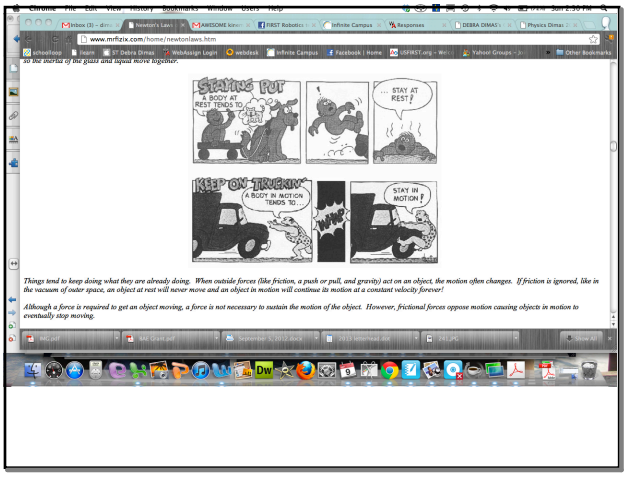
Chapter 4 - Dynamics - WHY things move

Newton has THREE laws of motion

1st Law

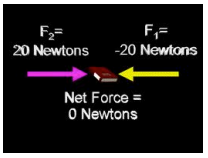
Law of Inertia - An object in CONSTANT motion remains in CONSTANT motion and an object at rest remains at rest UNLESS acted on by an OUTSIDE, NET FORCE

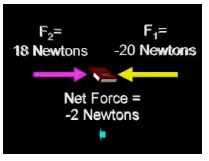


Inertia = resistance to change in motion

Outside force = force from another object

Net force = total sum of all outside forces acting on object





Check Q 1---

How much force is needed to keep a ball throwr in space moving after being thrown?

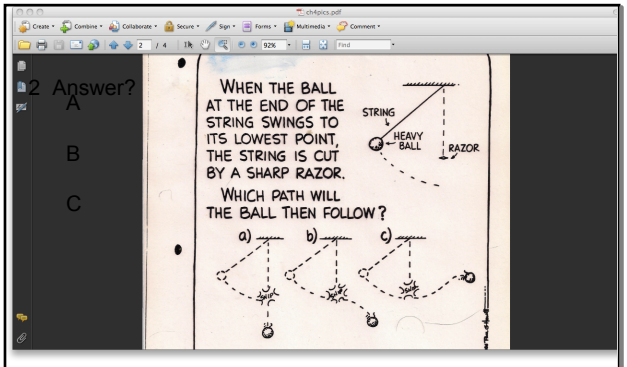
1 A book is sitting on the table, which statement is true?

A There are no forces acting on the book so it remains at rest

B There is only gravity acting on the book

C The table is keeping the book at rest.

D There are two forces on the book.



2 Answer?

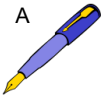
A

B

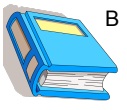
C

Which will hit the ground first, the book or the pen?

A



B



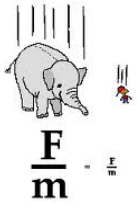
Newton's 2nd Law of Motion--

The acceleration of an object is DIRECTLY proportional to the net force and INVERSELY proportional to its Mass

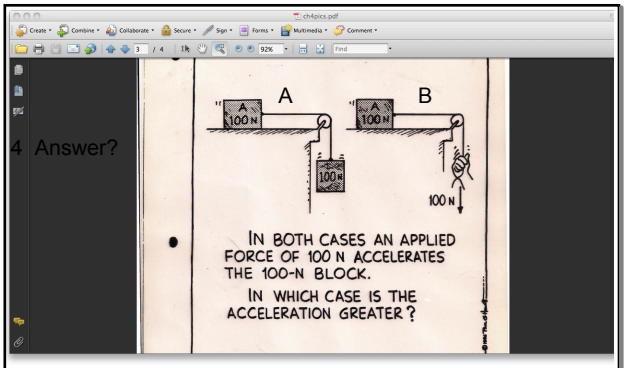
$a = F_{net}/m = \Sigma F/m$

or $\boxed{\Sigma F = ma}$

Units? $kg\,m/s^2 = Newton = N$



$\frac{F}{m}$ - $\frac{F}{m}$



Newton's 3rd Law of Motion -

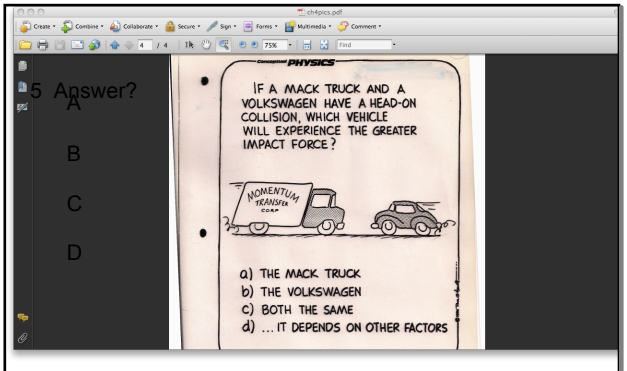
For every action there is an equal and opposite reaction

Action Reaction Pairs

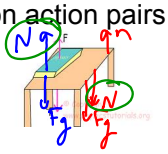
1) Come in pairs

2) NEVER cancel

3) Act on different object



Identify the reaction action pairs of forces in these pictures



Pushing at constant velocity

Types of Forces

1) Gravity - F_g = mass * acceleration of gravity

*** $F_g = F_w$ (weight) = mg

*** Always downwards

*** Mass is the SAME everywhere

*** Weight changes because gravity changes

Newton's Law of Gravity (NOT a law of motion)

$$F_g = \frac{Gm_1m_2}{r^2}$$

Universal Gravitational EQ

$G = 6.67 \times 10^{-11} N m^2/kg^2$

$= mg$ → only Earth

r = dist between centers

Nickname: **Green m&m's are square**

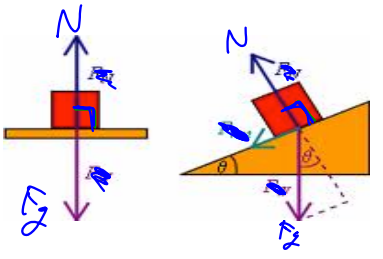
Inverse square law...as r increases F decreases by INVERSE SQUARE

R	F
x2	x 1/4
x4	x 1/16
x1/2	x 4
x 1/3	x 9

$F \propto \frac{1}{r^2}$

2) Normal Force = F_N = N

*** Alway perpendicular to surface



3) Frictional Force = F_f = f

*** Always opposes motion

μ = mu "mew"

*** Always parallel to surface

$f \leq \mu N$...where μ = coefficient of friction = "stickiness of surface---independent of weight

f depends on weight...more weight same μ more friction

Two types of friction

1) Static...

**starting to move or not moving

** if NOT moving $f_s < \mu_s N$

** if JUST starting $f_s = \mu_s N$

2) Kinetic

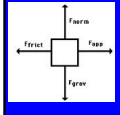
** must be moving

** $f_k = \mu_k N$ (can't be more or less)

** $f_k < f_s$...harder to start then to continue

Free body diagrams (FBD) of objects:

Horizontal Surface



$N = F_g$

$f = \mu N$

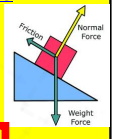
$F_g = mg$

$f = \mu mg$

$F_{net} = F_a - f$

Inclined Surface

$N = F_g \cos\theta$



$f = \mu N$

$F_g = mg$

$f = \mu mg\cos\theta$

$F_a = F_g \sin\theta = mg\sin\theta$

$F_{net} = F_a - f$

6 How does the mass of an object on an incline affect the acceleration of the object?

A directly…higher mass = higher acceleration

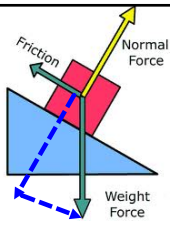
B inversely…higher mass = lower acceleration

C no affect

$F_{net} = F_a - f = ma$

$mg\sin\theta - \mu mg\cos\theta = ma$

note the m's cancel!



if JUST starting down ramp, a = 0 so...

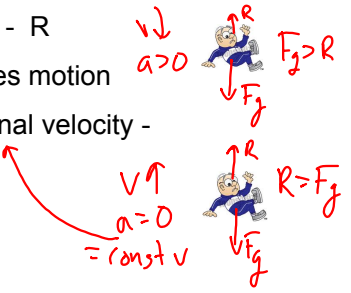
$mg\sin\theta = \mu mg\cos\theta$

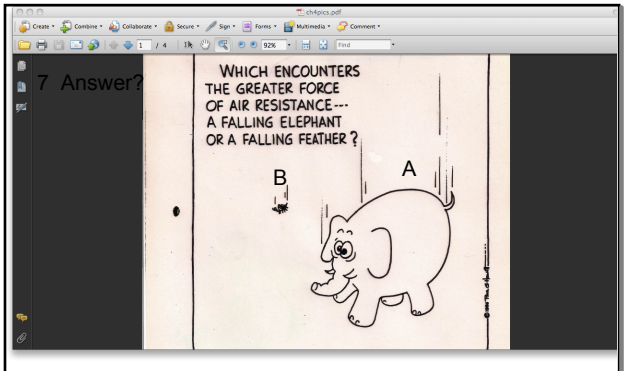
$\tan\theta = \mu_s$

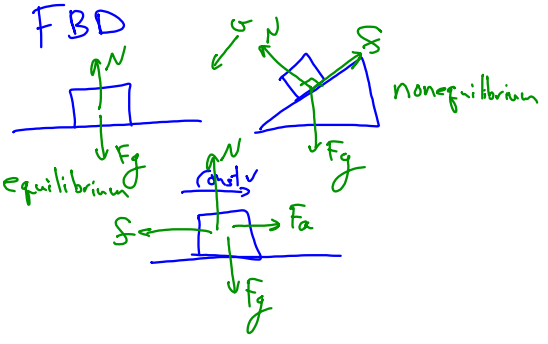
4) Air Resistance - R

***Always opposes motion

*** Causes Terminal velocity -

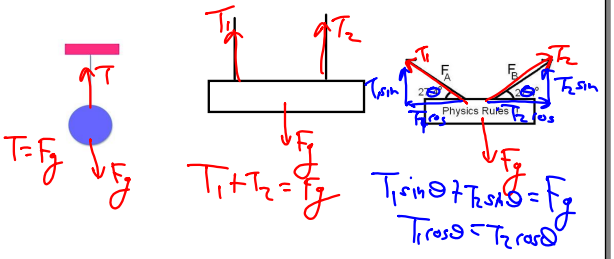


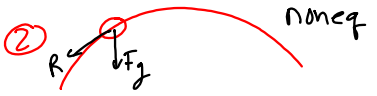


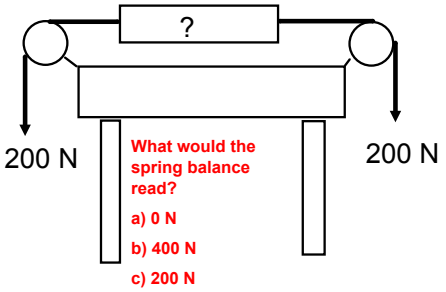


5) Tension - T

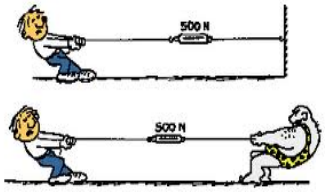
*** represents Tension in rope or string NOT applied force





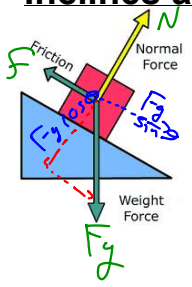


Tug of War---



Inclines and Fnet

$f = \mu N$



$\mu N = f = F_g \sin\theta$

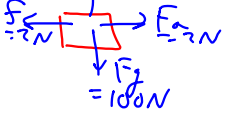
$N = F_g \cos\theta$

$\mu N = F_g \sin\theta$

$N = F_g \cos\theta$

$\mu = \tan\theta$

A 10kg box is moving at a constant velocity with a 2N applied force. What is μ_k?



G: $N = 100N$, $f = 2N$

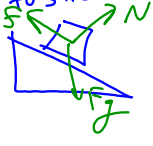
F: $\mu_k = ?$

E: $f = \mu N$

M: $\mu = f/N = \frac{2N}{100N}$

A: .02

A box is on an incline and starts to slide when the angle is 10°. What is μ_s?



G: $\theta = 10°$

F: $\mu_s = ?$

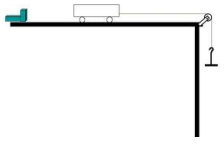
E: $\mu_s = \tan\theta$

M: $\mu_s = \tan 10°$

A: .18

Equilibrium problems **a = 0 Fnet = 0**

1) Draw a FBD
2) Set all the up forces = to all the down forces
3) Set all the left forces = to all the right forces
4) Solve

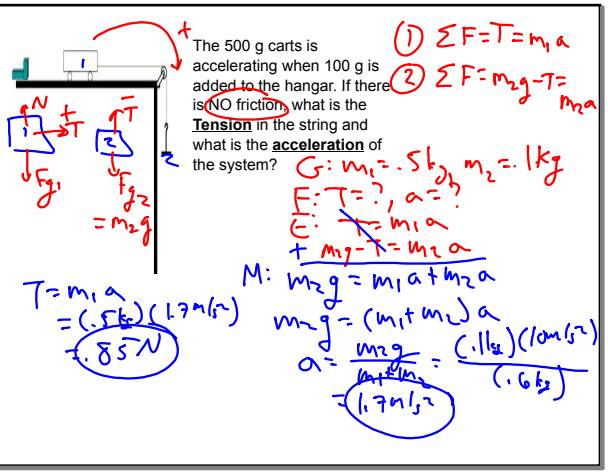


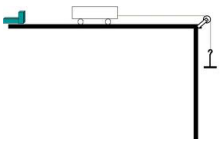
The .5 kg cart in the drawing is moving at a constant velocity while a 50 g mass pulls it down. What is μ?

Non equilibrium problems - a ≠ 0

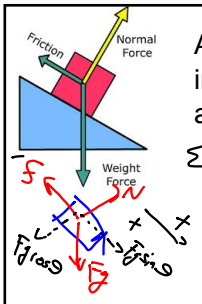
1) Draw your FBD
2) Write your ∑F = ma. Remember a is the SAME for all objects tied together
3) Solve the equations (usually by adding)

****Watch your signs...draw in picture + or -****





The 500 g carts is accelerating at 2 m/s^2 when 200 g is added to the hangar. What is the friction on the table?



A 300 N box sits on a 30 degree incline with friction. What is the acceleration of the box if μ = .4?

$\Sigma F: F_g \sin\theta - f = ma$ $m = 30\,kg$

G: $F_g = 300N$, $\theta = 30°$, $\mu_k = .4$

F: $a = ?$

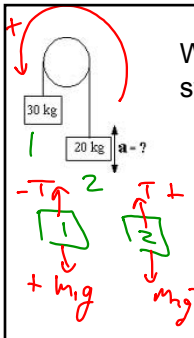
E: $F_g \sin\theta - f = ma$

$f = \mu N = \mu F_g \cos\theta$

M: $f = (.4)(300N)\cos 30° = 104N$

$a = \frac{F_g \sin\theta - f}{m} = \frac{(300N)\sin 30 - 104N}{30\,kg}$

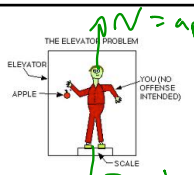
$= 1.5\,m/s^2$



What is the acceleration of the system?

① $\Sigma F = m_1 g - T = m_1 a$

② $\Sigma F: T - m_2 g = m_2 a$



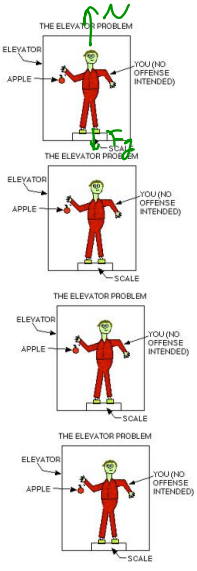
N = apparent

What forces are on the man?

F_g = true weight

Note Scale weight = apparent weight = N

Fg NEVER changes = true weight



If elevator is accelerating upwards, what happens to your apparent weight?

$\Sigma = N - F_g = ma$ $+a, \uparrow$ apparent

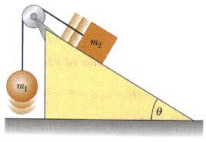
$N = F_g + ma$

If it accelerates downwards?

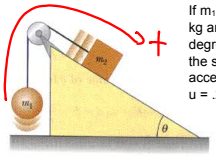
$N = F_g + ma$ $-a, \downarrow$ apparent

If it moves at constant velocity? $N = F_g + ma$ $a = 0, N = F_g$

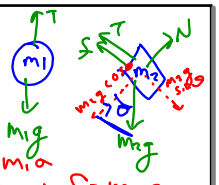
If it free falls? $N = F_g + ma$ $a = -g$ $N = 0$



If m_1 = 10 kg and m_2 = 40 kg and the angle is 20 degrees. What is the T in the string and what is the acceleration of the system if there is no friction?



If m_1 = 10 kg and m_2 = 40 kg and the angle is 20 degrees. What is the T in the string and what is the acceleration of the system if u = .2?



$\Sigma F_1 = T - m_1 g = m_1 a$

$\Sigma F_2 = m_2 g \sin\theta - T - f = m_2 a$

G: $m_1 = 10\,kg$, $m_2 = 40\,kg$, $\theta = 20°$, $\mu = .2$

F: $T = ?$, $a = ?$

E: $T - m_1 g = m_1 a$

$f = \mu N = \mu m_2 g \cos\theta$

$m_2 g \sin\theta - T - f = m_2 a$

$T - m_1 g = m_1 a$

$m_2 g \sin\theta - f - \mu m_2 g \cos\theta = m_2 a$

$m_2 g \sin\theta - m_1 g - \mu m_2 g \cos\theta = (m_1 + m_2) a$

$a = \dfrac{m_2 g \sin\theta - m_1 g - \mu m_2 g \cos\theta}{m_1 + m_2}$

$= \dfrac{(40\,kg)(10\,m/s^2)\sin 20 - (10\,kg)(10\,m/s^2) - .2\,(40\,kg)(10\,m/s^2)\cos 20}{50\,kg}$

$= \dfrac{137 - 100 - 75}{50} = .76\,m/s^2$