Free-Body Diagrams

"Physics is all about simplification."

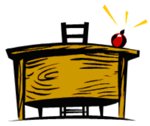
A ***free-body diagram*** (FBD) is a picture that shows ALL the forces acting on an object.

For the sake of simplicity, an object is usually represented by a dot and only the forces acting on the object are included on the diagram. The forces are represented by arrows.

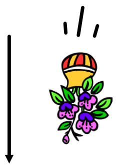
When drawing FBDs, put the tail of the force vectors on the object, with the arrow pointing away from the object. NEVER draw a force vector pointing toward an object.

Examples:

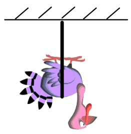
An ***apple*** rests on a desk.



A ***flower pot*** falls in the absence of air resistance.

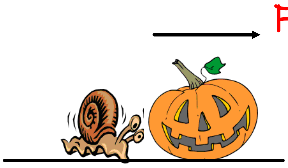


A ***turkey*** is hung from the ceiling of a classroom.



A snail pushes a ***pumpkin*** across the floor at constant speed.

$F_{net} = 0\ N$



A *car* speeds up while traveling on a dirt road.

Net Force Intro

Forces are vectors.

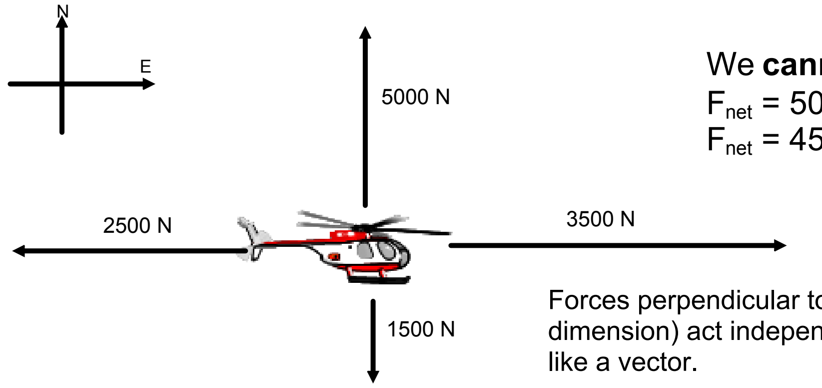
We can ADD them like any other vector!

http://www.teachertube.com/viewVideo.php?video_id=8015

Net Force

The *net force* is the vector sum of all the forces acting on an object. Only forces acting in the same dimension (i.e. left and right or up and down) can be mathematically added (or subtracted).

Consider the four forces acting on the object below:



We **cannot** say the net force is:
F_{net} = 5000 - 1500 + 3500 - 2500
F_{net} = 4500 N

Forces perpendicular to each other (or in a different dimension) act independently on an object and must be added like a vector.

We can talk about the net force in each dimension:

F_{net} [East] = 3500 N - 2500 N
F_{net} [E] = 1000 N

F_{net} [North] = 5000 N - 1500 N
F_{net} [N] = 3500 N

To find the actual net force on the object we would need to do a scale diagram with the vectors or a calculation (grade 12).

Often to identify which direction we are focusing on we use the subscripts x and y. Like in your math class, x - horizontal direction and y - vertical direction. Directions are all in the way your set up your problem for analysis - your frame of reference.

Wrap Up

Many forces can act on an object.

Visualize using a Free Body Diagram.

We can see what forces add together, what cancels out.

Forces = vectors, net force is related to the motion of the object.

HOW?? Next class: relationship between net force and motion.

Nov 19 2013 Start

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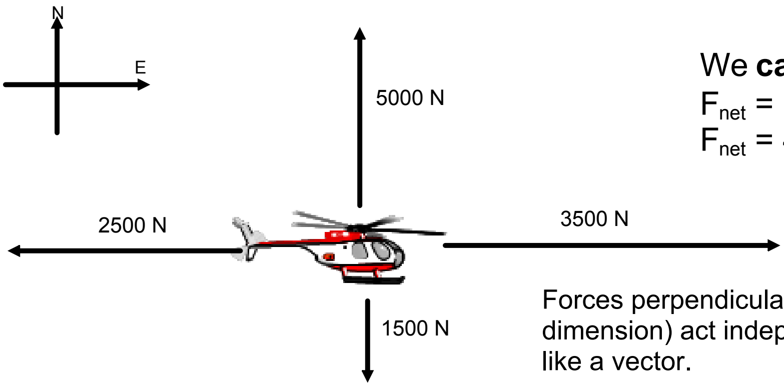

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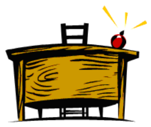
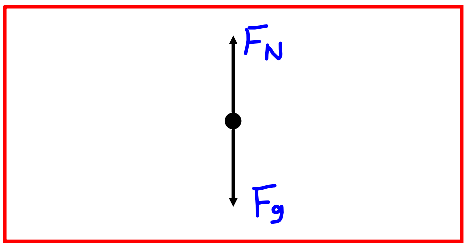

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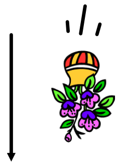
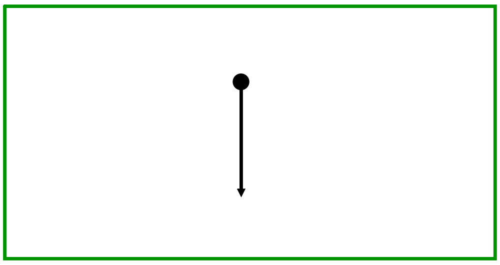

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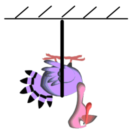
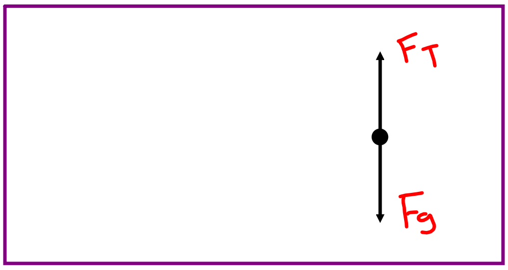

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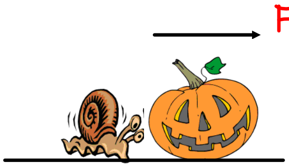
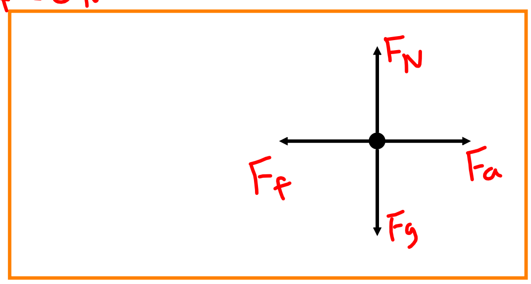

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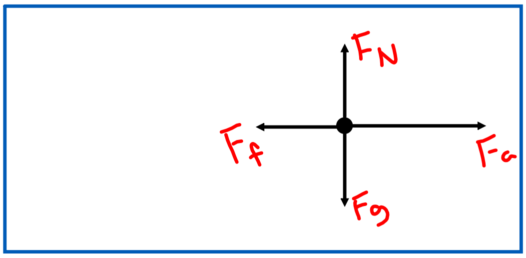


$\vec{F}_g$: gravitational force (force of *gravity*)

- this is an attractive force that acts over a distance between masses

NOTE: Weight is the force of gravity acting on an object.

$$\vec{F}_g = m\vec{g}$$

Fg -> Force of gravity or weight (N)
m -> mass (kg)
g -> acceleration due to gravity (m/s^2)

$\vec{F}_f$: the force of ***friction***

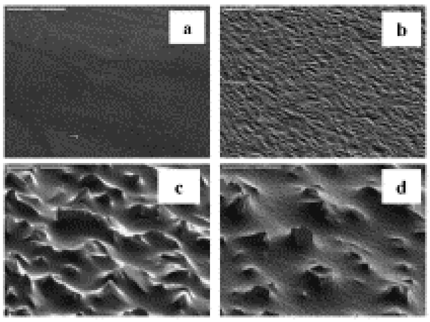
- a force that opposes an object's relative motion

<u>static frictional force</u> (F_{fs}) - exists when you start to move an object from rest

<u>kinetic frictional force</u> (F_{fk}) - exists while an object is in motion

$$F_f = \mu F_N$$

F_f -> force of friction (N)
μ -> coefficient of friction
F_N -> normal force (N)



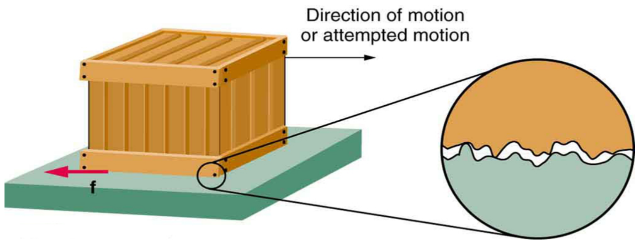


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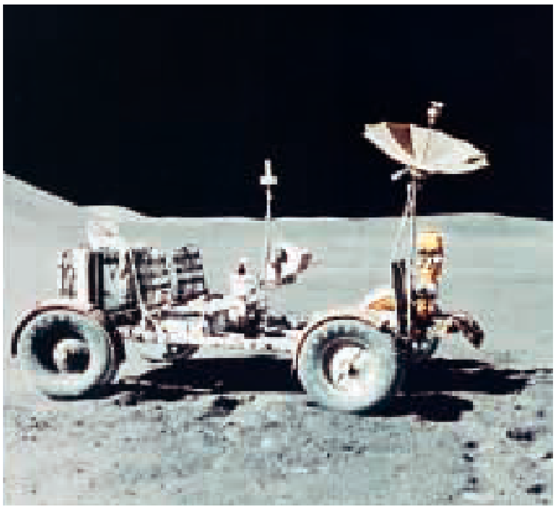
Table 4.5 Coefficients of Friction

Surfaces	Coefficient of Static Friction μ_s	Coefficient of Kinetic Friction μ_k
rubber on dry solid surfaces	1 – 4	1
rubber on dry concrete	1.00	0.80
rubber on wet concrete	0.70	0.50
glass on glass	0.94	0.40
steel on steel (unlubricated)	0.74	0.57
steel on steel (lubricated)	0.15	0.06
wood on wood	0.40	0.20
ice on ice	0.10	0.03
Teflon™ on steel in air	0.04	0.04
lubricated ball bearings	< 0.01	< 0.01
synovial joint in humans	0.01	0.003

PRACTICE PROBLEMS

1. Find the weight of a 2.3 kg bowling ball on Earth.
2. You have a weight of 652.58 N[down] while standing on a spring scale on Earth near the equator.
   (a) Calculate your mass.
   (b) Determine your weight on Earth near the North Pole.
   (c) Determine your weight on the International Space Station. Why would this value be impossible to verify experimentally?
3. The lunar roving vehicle (LRV) pictured here has a mass of 209 kg regardless of where it is, but its weight is much less on the surface of the Moon than on Earth. Calculate the LRV's weight on Earth and on the Moon.
4. A 1.00 kg mass is used to determine the acceleration due to gravity of a distant, city-sized asteroid. Calculate the acceleration due to gravity if the mass has a weight of 3.25×10^{-2} N[down] on the surface of the asteroid.



Nov 20, 2013 Start

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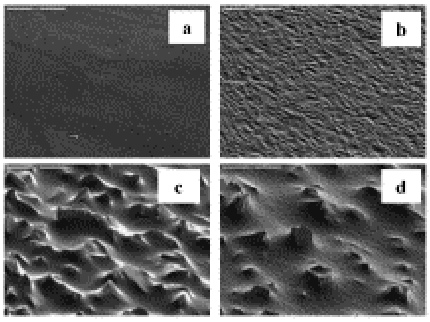

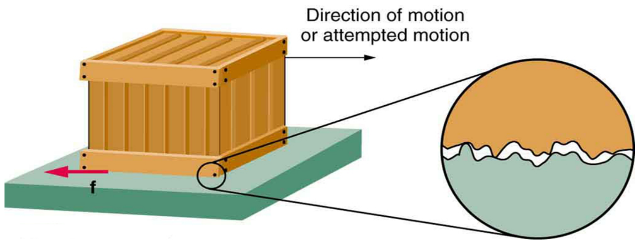

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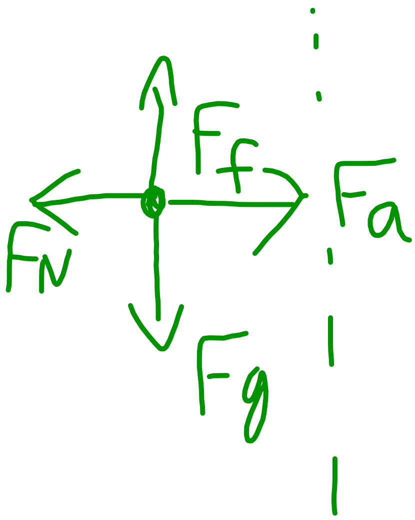
A new problem: Holding a book against a wall !?



Mini Motion Lab

http://phet.colorado.edu/en/simulation/forces-and-motion-basics

Complete the following activities as a small group. Submit ONE "good copy" of your answers by the end of class. Answers can be in point form or full sentences. You can use numbers to explain yourself but there are no "correct" values. This is all about the IDEAS and CONCEPTS!

How do the applied force and the force of friction change as an object goes from stationary to moving?

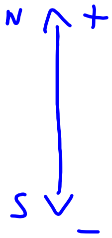
Once an object is moving, how much force must you apply to maintain a constant velocity?

How does the mass of an object affect the amount of force needed to move it (keep friction constant)?

Can the applied force be in one direction, but the object’s motion be in the other direction? Describe the object's motion over time in this scenario.

Compare a 50 kg and a 200 kg object sliding (on ice). Will a 500 N force stop the 50 kg mass faster or slower compared to the 200 kg mass? Is the difference in stopping time significant? What if the sliding masses were 50 kg and 400 kg?

The force of gravity on a ball is 10 N. An upward wind acts with 14 N. What is the net force on the ball?



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

$F_{net} = -10\,N + 14\,N$

$F_{net} = 4\,N$ (up)

The force applied to a car from the gas is 1575 N [E]. Air resistance acts with 1230 N [W]. What is the net force on the car?

$F_{net} = F_a + F_{air}$

$= 1575 - 1230$

$F_{net} = 345\,N$

Physics 112 Forces in 1D

1. A 25 kg crate is pulled at a constant velocity with an applied force of 125 N.
   a. Calculate the force of friction. (-125 N)
   b. Calculate the normal force on the crate. (245 N)
   c. Calculate the coefficient of kinetic friction. (0.51).

a) $F_{net} = \sum Forces$

$F_{net} = F_f + F_a$

$0 = F_f + 125$

$F_f = -125\ N$

b) $F_N = F_g$

$F_N = mg$

$F_N = (25)(9.81)$

$F_N = 245\ N$

c) $|F_f| = \mu |F_N|$

$\mu = \frac{F_f}{F_N} = \frac{125}{245} = 0.51$

Physics 112 Forces in 1D

3. A 55 kg box is moved with a net force of 28 N. The applied force necessary is 185 N.
   a. What is the force of friction? (-157 N)
   b. What is the normal force? (540 N)
   c. What is the coefficient of kinetic friction? (0.29)

a) $F_{net} = \sum Forces$

$F_{net} = F_a + F_f$

$28 = 185 + F_f$

$\boxed{-157\ N = F_f}$

b) $F_N = F_g$

$F_N = mg$

$F_N = (55\ kg)(9.81\ m/s^2)$

$\boxed{F_N = 540\ N}$

c) $F_f = \mu F_N$

$\mu = \dfrac{F_f}{F_N}$

$\mu = \dfrac{157}{540} = \boxed{0.29}$

Wrap Up

Net force = sum of force vectors

Key forces: Gravity ($F = mg$) and Friction ($F = \mu F_N$)

Many forces oppose each other: FBD great way to visualize!

Next Class: Using Net Force to predict motion and CHANGES in motion.