

Ex 2: What is the force of gravity acting on a 70.0 kg astronaut who is at an ***altitude*** of 6.38×10^6 m?

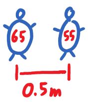


$r = r_E + alt$
$= 6.38\times10^6 + 6.38\times10^6$
$= 1.276\times10^7\ m$

$$F_g = \frac{6.67\times10^{-11}(5.98\times10^{24})(70)}{(1.276\times10^7)^2}$$

$F_g = 171\ N$

Ex 3: Two physics lab partners sit side by side. One has a mass of 55 kg and the other a mass of 65 kg. If they sit 50.0 cm apart, what is the irresistible force of attraction between them?



$$F_g = \frac{GMm}{r^2}$$

$$F_g = \frac{6.67\times10^{-11}(65)(55)}{(0.5)^2}$$

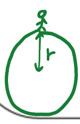
$F_g = 9.54 \times 10^{-7}\ N$ too small to notice

$= 0.000000954\ N$

A typical problem type...

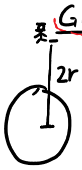
An astronaut weighs 800 N on Planet X. How much would she weigh if she was at an altitude equal to the radius of Planet X?

old: $F_g = \frac{GMm}{r^2} = 800N$



New: $F_g = \frac{GMm}{(2r)^2}$

$= \frac{GMm}{4r^2}$ ← 800N



$= \frac{800N}{4}$

$= 200N$

A spaceship orbits a planet at radius, r and weighs 10 000N. How much would it weigh if it orbits a planet twice as massive at half the radius?

old: $F_g = \frac{GMm}{r^2} = 10{,}000\ N$

New: $M_{new} = 2M$
$r_{new} = \frac{1}{2}r$

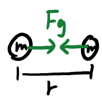
$$F_g = \frac{G(2M)m}{(\frac{1}{2}r)^2} = \frac{2}{(\frac{1}{4})}\frac{GMm}{r^2}$$

(old = 10000 N)

$= \frac{2\times 10000}{\frac{1}{4}} = 80{,}000\ N$

WS 5.1

Force of Gravity: $F_g = mg$ $\quad F_g = \frac{GMm}{r^2}$



Force of Gravity: $F_g = mg$ $F_g = \frac{GMm}{r^2}$
(Weight)

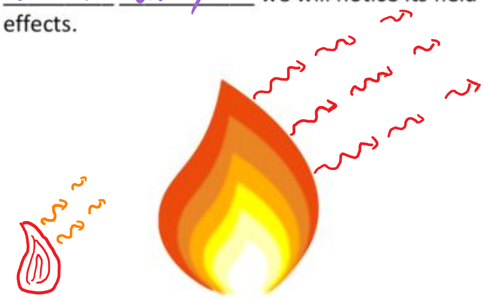
Note 2: Gravitation field strength (g)

To help explain how two bodies that are not in contact can exert a force on one another (i.e. gravitational, magnetic or electrostatic) we use the concept of __field__.

Fields are spheres of influence. They are __invisible__ and __intangible__; they simply demonstrate how strong a characteristic is at a certain distance.

Consider a campfire. We can think of it as having a __Heat__ *field*. The __closer__ we get to the fire, the __stronger__ the field becomes.

Likewise, the __larger__ the fire is, the __further away__ we will notice its field of effects.



To represent this force field around earth, we draw vectors of force pointing towards earth's centre. Their __magnitude__ (length of field line) indicate that the field becomes __weaker__ as the distance from earth's centre __increases__.

Gravitational fields are defined as: accel due to gravity / gravitational field

$$g = \frac{GM}{r^2}$$

$$mg = \frac{GMm}{r^2}$$

Notice that its units are in N/kg or m/s^2

Ex 1

The Earth is not actually a perfect sphere. Just like a spinning basketball, it is an ***oblate spheroid*** … or kinda bulgy in the middle.

Calculate the acceleration due to gravity:

a) At the North Pole (r = 6.370x10^6 m)

b) At the Equator (r = 6.386x10^6 m)

a) $g = \frac{GM}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24}\ kg)}{(6.37\times10^{6})^2}$

$g = 9.83\ m/s^2$ or N/kg North Pole.

b) $g = 9.78\ m/s^2$ Equator

Ex 2

The moon is 385 000 km away from the Earth's surface. What is the Earth's gravitational field strength at this distance?

385000 km

$r = 6.37\times10^6\ m + 385000\,000\ m = 3.9137\times10^8\ m$

$g = \frac{GM}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24}\ kg)}{(3.9137\times10^8)^2} = 2.6\times10^{-3}\ m/s^2 = 0.0026\ m/s^2$

HW WS #2

Note 3: Force of Friction

F_N, F_f, F_a, F_g

Friction is created whenever... two surfaces move past each other.

Friction is created whenever... two surfaces move past each other.

On the microscopic level... irregularities in the two surfaces catch on each other.

Friction is given by the equation:

$$F_f = \mu F_N$$

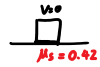
(N) (N)

Where:

F_N = Normal Force
= always ⊥ to surface.

μ = coefficient of Friction (no unit)
= greek letter "myu"
= depends on the surfaces.

Static Friction: friction force on a stationary object.



Kinetic Friction: friction on a moving object

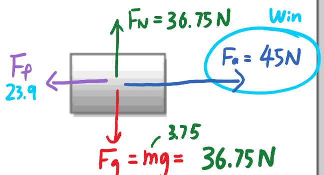
Friction$_{static}$ Friction$_{kinetic}$

$\mu_{static} > \mu_{kinetic}$

Ex 1: A 3.75 kg block is pushed along a tabletop with a force of 45.0N. The coefficient of friction is 0.65.

a) Find the force of friction.

b) Find the acceleration.



a) $F_f = \mu F_N = (0.65)(36.75) = \boxed{23.9 \text{ N}}$

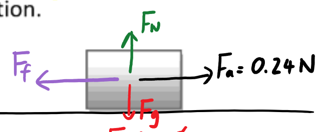
b) $\boxed{F_{net} = F_a - F_f}$

$ma = 45\text{N} - 23.9\text{N}$

$(3.75)\,a = 21.1$

$\boxed{a = 5.63 \text{ m/s}^2}$

Ex 2: A 0.200 kg puck is pushed along a sheet of ice with a force of 0.240 N. If it moves at a constant velocity, find the coefficient of friction.



$a = \emptyset \rightarrow F_{net} = \emptyset$

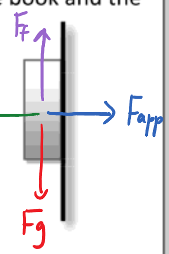
$F_f = F_a = 0.24$N

$F_N = F_g = mg = (0.2)(9.8) = \boxed{1.96 \text{ N}}$

$F_f = \mu F_N \quad \mu = \frac{F_f}{F_N} = \frac{0.24}{1.96}$

$\boxed{\mu = 0.122}$

Ex 3: A 1.1 kg textbook is held against a vertical wall with a force of 45 N. What is the coefficient of friction between the book and the wall?



$F_N = F_{app} = 45$N

$F_f = F_g = mg$

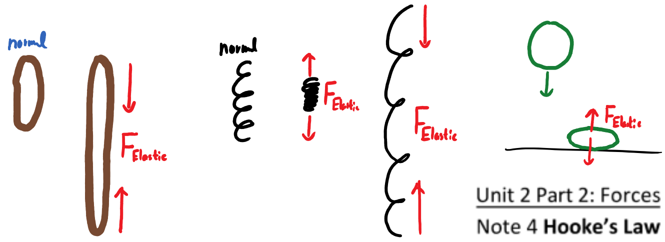
$F_f = (1.1)(g)$

$F_f = 10.78$N

$\mu = \frac{F_f}{F_N} = \frac{10.78}{45}$

$\boxed{\mu = 0.24}$

HW: WS #3 Force of Friction.



Unit 2 Part 2: Forces

Note 4 **Hooke's Law**

$F_{Elastic}$: A force that work to return a distorted object to it equilibrium (rest) position.

Examples: elastics, springs, bouncy ball, trampoline, bungee cord, hockey stick.

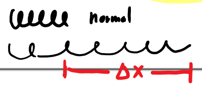
Hooke's Law:

Where:

(rest) position.

Hooke's Law:

The amount of restoring (elastic) Force is proportional the amount of distortion.



$$F_s = k\Delta x$$

$F_s = k\Delta L$

Where:

k (N/m) = spring constant = how stiff the spring is

Δx (m) = distortion from Equilibrium.

Ex:

A student stretches an elastic band with a spring constant of 50.0 N/m by 15 cm. How much force are they applying?

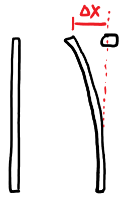
15 cm → 0.15 m

$F_s = k\Delta x$

$F_s = (50 N/m)(0.15 m) = \boxed{7.5 N}$

Ex:

Al McInnis uses a wooden stick with a spring constant of 850 N/m. What is the distortion on the stick if he exerts 525 N while taking a slapshot?



$F_s = k\Delta x$

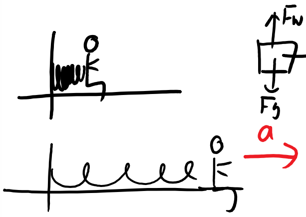
$\Delta x = \frac{F_s}{k} = \frac{525 N}{850 N/m}$

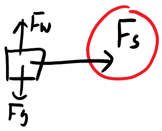
$N \div \frac{N}{m}$ → $N \times \frac{m}{N}$

$\boxed{\Delta x = 0.62 m}$

Ex:

A 65 kg girl sits in a redneck sling shot that has a spring constant of 10.5 N/m. If the sling is stretched by 45 m, what is her *initial* acceleration when released?



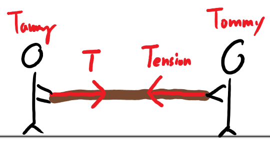


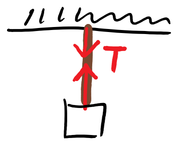
$F_{net} = F_s$

$ma = k\Delta x$

$a = \frac{k\Delta x}{m} = \frac{10.5 (45 m)}{65 kg} = \boxed{7.3 m/s^2}$

WS: #4 Elastic/Spring.





Unit 2 Part 2: Forces

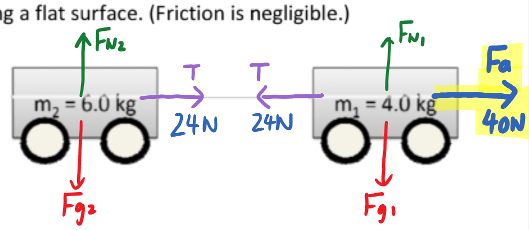
Note 5 Tension

Tension occurs within a material that is being... pulled or stretched.

It is an internal force that acts at all part along a rope (string, chain, etc) in both directions.

Consider two carts attached by a rope being pulled along a flat surface. (Friction is negligible.)

If m_1 is pulled to the right by a force of 40.0 N find:



a) The acceleration of the carts.

$F_{net\ sys} = F_a$

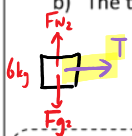
$M_T a = 40N$

$(6kg + 4kg)\,a = 40N \rightarrow a = 4\,m/s^2$

$F_{net\ sys} = M_T a$ for both boxes.

NOTE: tension... Cancels out of the $F_{net\ sys}$ Eq.

b) The tension in the string connecting them.



$F_{net} = T$

$ma = T$

$(6kg)\,a = T$

$T = 6kg \times 4\,m/s^2$

$T = 24N$

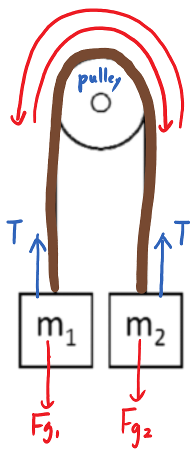
NOTE: Since it cancels out of the total F_{net} equation, we will only consider the forces acting... on one mass

NOTE: Since tension acts on both masses equally we can use... either mass.

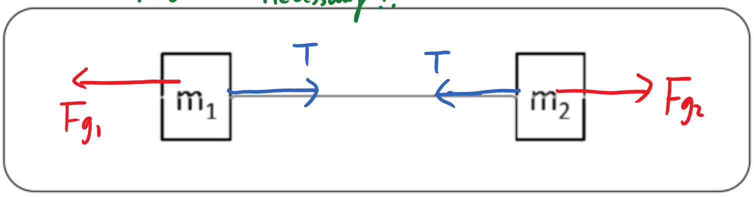
Consider two equal masses hanging from a pulley.

Diagram the forces acting on the entire system.

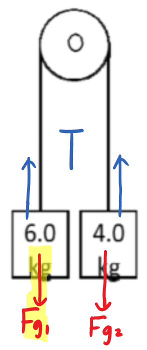
With pulley problems it is sometime easier to "*unfold*" the rope as shown.

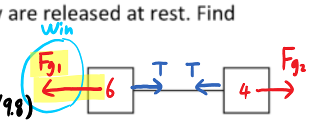


Not necessary!!



Ex: The two masses shown hanging from a frictionless pulley are released at rest. Find





a) The acceleration of the system.

$F_{net\,sys} = F_{g1} - F_{g2}$

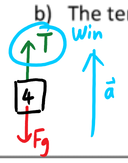
$M_T a = m_1 g - m_2 g$

$(6kg + 4kg)\,a = 6(9.8) - 4(9.8)$

$10\,a = 19.6$

$\boxed{a = 1.96\ m/s^2}$ down for 6kg box, up for 4kg box

b) The tension in the string.



$F_{net\,box} = T - F_g$

$ma = T - mg$

$T = ma + mg$

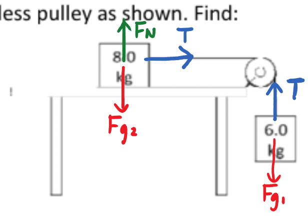
$T = m(a + g)$

$T = (4)(1.96 + 9.8) = \boxed{47N}$

NOTES: 1. When solving for acceleration of the whole system we consider total mass

2. When finding T we only use One mass.

Ex: A mass on a frictionless table is attached to a hanging mass over a frictionless pulley as shown. Find:



a) The acceleration of the masses.

$F_{net\,sys} = F_{g1}$

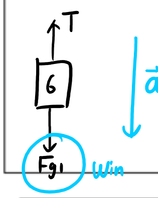
$M_T a = m_1 g$

$(8kg + 6kg)\,a = (6kg)\,9.8$

$14\,a = 58.8$

$\boxed{a = 4.2\ m/s^2}$ [8] right

b) The tension in the rope.



$F_{net\,box} = F_{g1} - T$

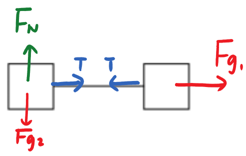
$ma = mg - T$

$T = mg - ma$

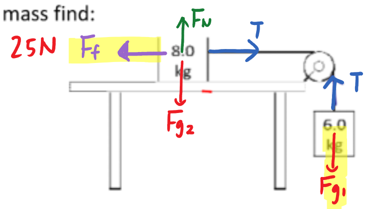
$T = m(g - a)$

$T = 6kg\,(9.8 - 4.2)$

$T = 33.6\ N$



Ex2: If the same system has a friction force of 25 N acting on the 8.0 kg mass find:



a) The acceleration of the masses.

$F_{net\,sys} = F_{g1} - F_f$

$M_T a = mg - 25$

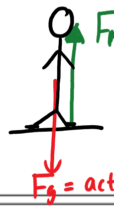
$14\,a = 58.8 - 25$

$a = \boxed{2.4\ m/s^2}$

b) The tension in the rope.

$\boxed{44N}$

WS # 5



Unit 2 Part 2: Newton's Laws

Note 6 - Elevators and Apparent Weight

When a person is accelerating upwards or downwards they can sometimes *feel* heavier or lighter than they actually are. Although their __actual__ weight (force of gravity) is the same, their __apparent__ weight differs. Apparent weight (how heavy we *feel*) is equal to the __normal__ force supporting us.

Mass + Spring Scale = Elevator

Describe **2 times** when the mass appears *heavier* than normal.

1) go ↑ from rest
2) go ↓ and stop

What can you summarize about the acceleration of the mass?

upward a ↑

Describe **2 times** when the mass appears *lighter* than normal.

1) go ↓ from rest
2) go ↑ and stop

What can you summarize about the acceleration of the mass?

downward a ↓

Describe **3 times** when the mass' apparent and actual weights are equal.

1) rest
2) up @ constant speed
3) down @ const. speed

What can you summarize about the acceleration of the mass?

$a = 0$

Ex 1: A 65 kg person in an elevator is traveling upwards at 5.0 m/s. What is their apparent weight?

$a = 0 \quad F_{net} = 0$

$F_g = F_N$

$F_N = mg$

$F_N = (65\,kg)(9.8)$

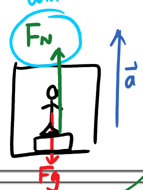
App. Weight = $\boxed{640\,N}$

Ex 2: The same 65 kg person is in an elevator that accelerates upwards at 4.9 m/s^2. What is their apparent weight?

$F_{net} = F_N - F_g$

$ma = F_N - mg$

$F_N = ma + mg$



$F_N = 65[4.9 + 9.8]$

$\boxed{F_N = 960\,N}$

feel heavier !!

Ex 3: The elevator reaches the top floor and decelerates at 4.9 m/s^2. What is their apparent weight?

$F_{net} = F_g - F_N$

$F_N = F_g - F_{net}$

$F_N = mg - ma$

$F_N = 65[9.8 - 4.9]$

$\boxed{F_N = 320\,N}$

Lighter

actual weight 640N

Try: An 85.0 kg person in an elevator goes from the top to the bottom floor. Find their apparent weight when they:

a) accelerate downwards at 3.00m/s^2?

$F_N = \boxed{578\,N}$

b) continue downward at a velocity of 12.0 m/s?

$F_{net} = 0$

$F_N = F_g = mg$

$F_N = \boxed{833\,N}$

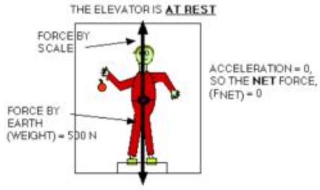
c) accelerate upwards at 3.00 m/s^2?

$F_N = \boxed{1090\,N}$

Scale reading = F_{Normal}

The Elevator Problem

Imagine that you are standing on a bathroom scale in an elevator. You are holding an apple. (Yes, people *are* staring at you...). You weigh 500 N, so your mass is about 50 kg.

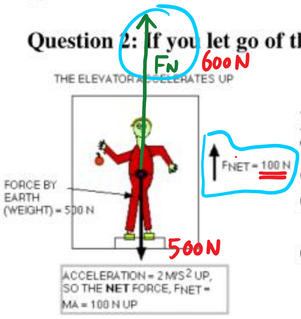


Part A: Elevator Is At Rest.

You have just boarded the elevator, so it (with you inside) is at rest...

Question 1: What does the scale read? 500N

Question 2: If you let go of the apple, what does it do? Falls normally



Part B: The Elevator Accelerates Upward.

The elevator, (with you inside) begins to accelerate upward from rest at 2 m/s^2.

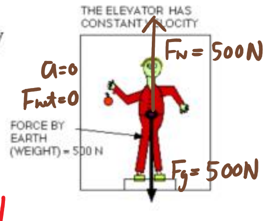
Complete the FBD!

Question 3: What will the scale read now? 600N

Question 4: If you let go of the apple now, what does it do? Falls faster

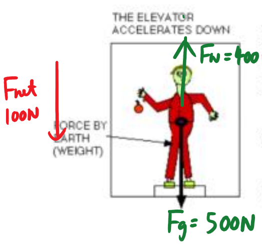
Part C: The Elevator Moves Up With Constant Velocity

The elevator (and you) accelerated for 5 seconds, so it is moving upward with a velocity of 10 m/s. It now moves with this constant upward velocity of 10 m/s.



Question 5: What does the scale read now? 500 N

Question 6: If you let go of the apple, what does it do? falls normally



Part D: The Elevator Slows Down (While Going Up)

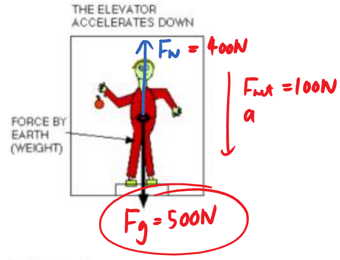
The elevator, (with you inside) begins to slow down as it approaches its destination. Its acceleration (or deceleration) is 2 m/s^2 downward.

Question 7: What does the scale read now? 400N

Question #8: If you let go of the apple now, what does it do? fall slowly.

Part E: The Elevator Speeds Up (While Going Down)

The elevator, (with you inside) reaches its floor, stops for a while, and then begins to accelerate downward. Its acceleration is 2 m/s^2 downward.



Question 9: What does the scale read now? 400N

Question #10: If you let go of the apple now, what does it do? Falls slowly.

Part F: Oh, No!

The elevator cable snaps, and the elevator (with you inside!) begins to fall! Perhaps you have time for one last Physics observation!

Question 11: What does the scale read as the elevator falls? Zero!!

Question 12: If you let go of the apple now, what does it do?

.... hangs in the air.....