 Name: answers

Balanced vs. Unbalanced Forces

Read from **Lesson 1** of the **Newton's Laws** chapter at **The Physics Classroom**:

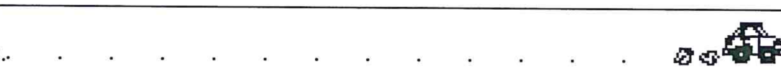
http://www.physicsclassroom.com/Class/newtlaws/u2l1c.html
http://www.physicsclassroom.com/Class/newtlaws/u2l1d.html

MOP Connection: Newton's Laws: sublevels 2 and 3

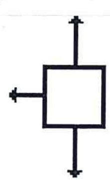
Review: An object at rest ... stays at rest ;
An object in motion .... stays in motion ;
unless ... acted upon by an outside force.

1. The amount of force required to keep a 6-kg object moving with a constant velocity of 2 m/s is __ N.
a. 0.333 b. 2 c. 3 d. 6 e. 12
f. ... nonsense! A force is NOT required to keep an object in motion.

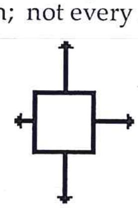
2. Renatta Oyle is having car troubles. She is notorious for the trail of oil drops that she leaves on the streets of Glenview. Observe the following oil traces and indicate whether Renatta's car is being acted upon by an unbalanced force. Give a reason for your answers.

	Unbalanced Force?
a.  **Reason:** ______	**Yes** or **No**
b.  **Reason:** ______	**Yes** or **No**
c.  **Reason:** ______	**Yes** or **No**

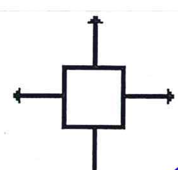
3. Each one of the dot diagrams in question #2 can be matched to a force diagram below. The force diagrams depict the individual forces acting upon the car by a vector arrow. The arrow direction represents the direction of the force. The arrow length represents the strength of the force. Match the dot diagrams from #2 to a force diagram; not every force diagram needs to be matched.



Dot Diagram(s): C



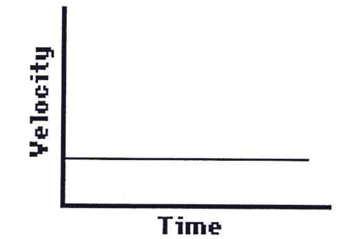
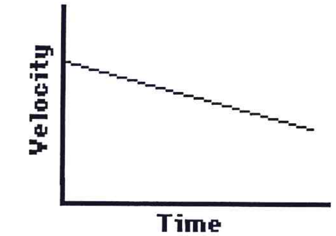
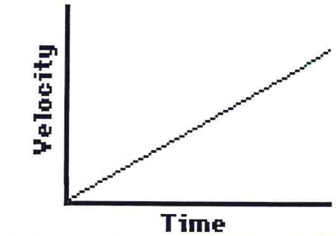
Dot Diagram(s): A



Dot Diagram(s): B

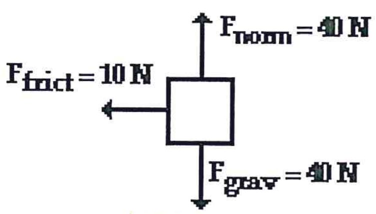
4. If the net force acting upon an object is 0 N, then the object MUST ____. Circle one answer.
a. be moving b. be accelerating c. be at rest
d. be moving with a constant speed in the same direction e. either c or d.

5. These graphs describe the motion of Carson Busses at various times during his trip to school. Indicate whether Carson's vehicle is being acted upon by an unbalanced force. Give a reason in terms of a description of what the car is doing (speeding up, slowing down, or constant velocity).

		
Unbalanced Force? Yes or No? Reason/Description: constant $\vec{v}$	Unbalanced Force? Yes or No? Reason/Description: $\vec{a} \neq 0 m/s^2$ ⟶	Unbalanced Force? Yes or No? Reason/Description:

6. A free-body diagrams show all the individual forces acting upon an object. The net force is the *vector sum* of all these forces (ΣF). Determine the net force and state if there is an acceleration.

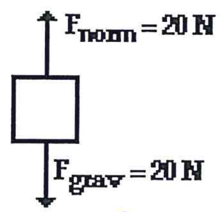
a.



ΣF = 10N ←

Accel'n? Yes or No

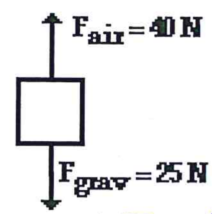
b.



ΣF = 0

Accel'n? Yes or No

c.



ΣF = 15 N ↑

Accel'n? Yes or No

7. During an in-class discussion, Anna Litical suggests to her lab partner that the dot diagram for the motion of the object in #6b *could be*

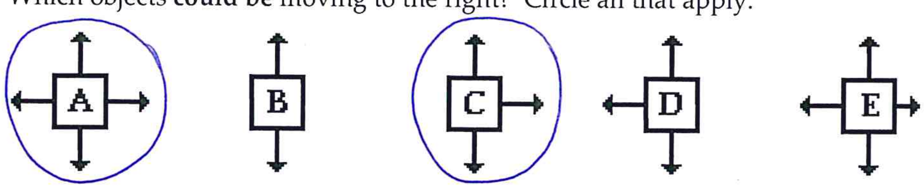
Anna's partner objects, arguing that the object in #6b could not have any horizontal motion if there are only vertical forces acting upon it. Who is right? ~~Anna's~~ Explain.

Anna's partner.

8. During an in-class discussion, Aaron Agin asserts that the object in #6a **must** be moving to the left since the only horizontal force acting upon it is a "left-ward" force. Is he right? ______ Explain.

No, $\vec{F_f}$ not $\vec{F_{app}}$

9. The diagrams below depict the magnitude and direction of the individual forces acting upon an object. Which objects **could be** moving to the right? Circle all that apply.



Name: ______________________

Recognizing Forces

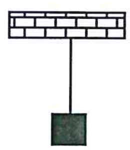
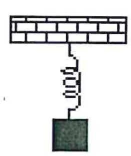
Read from **Lesson 2** of the **Newton's Laws** chapter at **The Physics Classroom:**

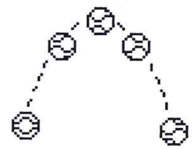
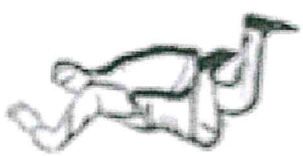
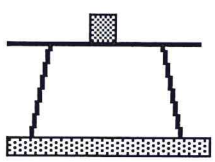
http://www.physicsclassroom.com/Class/newtlaws/u2l2a.html
http://www.physicsclassroom.com/Class/newtlaws/u2l2b.html

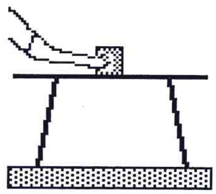
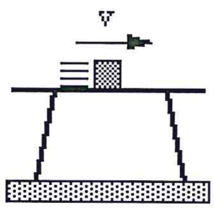
MOP Connection: Newton's Laws: sublevel 4

There are several situations described below. For each situation, fill in the list provided by indicating which forces are present and stating which features of the situation you used to determine the presence or absence of the force. To facilitate this exercise, utilize the Net Force Help Sheet. Upon completion of this assignment, check your answers using the available Web page.

http://www.physicsclassroom.com/morehelp/recforce/recforce.html

Description of Situation	Force Present (P) or Absent (A)?		Explanation
	**Gravity**	P or A?	always
	Spring:	P or A?	
	Tension	P or A?	Rope
	Normal:	P or A?	
1. A block hangs at rest from the ceiling by a piece of rope. Consider the forces acting on the block.	**Friction**	P or A?	
	Air Res.:	P or A?	
	**Gravity**	P or A?	always
	Spring:	P or A?	spring
	Tension	P or A?	
2. A block hangs from the ceiling by a spring. Consider the forces acting on the block when it is at rest (at its equilibrium position).	**Normal:**	P or A?	
	Friction	P or A?	
	Air Res.:	P or A?	

Description of Situation	Force Present (P) or Absent (A)?	Explanation
	Gravity P or A?	always
	Spring: P or A?	
	Tension P or A?	
3. A ball is shot into the air with a spring-loaded cannon. Consider the forces acting on the ball while it is <u>in the air</u>.	Normal: P or A?	
	Friction P or A?	
	Air Res.: P or A?	moving.
	Gravity P or A?	always
	Spring: P or A?	
	Tension P or A?	
4. A skydiver (who hasn't opened his parachute yet) falls <u>at terminal velocity</u>. Consider the forces acting on the <u>skydiver</u>.	Normal: P or A?	
	Friction P or A?	
	Air Res.: P or A?	moving.
	Gravity P or A?	always
	Spring: P or A?	
	Tension P or A?	
5. A block rests on top of a table. Consider only the forces acting upon the block.	Normal: P or A?	surface
	Friction P or A?	not
	Air Res.: P or A?	moving

Description of Situation	Force Present (P) or Absent (A)?		Explanation
	Gravity	P or A?	always
	Spring:	P or A?	
	Tension	P or A?	
6. A block is being pushed across the top of a table. Consider only the forces acting upon the block.	Normal:	P or A?	surface
	Friction	P or A?	moving
	Air Res.:	P or A?	
	Gravity	P or A?	
	Spring:	P or A?	
	Tension	P or A?	
7. A block slides across the top of a table. Consider only the forces acting upon the block.	Normal:	P or A?	
	Friction	P or A?	
	Air Res.:	P or A?	
	Gravity	P or A?	
	Spring:	P or A?	
	Tension	P or A?	
8. The driver of a car has her foot on the gas pedal. The wheels are turning as the car accelerates down the road. Consider only the forces acting upon the car.	Normal:	P or A?	
	Friction	P or A?	
	Air Res.:	P or A?	

 Name: ______________________

Mass and Weight

$g = 9.8 m/s^2$

$g \approx 10 m/s^2$

Read from **Lesson 2** of the **Newton's Laws** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/newtlaws/u2l2b.html#mass

MOP Connection: Newton's Laws: sublevel 6

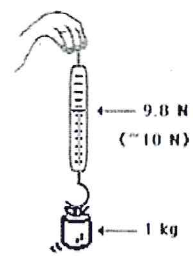
1. The standard metric unit for mass is Kg and the standard metric unit for weight is N.

2. An object's mass refers to D and an object's weight refers to B. Fill in each blank.
   a. the amount of space it takes up
   b. the force of gravitational attraction to Earth
   c. how dense an object is
   d. the amount of stuff present in the object

3. Complete the following table showing the relationship between mass and weight.

Object	Mass	Approx. Weight
Melon	**1 kg**	9.8 N
Apple	0.1 Kg	**~1.0 N**
Pat Eatladee	**25 kg**	245 N

4. Different masses are hung on a spring scale calibrated in Newtons.
   The force exerted by gravity on 1 kg = ~10 N.
   The force exerted by gravity on 5 kg = ~ 49 N.
   The force exerted by gravity on 70 kg = ~ 686 N.



5. ~~The value of g in the British system is 32 ft/sec^2. The unit of force is pounds. The unit of mass is the slug. Use your weight in pounds to calculate your mass in units of slugs. **PSYW**~~

6. You might be wondering about your metric weight. Using conversion factors, convert your weight in pounds to units of N. (Use 1 N = 0.22 pounds) **PSYW**

   answers vary

7. What is the mass and weight of a 10-kg object on earth?
   Mass = 10 Kg Weight = 98N

   What is the mass and weight of a 10-kg object on the moon where the force of gravity is 1/6-th that of the Earth's? → $1.63 m/s^2$
   Mass = ~~0.3kg~~ 10 kg Weight = ~~10~~ 16.3 N

8. Conclusion: The mass of an object is independent of the object's location in space.

Newton's Second Law of Motion

Read from **Lesson 3** of the **Newton's Laws** chapter at **The Physics Classroom:**

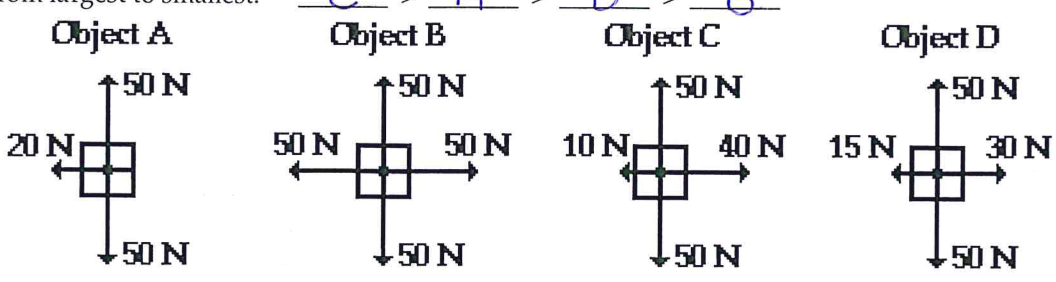
http://www.physicsclassroom.com/Class/newtlaws/u2l3a.html
http://www.physicsclassroom.com/Class/newtlaws/u2l3b.html

MOP Connection: Newton's Laws: sublevel 7

1. The acceleration of an object is ________________ related to the net force exerted upon it and ________________ related to the mass of the object. In equation form: $a = F_{net} / m$.
   a. directly, inversely b. inversely, directly c. directly, directly d. inversely, inversely

2. Use Newton's second law to predict the effect of an alteration in mass or net force upon the acceleration of an object.
   a. An object is accelerating at a rate of 8 m/s^2 when it suddenly has the net force exerted upon increased by a factor of 2. The new acceleration will be __16__ m/s^2.
   b. An object is accelerating at a rate of 8 m/s^2 when it suddenly has the net force exerted upon increased by a factor of 4. The new acceleration will be __32__ m/s^2.
   c. An object is accelerating at a rate of 8 m/s^2 when it suddenly has the net force exerted upon decreased by a factor of 2. The new acceleration will be __4__ m/s^2.
   d. An object is accelerating at a rate of 8 m/s^2 when it suddenly has its mass increased by a factor of 2. The new acceleration will be __4__ m/s^2.
   e. An object is accelerating at a rate of 8 m/s^2 when it suddenly has its mass decreased by a factor of 4. The new acceleration will be __32__ m/s^2.
   f. An object is accelerating at a rate of 8 m/s^2 when it suddenly has the net force exerted upon increased by a factor of 2 and its mass decreased by a factor of 4. The new acceleration will be __64__ m/s^2.
   g. An object is accelerating at a rate of 8 m/s^2 when it suddenly has the net force exerted upon increased by a factor of 4 and its mass increased by a factor of 2. The new acceleration will be __16__ m/s^2.
   h. An object is accelerating at a rate of 8 m/s^2 when it suddenly has the net force exerted upon increased by a factor of 3 and its mass decreased by a factor of 4. The new acceleration will be __96__ m/s^2.

3. These force diagrams depict the magnitudes and directions of the forces acting upon four objects. In each case, the down force is the force of gravity. Rank these objects in order of their acceleration, from largest to smallest: __C__ > __A__ > __D__ > __B__



$\Sigma F = 20 \leftarrow$ $\Sigma F = 0$ $\Sigma F = 30 \rightarrow$ $\Sigma F = 15 \rightarrow$

4. For each force diagram, determine the net or resultant force (ΣF), the mass and the acceleration of the object. Identify the direction (the second blank) of the two vector quantities. NOTE: F_{grav} stands for the weight of the object.

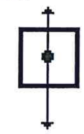
a.

ΣF = $\vec{F_g}$, DOWN

m = 61.2 Kg

a = 9.8 m/s², DOWN

b.

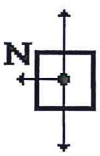


ΣF = $\vec{F_{air}} + \vec{F_g}$, DOWN = 200 N

m = 61.2 Kg

a = 0.33 m/s², DOWN

c.

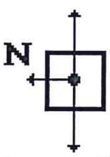


ΣF = 2000 N , LEFT

m = 816.33 Kg

a = 2.45 m/s², LEFT

d.

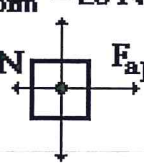


ΣF = 4000 N , LEFT

m = 816.33 Kg

a = 4.9 m/s², LEFT

e.

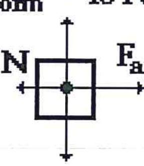


ΣF = 8 N , RIGHT

m = 2.04 Kg

a = 3.92 m/s², RIGHT

f.



ΣF = 16 N , RIGHT

m = 4.08 Kg

a = 3.92 m/s², RIGHT.

F

m | a

$\frac{\vec{F_g}}{g} = m$

Newton's Second Law

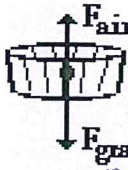
Read from **Lesson 3** of the **Newton's Laws** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/newtlaws/u2l3c.html
http://www.physicsclassroom.com/Class/newtlaws/u2l3d.html

MOP Connection: Newton's Laws: sublevels 8 and 9

Free-body diagrams are shown for a variety of physical situations. Use Newton's second law of motion ($\sum F = m \cdot a$) to fill in all blanks. Use the approximation that $g = \sim 10$ m/s/s.

a.



F_{air} = 0.10 N

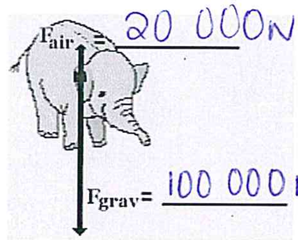
F_{grav} = 0.10 N

m= 0.01 Kg

a= 0 m/s²

ΣF= 0 m/s²

b.



F_{air} = 20 000 N

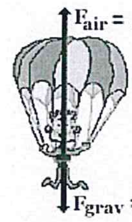
F_{grav} = 100 000 N

m=10000 kg

a = 8.0 m/s/s, down

ΣF = 80 000 N

c.



F_{air} = 3200 N

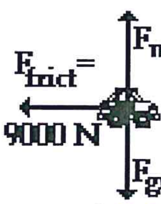
F_{grav} = 8 000 N

m=800 kg

a = 6.0 m/s/s, up

ΣF = 4800 N

d.



F_{norm}=10 000 N

F_{frict}= 9000 N

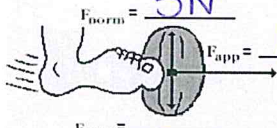
F_{grav}=10 000 N

m= 1000 Kg

a= 9 m/s²

ΣF= 9000 N ←

e.



F_{norm} = 5 N

F_{app} = 124 N

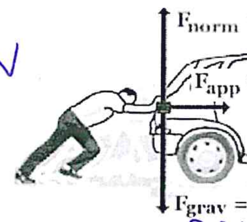
F_{grav} = 5 N

m=0.500 kg

a = 248

ΣF = 124 N, right

f.



F_{norm} = 9000 N

F_{app} = 1350 N

F_{grav} = 9000 N

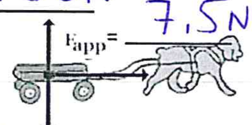
m= 900 N

a = 1.50 m/s/s, right

ΣF = 1350 N →

g.

F_{norm} = 150 N



F_{app} = 7.5 N

F_{grav} = 150 N

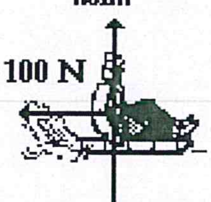
m=15.0 kg

a = 0.50 m/s/s, right

ΣF = 7.5 N →

h.

F_{norm}=600 N



F_{frict}=100 N

F_{grav}=600 N

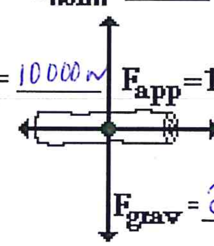
m= 60 Kg

a= 1.6 m/s²

ΣF= 100 N ←

i.

F_{norm}= 20 000 N



F_{frict}= 10 000 N

F_{app}=14000 N

F_{grav}= 20 000 N

m=2000 kg

a=2.0 m/s/s, right

ΣF= 4000 →

 Name: ______________________

Newton's Third Law

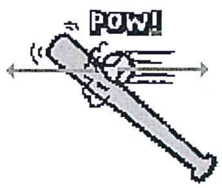
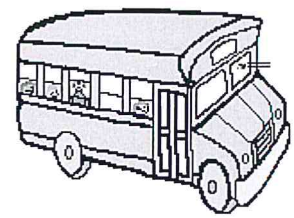
Read from **Lesson 4** of the **Newton's Laws** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/newtlaws/u2l4a.html
http://www.physicsclassroom.com/Class/newtlaws/u2l4b.html

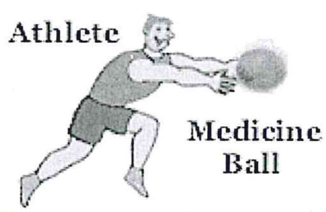
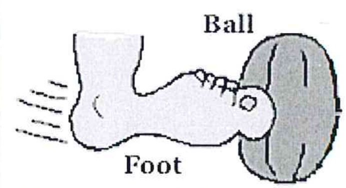
MOP Connection: Newton's Laws: sublevel 12

A force is a push or pull resulting from an interaction between two objects. Whenever there is a force, there are two objects involved - with both objects pushing (or pulling) on each other in opposite directions. While the direction of the pushes (or pulls) is opposite, the strength or magnitude is equal. This is sometimes stated as Newton's Third Law of motion: *for every action, there is an equal and opposite reaction.* A force is a push or a pull and it always results from an interaction between two objects. These forces always come in pairs.

1. For each stated *action force*, identify the *reaction force*.

		
Bat hits ball.	Man pushes car.	Bus hits bug.
Ball hits bat.	car pushes man.	Bug hits bus

2. Identify by words the action-reaction force pairs in each of the following diagrams.

		
(A) Athtete catches ball (R) Ball hits athlete	(A) Foot pushes floor (R) Floor pushes foot.	(A) Ball hits foot (R) Foot hits ball

3. TRUE or FALSE:

As you sit in your seat in the physics classroom, the Earth pulls down upon your body with a gravitational force; the reaction force is the chair pushing upwards on your body with an equal magnitude.

If False, correct the answer.

$\vec{F_g} = \vec{F_N}$

4. Shirley Bored sits in her seat in the English classroom. The Earth pulls down on Shirley's body with a gravitational force of 600 N. Describe the reaction force of the force of gravity acting upon Shirley.

600N Normal

5. Use Newton's third law (law of action-reaction) and Newton's second law (law of acceleration: $a = F_{net}/m$) to complete the following statements by filling in the blanks.

a. A bullet is loaded in a rifle and the trigger is pulled. The force experienced by the bullet is EQUAL (less than, equal to, greater than) the force experienced by the rifle. The resulting acceleration of the bullet is greater (less than, equal to, greater than) the resulting acceleration of the rifle.

b. A bug crashes into a high-speed bus. The force experienced by the bug is EQUAL (less than, equal to, greater than) the force experienced by the bus. The resulting acceleration of the bug is EQUAL (less than, equal to, greater than) the resulting acceleration of the bus.

c. A massive linebacker collides with a smaller halfback at midfield. The force experienced by the linebacker is EQUAL (less than, equal to, greater than) the force experienced by the halfback. The resulting acceleration of the linebacker is less (less than, equal to, greater than) the resulting acceleration of the halfback.

d. The 10-ball collides with the 14-ball on the billiards table (assume equal mass balls). The force experienced by the 10-ball is EQUAL (less than, equal to, greater than) the force experienced by the 14-ball. The resulting acceleration of the 10-ball is EQUAL. (less than, equal to, greater than) the resulting acceleration of the 14-ball.

 Name: ____________________

Another Angle on F-m-a

Read from **Lesson 3** of the **Vectors and Motion in Two-Dimensions** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/vectors/u3l3a.html

MOP Connection: Forces in Two Dimensions: sublevels 1 and 3

Directions:
1. Draw and label the forces (direction and magnitude) acting upon the objects below in order that the objects experience the acceleration which is specified in each case.
2. At least two forces must be added to the object in each situation.
3. If forces are already present, #2 above still applies.

Acceleration	Forces

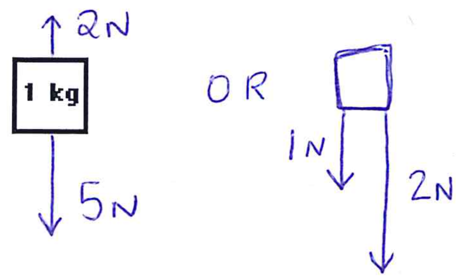
Example:

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

1. $a = 3\ m/s^2$, Down

$\Sigma\vec{F} = 1Kg\ (3m/s^2)$

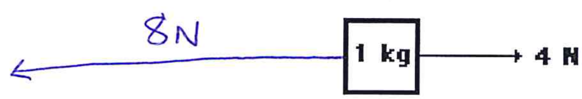
$\Sigma\vec{F} = 3N\ \downarrow$



2. $a = 4\ m/s^2$, Left

$\Sigma\vec{F} = 1Kg\ (4m/s^2)$

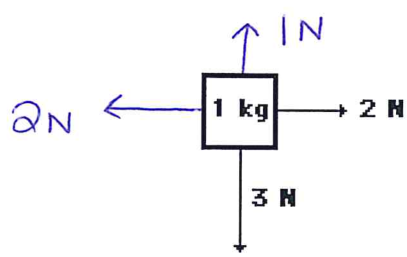
$\Sigma\vec{F} = 4N$ L



3. $a = 2\ m/s^2$, Down

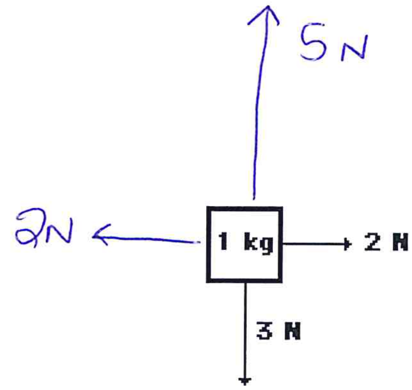
$\Sigma\vec{F} = 1Kg\ (2m/s^2)$

$\Sigma\vec{F} = 2N$ DOWN



Force and Vector Applications

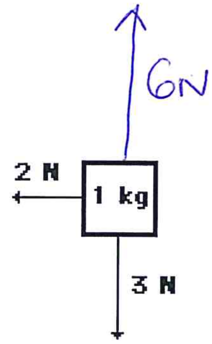
4. a = 2 m/s^2, Up

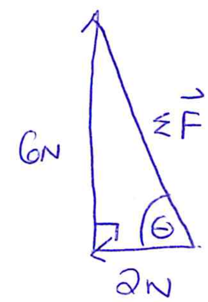


$\Sigma\vec{F} = 1kg\,(2m/s^2)$

$\Sigma F = 2N$ up

5. a = 2 m/s^2, Left and 3 m/s^2, Up



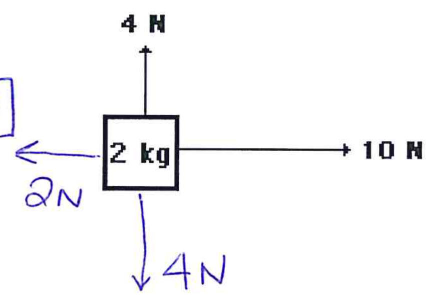


$\Sigma\vec{F} = 2N\,[L]$

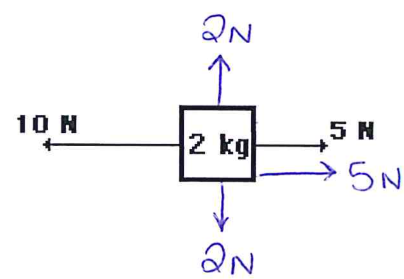
$\Sigma\vec{F} = 3N\,[Up]$

6. a = 4 m/s^2, Right and constant velocity, Up

$\Sigma\vec{F} = 2kg\,(4m/s^2) = 8N\,[R]$



7. constant velocity, Right & constant velocity, Up



Make your own problem and have your lab partner solve it.

8.

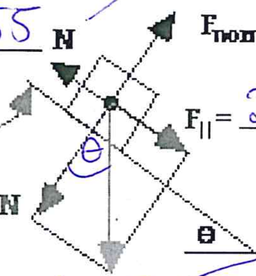
Force and Vector Applications

$\mu_F = \dfrac{F_F}{F_N}$ $\qquad \vec{F_F} = \mu_F(F_N)$

$\vec{F_F} = 0.548(35.68)$

Use equations for calculating the components of gravity (#4) and Newton's laws to fill in the blanks.

6. A 4.50-kg object is accelerating down an inclined plane inclined at 36.0° (with the horizontal) and having a coefficient of friction of 0.548.



F_{frict} = 19.55 N $\qquad F_{norm}$ = 35.68 N

$\vec{F_g} = 4.5(9.8)$

$F_g = 44.1N$

μ = 0.548 $\qquad F_{\parallel}$ = 25.92 N

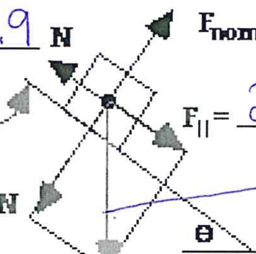
$\cos 36°(44.1N)$ ← $F_{\perp}$ = 35.68 N

→ $\sin 36°(44.1N)$

$25.92 - 19.55$

m = 4.5 kg $\qquad F_{net}$ = 6.37 N $\qquad$ a = 1.4 m/s/s

7. A 65.0-kg crate remains at rest on an inclined plane that is inclined at 23.0° (with the horizontal).



$\dfrac{F_F}{F_N} = \mu_F$

F_{frict} = 248.9 N $\qquad F_{norm}$ = 586.4 N

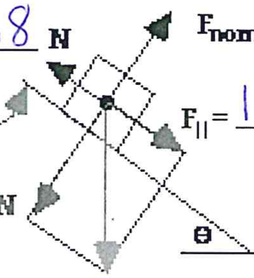
μ = 0.424 $\qquad F_{\parallel}$ = 248.9 N → $\sin 23°(637N)$

$\cos 23°(637)$ ← $F_{\perp}$ = 586.4 N

$\vec{F_g} = 637N$

m = 65 kg $\qquad F_{net}$ = 0 N $\qquad$ a = 0 m/s/s

8. A 41.3-kg box slides down an inclined plane (inclined at 29.1 degrees) at a constant speed of 2.1 m/s.



$\dfrac{F_F}{F_N} = \mu_F$

F_{frict} = 196.8 N $\qquad F_{norm}$ = 353.6 N

$\cos 29.1°(404.7)$

μ = 0.56 $\qquad F_{\parallel}$ = 196.8 N $\quad \sin(29.1°)(404.7)$

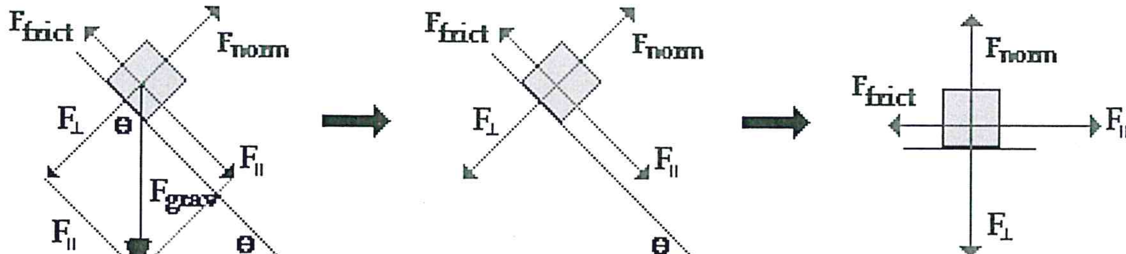
$F_{\perp}$ = 353.6 N

$\vec{F_g} = 404.7N$

m = 41.3 kg $\qquad F_{net}$ = 0 N $\qquad$ a = 0 m/s/s

The Tilted Head Trick

Inclined plane problems can be easy. Resolve gravity into its components. Then, ignore the force of gravity. Finally, tilt the paper or your head and the problem becomes a simple F_{net}= m•a problem.



Inclined Plane Analysis

Read from **Lesson 3** of the **Vectors and Motion in Two-Dimensions** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/vectors/u3l3e.html

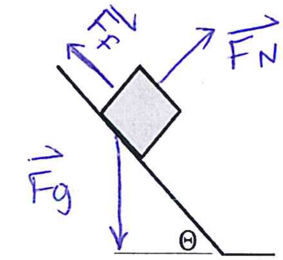
MOP Connection: Forces in Two Dimensions: sublevels 5 and 6

Review:

1. A normal force is a force which is <u>always</u> directed ____.
   a. upwards b. sideways c. perpendicular to the surface the object is contacting
2. An object is upon a surface. The normal force is equal to the force of gravity ____.
   a. in all situations b. only when the object is at rest
   c. only when the object is accelerating d. only when there is no vertical acceleration
   e. only when there is no vertical acceleration AND F_{norm} and F_{grav} are the only vertical forces

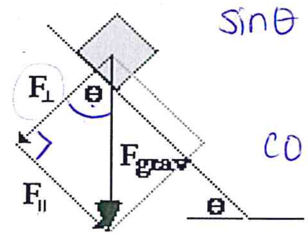
Getting the Forces Right:

3. The object at the right has been placed on a tilted surface or *inclined plane*. If there is enough tilt, it will accelerate from rest and begin its motion down the incline. Draw a free-body diagram for the object sliding down the *rough* incline. Label the three forces according to type (F_{grav}, F_{norm}, F_{frict}, F_{air}, F_{tens}, F_{app}, etc.).



Physics Tip: When you encounter a situation involving a force directed at angles to all other forces, immediately convert the *uncooperative* force(s) into two perpendicular components. Use SOH CAH TOA to resolve any uncooperative force into components directed at right angles to each other. One component should be in the direction of the acceleration; the other should be perpendicular to it. In the case of inclined planes, resolve the uncooperative force into components parallel and perpendicular to the inclined plane.

4. The force of gravity (or weight vector) is the *uncooperative force*. It is typically resolved into two components - one parallel to the plane and the other perpendicular to the plane. Given the diagram at the right with the two components of gravity represented as $F_{\parallel}$ and $F_{\perp}$, use trigonometric functions to write equations relating these components to the force of gravity.



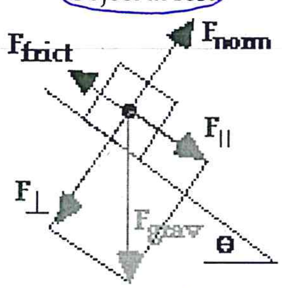
$\sin\theta = \frac{\vec{F_{\parallel}}}{\vec{F_g}}$

$\cos\theta = \frac{\vec{F_{\perp}}}{\vec{F_g}}$

$F_{\parallel}$ = $\sin\theta\,(\vec{F_g})$ $F_{\perp}$ = $\cos\theta\,(\vec{F_g})$

5. For the three situations described below, use <, >, or = symbols to complete the statements.

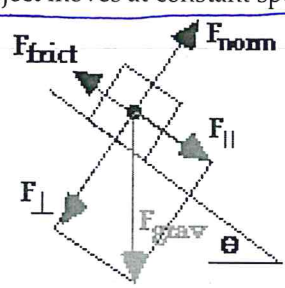
Object at rest.



$F_{\parallel}$ = < F_{frict}

$F_{\perp}$ = F_{norm}

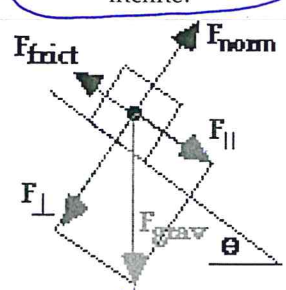
Object moves at constant speed.



$F_{\parallel}$ = F_{frict}

$F_{\perp}$ = F_{norm}

Object accelerates down incline.



$F_{\parallel}$ > F_{frict}

$F_{\perp}$ = F_{norm}