

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:

$a = 2 \text{ m/s}^2$, Right



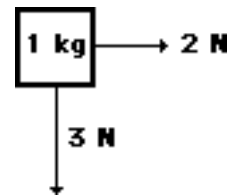
1. $a = 3 \text{ m/s}^2$, Down



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

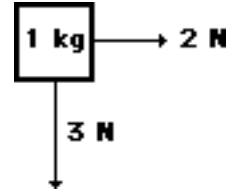


3. $a = 2 \text{ m/s}^2$, Down

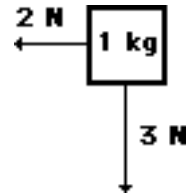


Forces in Two Dimensions

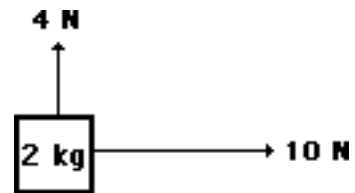
4. $a = 2 \text{ m/s}^2$, Up



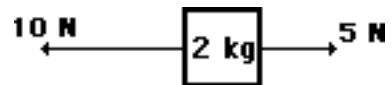
5. $a = 2 \text{ m/s}^2$, Left and 3 m/s^2 , Up



6. $a = 4 \text{ m/s}^2$, Right and constant velocity, Up



7. constant velocity, Right & constant velocity, Up



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

8.

Adding and Resolving Forces

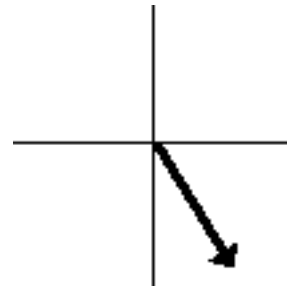
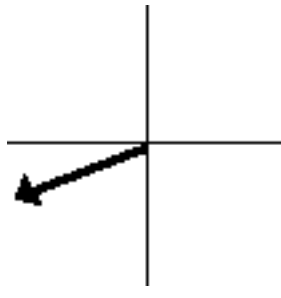
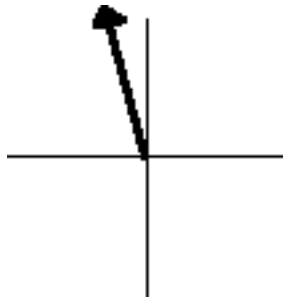
Read from **Lesson 3** of the **Vectors and Motion in Two-Dimensions** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/vectors/u3l3a.html>
<http://www.physicsclassroom.com/Class/vectors/u3l3b.html>

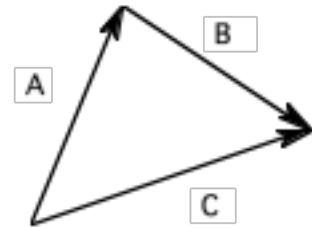
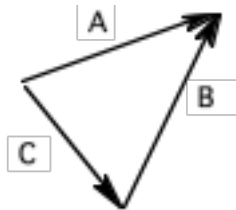
MOP Connection: Forces in Two Dimensions: sublevels 1 (mostly) and 3 (a little)

Review:

- Quantities fully described by magnitude alone are _____; quantities that are described fully by both magnitude and direction are _____.
- Use a protractor to estimate the direction of the following vectors using the CCW notation.



- Identify the resultant in the following vector addition diagrams. Finally, indicate which two vectors were added to achieve this resultant (express as an equation such as $X + Y = Z$).



Resultant: _____

Resultant: _____

Eq'n: _____

Eq'n: _____

- A vector component _____. Choose two.
 - describes the effect of a vector in a given direction.
 - is found as the projection of a vector onto a coordinate axes.

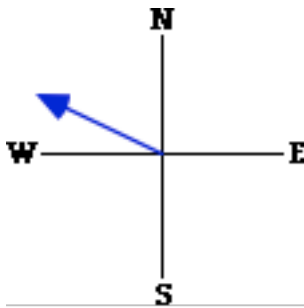
Addition of Vectors and the Equilibrium Principle

- When vectors are added using the head-to-tail method, the sum is known as the resultant. When force vectors are added, the sum or resultant is also known as the _____.
 - scalar
 - average
 - equilibrant
 - net force
- Several forces act upon an object. The vector sum of these forces ends up being 0 Newtons. The object is described as being _____.
 - weightless
 - at equilibrium
 - stationary
 - disturbed
- Which of the following is always true of an object that is at equilibrium? Select all that apply.
 - The net force acting upon it is 0 Newtons.
 - The individual forces acting upon it are balanced.
 - The object is at rest.
 - The object has no acceleration.
 - The object has a constant (unchanging) velocity.

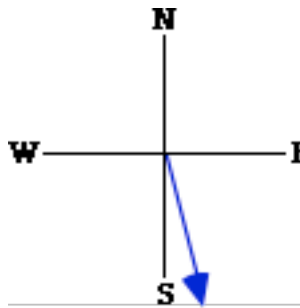
Forces in Two Dimensions

Resolving Forces into Vector Components

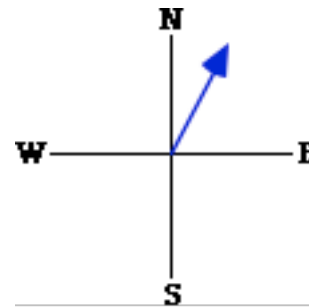
8. Consider the vectors below. Determine the direction of the two components by circling two directions (E, W, N or S). Finally indicate which component (or effect) is greatest in magnitude.



Components: E W N S
Greatest magnitude? _____

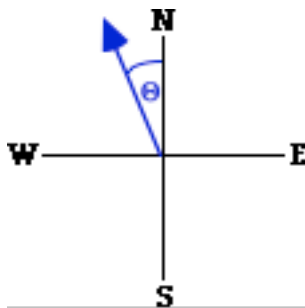


Components: E W N S
Greatest magnitude? _____

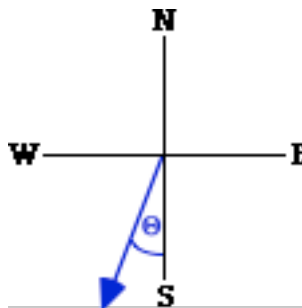


Components: E W N S
Greatest magnitude? _____

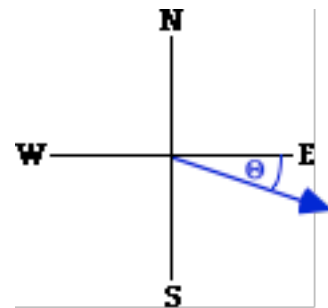
9. Each diagram displays a vector. The angle between the vector and the nearest coordinate axes is marked as theta (θ). If θ is gradually increased to 90 degrees, the magnitudes of the components would change. Which component would increase - horizontal (E/W) or vertical (N/S)?



Increasing component?
E W N S



Increasing component?
E W N S



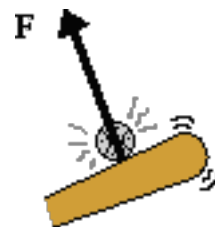
Increasing component?
E W N S

10. For the following situations, draw and label the force components of the given vector. Then use trigonometric functions to determine the magnitude of each component. Label the magnitudes of the component on the diagram. **PSYW**

- a. A 5.0 N force is exerted upon a dog chain at an angle of 65° above the horizontal.



- b. A baseball is hit by a bat with a force of 325 N at a direction of 105° .



Using Vector Components to Analyze Equilibrium Situations

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

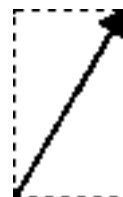
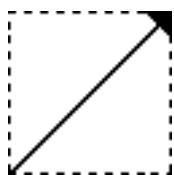
<http://www.physicsclassroom.com/Class/vectors/u3l3b.html>

<http://www.physicsclassroom.com/Class/vectors/u3l3c.html>

MOP Connection: Forces in Two Dimensions: sublevels 3 and 4

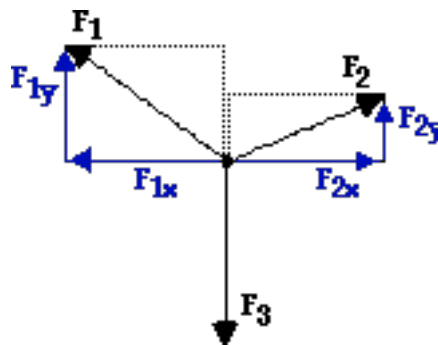
Many physical situations involve forces exerted at angles to the coordinate axes. A proper analysis of these situations demands that the forces be resolved into components that lie along the horizontal and vertical axes. This involves the use of trigonometric functions.

1. For the following situations, draw and label the force components as the projection onto the axes. Then use trigonometric functions to determine the magnitude of each component. Label the magnitudes of the component on the diagram. **PSYW**
 - a. Lon Mauer pulls up with a force of 75 N at an angle of 45° to the horizontal on the handle of his manual lawn mower.
 - b. Jean Yuss yanks on Spot's dog chain with a force of 12 N at an angle of 60° to the horizontal.



Use *your noodle* (that's your brain) to logically think through the following two questions.

2. Which of the following statements is **ALWAYS** true of an object at equilibrium?
 - a. The object is at rest.
 - b. The object is maintaining its state of motion.
 - c. The object's velocity is not changing.
 - d. The net force on the object is 0 Newtons.
 - e. The object is NOT accelerating.
 - f. The individual forces acting on the object are balanced.
 - g. All individual forces acting on the object are equal in magnitude.
3. The following statements were made about an object. In which case could you conclude that the object is at equilibrium?
 - a. The object is at rest.
 - b. The object has a constant velocity.
 - c. The object is moving.
 - d. The object has a constant speed.
 - e. The object is stationary.
 - f. The acceleration of the object is 0 m/s/s.
 - g. The individual forces acting on the object are balanced.
4. Three forces - F_1 , F_2 , and F_3 - are acting upon an object. Their relative magnitude and direction are shown at the right. The x- and y-components are also shown. Complete the following mathematical statements by placing $>$, $<$, and $=$ symbols in the blanks.



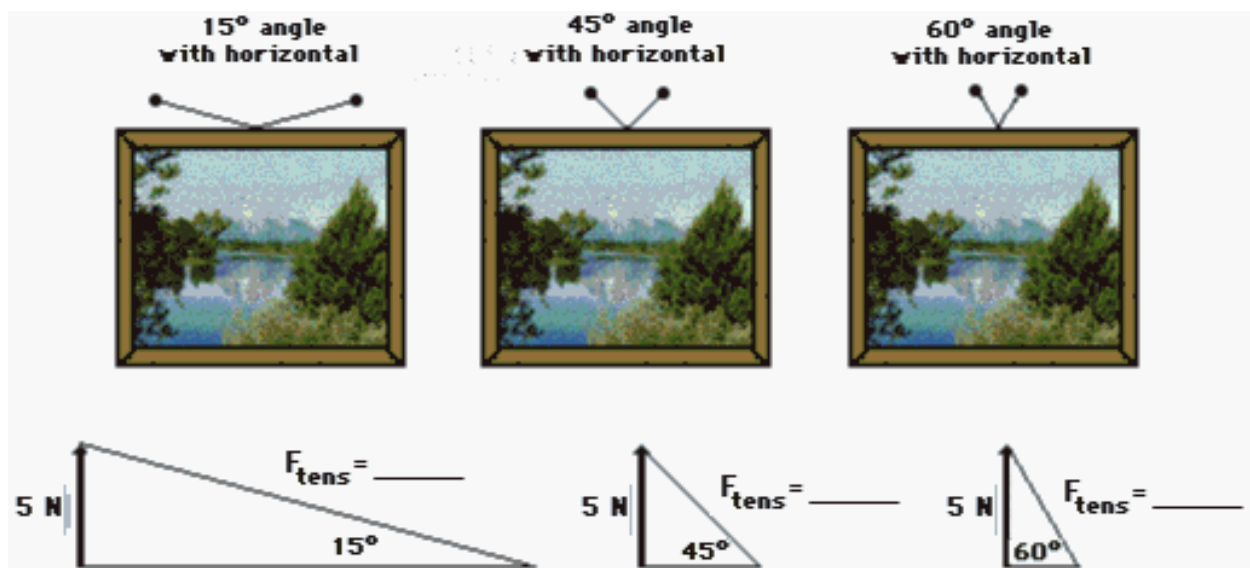
$$F_{1x} \text{ ____ } F_{2x} \qquad F_{1y} \text{ ____ } F_3$$

$$F_{2y} \text{ ____ } F_3 \qquad F_{1y} + F_{2y} \text{ ____ } F_3$$

Forces in Two Dimensions

Physics Tip: When a sign is hung *at equilibrium*, the downward pull of gravity must be balanced by the upward pull of the wires (cables, strings, etc.). In most cases, the wires are oriented diagonally such that the tension force has both a horizontal and vertical component. If the sign is hung symmetrically, then each wire pulls with the same amount of force and at the same angle. The vertical component of the tension will be the same in each wire. And if there are two wires, each wire must supply sufficient up pull to balance one-half the weight of the sign.

5. The three identical signs below are supported by wires at three different angle orientations. Since each sign has a weight of 10.0 N, each wire must exert a vertical component of force of 5.0 N. Use a trigonometric function to determine the tension in each wire. A diagram of each situation is shown.



If hanging the above sign with a given wire, which one of the above angles would provide for the safest arrangement? _____ Explain.

6. Suppose that a student pulls with two large forces (F_1 and F_2) in order to lift a 1-kg book by two cables. If the cables make a 1-degree angle with the horizontal, then what is the tension in the cable?



Using Vector Components to Analyze Accelerations along Level Surfaces

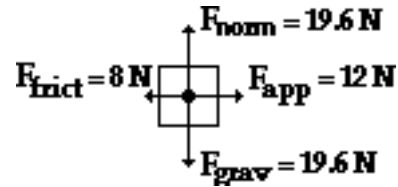
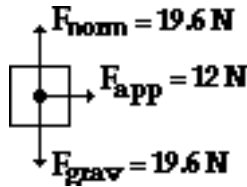
Read from Lesson 3 of the Vectors and Motion in Two-Dimensions chapter at The Physics Classroom:

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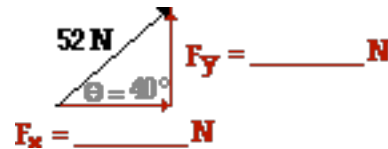
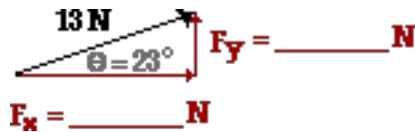
MOP Connection: Forces in Two Dimensions: sublevel 2

Review:

- Determine the acceleration value for the following two objects. PSYW

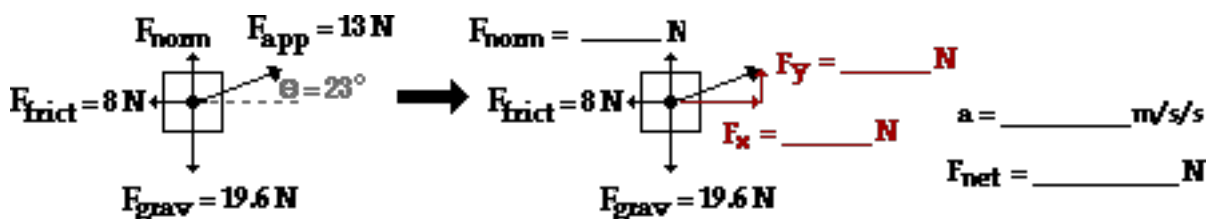
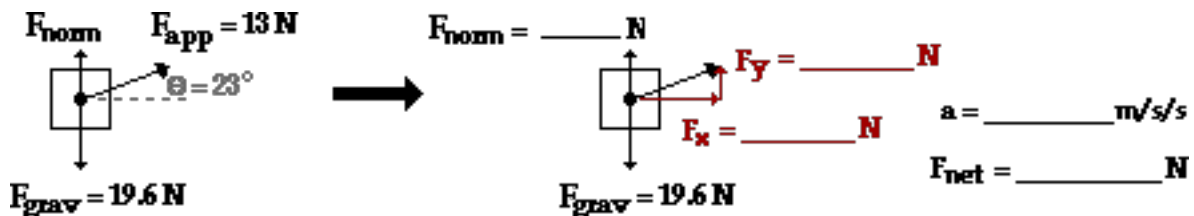


- Resolve the following two forces into horizontal and vertical components.

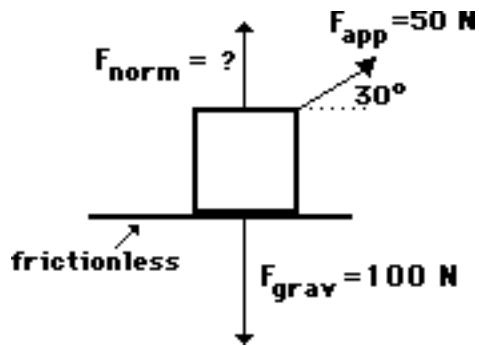


Physics Tip: Whenever you encounter a situation involving a force directed diagonally, make an effort to immediately convert the diagonal force into two perpendicular components. Use SOH CAH TOA to resolve any *uncooperative* force into two components - one being in the direction of the acceleration (or the motion) and the other being at right angles to it. Upon completing *the conversion*, ignore the uncooperative force and treat it as though it has been replaced by the two components.

- Use the above Physics Tip and SOH CAH TOA to fill in the blanks and determine the acceleration value for the following two situations.

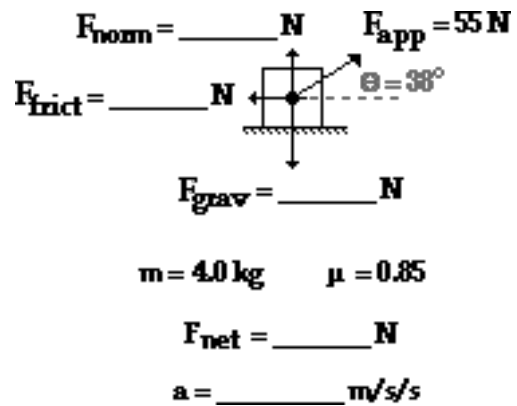
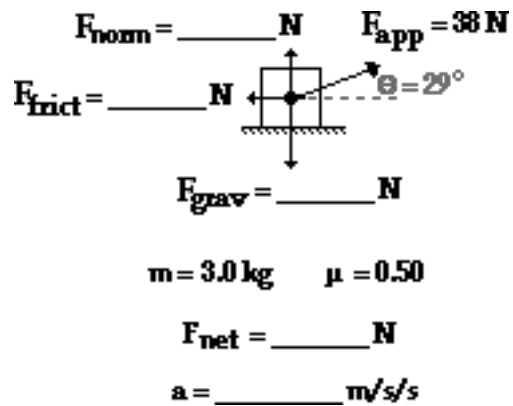


Forces in Two Dimensions

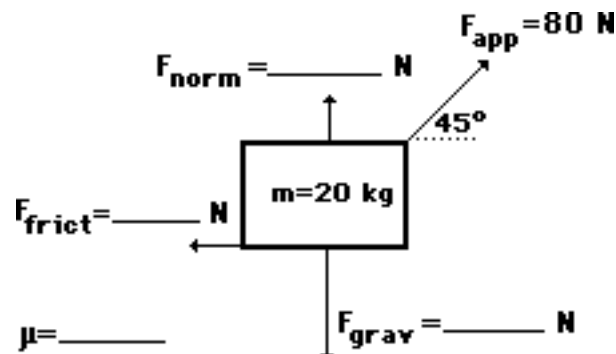


4. A 50-N applied force (30° to the horizontal) accelerates a 10-kg box across a horizontal sheet of ice (see diagram). Ben Thayer, Don Thatt, and Warren Peace are discussing the problem. Ben suggests that the normal force is 50 N; Don suggests that the normal force in the diagram is 75 N; and Warren suggests that the normal force is 100 N. While all three answers seem reasonable, only one is correct. Which is the correct normal force? _____ What error are the incorrect students likely making?

5. Fill in the blanks for the following two situations. PSYW



6. A box is pulled at a constant speed of 0.4 m/s across a frictional surface. Perform an extensive force analysis of the diagram and fill in the blanks. PSYW



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>

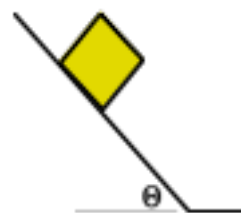
MOP Connection: Forces in Two Dimensions: sublevels 5 and 6

Review:

- A normal force is a force which is always directed _____.
 - upwards
 - sideways
 - perpendicular to the surface the object is contacting
- An object is upon a surface. The normal force is equal to the force of gravity _____.
 - in all situations
 - only when the object is at rest
 - only when the object is accelerating
 - only when there is no vertical acceleration
 - only when there is no vertical acceleration AND F_{norm} and F_{grav} are the only vertical forces

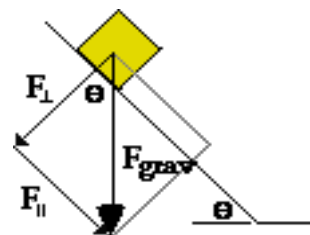
Getting the Forces Right:

- 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 *rough* 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.).



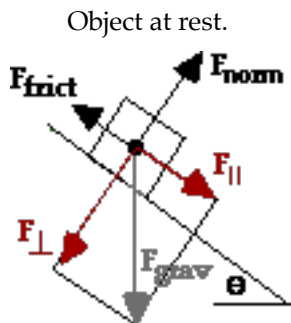
Physics Tip: When you encounter a situation involving a force directed at angles to all other forces, immediately convert the *uncooperative* force(s) into two perpendicular components. Use SOH CAH TOA to resolve any uncooperative force into components directed at right angles to each other. One component 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.

- 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 $F_{||}$ and F_{\perp} , use trigonometric functions to write equations relating these components to the force of gravity.

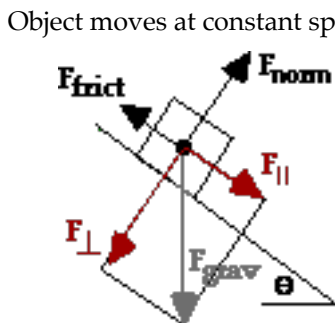


$F_{||} =$ _____ $F_{\perp} =$ _____

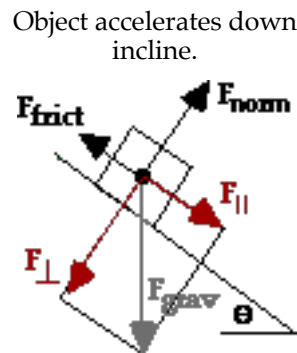
- For the three situations described below, use $<$, $>$, or $=$ symbols to complete the statements.



$F_{||}$ _____ F_{frict}
 F_{\perp} _____ F_{norm}



$F_{||}$ _____ F_{frict}
 F_{\perp} _____ F_{norm}

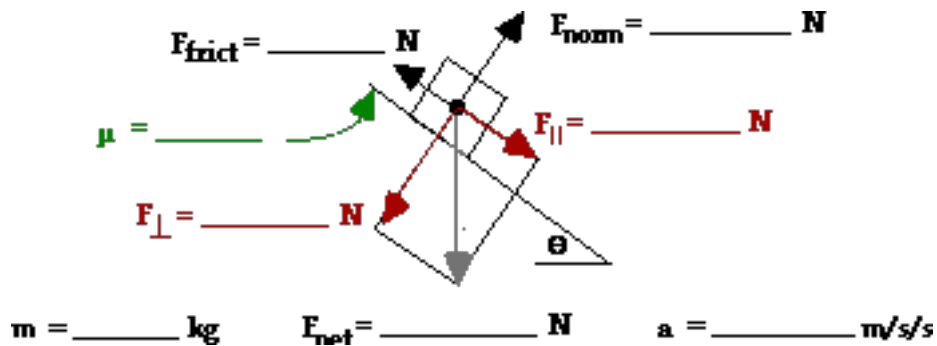


$F_{||}$ _____ F_{frict}
 F_{\perp} _____ F_{norm}

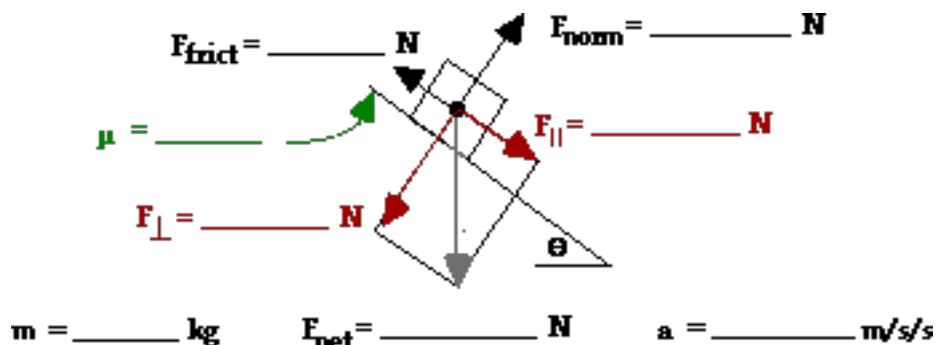
Forces in Two Dimensions

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

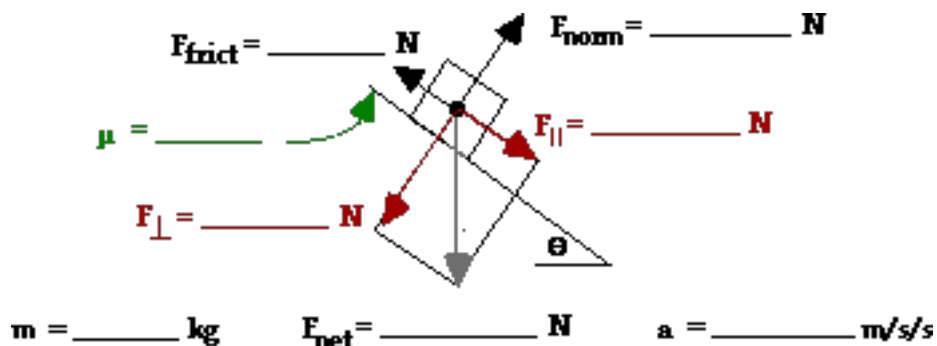
6. A 4.50-kg object is accelerating down an inclined plane inclined at 36.0° (with the horizontal) and having a coefficient of friction of 0.548.



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



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.



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 turns into a simple $F_{\text{net}} = m \cdot a$ problem.

