Physics 122/121

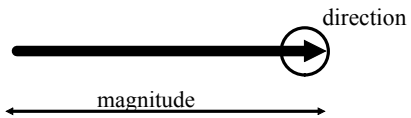
Unit 1

Dynamics Extension

VECTOR REVIEW

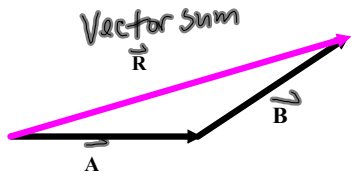
Vector quantities have both magnitude and direction. Some vector quantities are velocity, force, acceleration and momentum.

Vectors are represented by arrows.

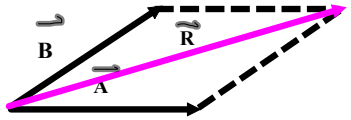


Graphical Methods of Adding Vectors

1. Tip-to-tail Method



2. Parallelogram Method



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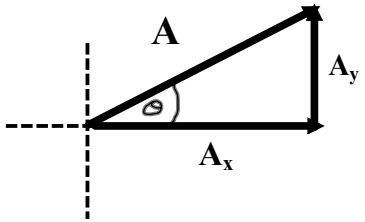
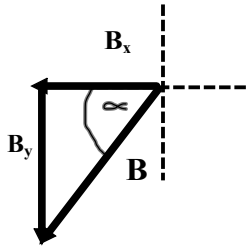
Perpendicular Components of a Vector

A vector can be expressed as the sum of two other vectors, called the components of the vector. The process of finding the components of a vector is called vector resolution. We will always be finding the perpendicular components of a vector.





Use trigonometric ratios to determine the magnitudes of the components. The arrows on the components show their directions.

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Try: Determine the perpendicular components of a velocity vector with a magnitude of 12 km/h and a direction of 35° S of E.

$\vec{A}_x$ = 9.8 km/h, east

$\vec{A}_y$ = 6.9 km/h, south

Adding Vectors Using Perpendicular Components

1. Resolve each vector into its perpendicular components.

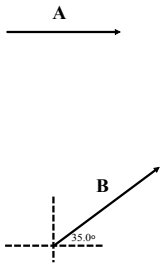
2. Add corresponding vector components.

$$\mathbf{R_x} = \mathbf{A_x} + \mathbf{B_X}$$
$$\mathbf{R_y} = \mathbf{A_y} + \mathbf{B_y}$$

3. Sketch $\mathbf{R_x}$ and $\mathbf{R_y}$ tip-to-tail.

4. Use the Law of Pythagoras and a trig ratio to determine the magnitude and direction of the resultant.

Example - Find the resultant of 1.60 km, east and 3.40 km, 35.0° N of E.



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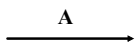
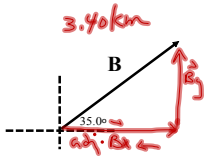
Example - Find the resultant of 1.60 km, east and 3.40 km, 35.0° N of E.



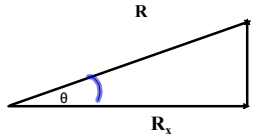
$A_x = +1.60$ km
$A_y = 0$ km



$B_x = (3.40 \text{ km})(\cos 35.0^\circ)$
$B_x = +2.785$ km

$B_y = (3.40 \text{ km})(\sin 35.0^\circ)$
$B_y = +1.950$ km

$R_x = 1.60 \text{ km} + 2.785 \text{ km} = 4.385 \text{ km}$
$R_y = 0 \text{ km} + 1.950 \text{ km} = 1.950 \text{ km}$



$R = \sqrt{(4.385)^2 + (1.950)^2}$

$R = 4.80$ km ← magnitude

$\tan\theta = \frac{R_y}{R_x}$

$\theta = 24.0^\circ$ ← direction

$\vec{R} = 4.80$ km, 24.0° N of E

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Handout: Vectors - Perpendicular Components

Reminders and Important Notes

Newton's Second Law

$$F_{net} = ma$$

- If an object is at rest or moving with constant velocity, its acceleration is zero.
- Forces acting vertically cannot be combined with horizontal forces.
- In force problems, include a labelled sketch or FBD (free body diagram).

Remember: $W = mg$ and $F_f = \mu N$

Force Problems Involving Components

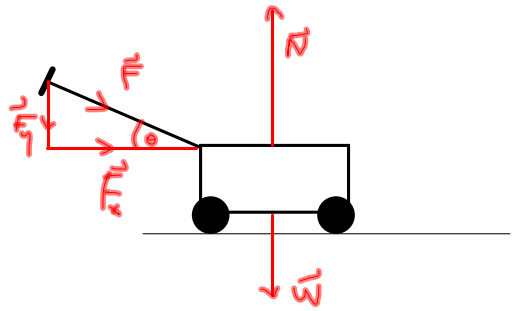
Type I - Pulling or Pushing An Object (lawnmower, wagon, cart)

A person pulls a 10.0 kg box by a rope along the smooth surface of the floor. The magnitude of the force exerted by the person is 40.0 N and it is exerted at a 30.0° angle. Calculate:

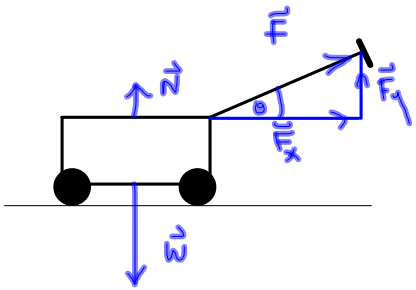
a) the acceleration of the box
b) the magnitude of the upward force exerted by the floor on the box

Push vs. Pull
Including Friction

push



pull



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Handout: Force Problems - Type I

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17. A student pushes a 25 kg lawn mower with a force of 150 N. The handle makes an angle of 35° to the horizontal.

(a) Find the vertical and horizontal components of the applied force.

(b) Calculate the normal force supporting the lawn mower while it is being pushed.

(c) Calculate the net force propelling the mower if a frictional force of 85 N exists.

(d) Calculate the horizontal acceleration of the lawn mower. (Remember: Only part of the $F_{applied}$ is parallel to the direction of horizontal acceleration.)

a) 86 N, down
1.2×10^2 N, right
b) 3.3×10^2 N, up
c) 38 N, right
d) 1.5 m/s^2, right

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24. A toboggan with a mass of 15 kg is being pulled with an applied force of 45 N at an angle of 40° to the horizontal. What is the acceleration if the force of friction opposing the motion is 28 N?

0.43 m/s^2, right

25. A grocery cart is being pushed with a force of 450 N at an angle of 30.0° to the horizontal. If the mass of the cart and the groceries is 42 kg,

(a) Calculate the force of friction if the coefficient of friction is 0.60.

(b) Determine the acceleration of the cart.

a) 3.8×10^2 N, left
b) 0.23 m/s^2, right

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36. A 45.0 kg box is pulled with a force of 205 N by a rope held at an angle of 46.5° to the horizontal. The velocity of the box increases from 1.00 m/s to 1.50 m/s in 2.50 s. Calculate

(a) the net force acting horizontally on the box.

(b) the frictional force acting on the box.

(c) the horizontal component of the applied force.

(d) the coefficient of kinetic friction between the box and the floor.

a) 9.0 N, right
b) 132 N, left
c) 141 N, right
d) 0.451

Pocket Lab

Force Vectors

- Tie two loops in the ends of a rope that is about 1 m long.
- Hold a loop in each hand as a classmate carefully hangs a 1 kg mass on the ribbon.
- Start with your hands together and slowly move your hands apart.
- Try to make the ribbon straight.

Is it possible? How are the forces acting?

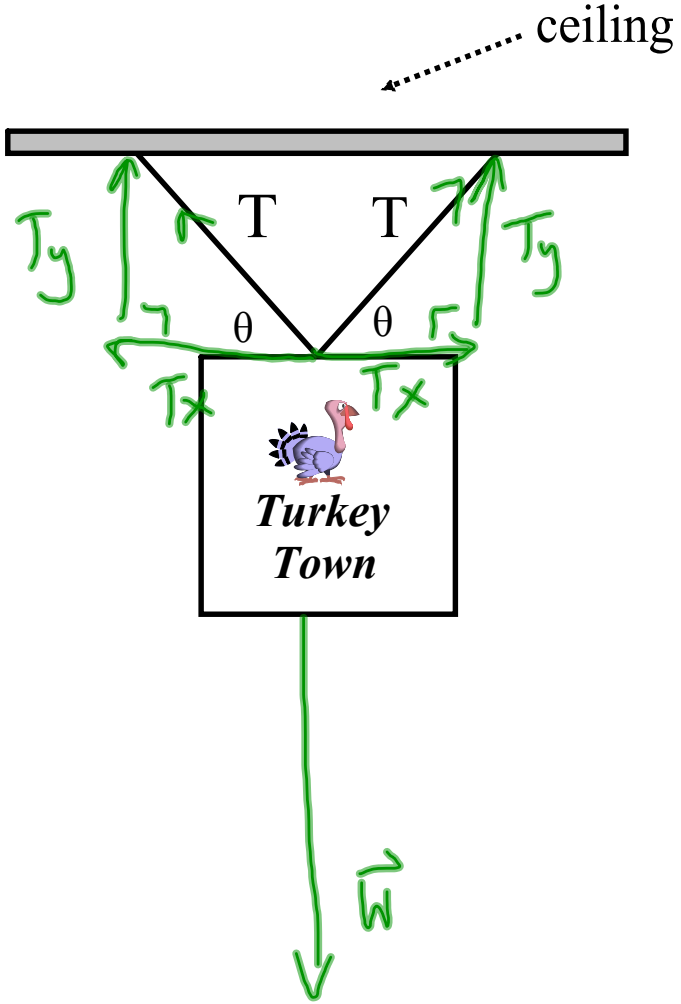
Static Equilibrium

equilibrium: *the state of an object when the vector sum of all the forces acting on it is zero*

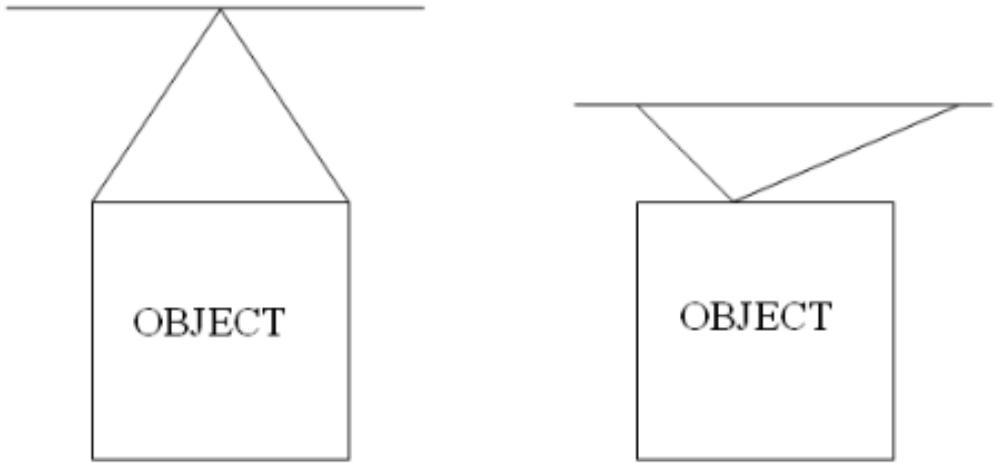
If an object is at ***rest*** and is in ***equilibrium***, then we say that it is in a state of "***static equilibrium***."

Type II - Signs/Pictures/Hanging Objects

If an object is hung by a rope (wire, chain, etc.), we can resolve the force of tension along the rope.

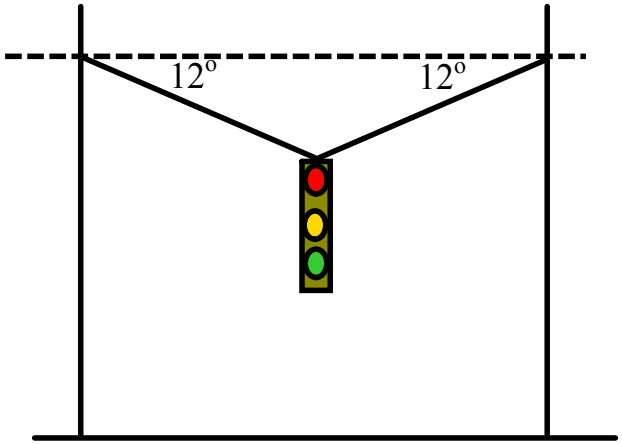


An object can be hung in a variety of ways.



Example

A traffic light hangs in the center of the road from cables as shown in the figure. If the mass of the traffic light is 65 kg, what is the magnitude of the force that each cable exerts on the light to prevent it from falling? (1.5×10^3 N)

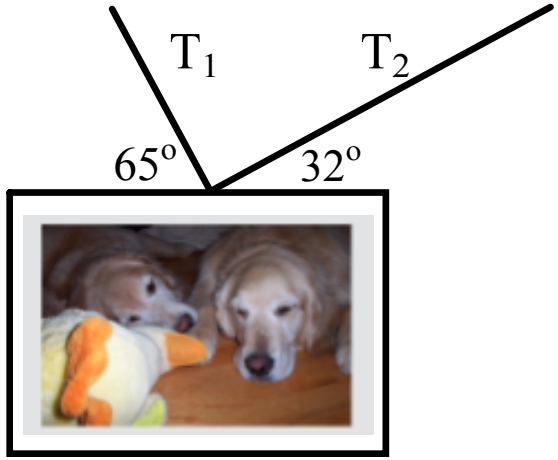


Example

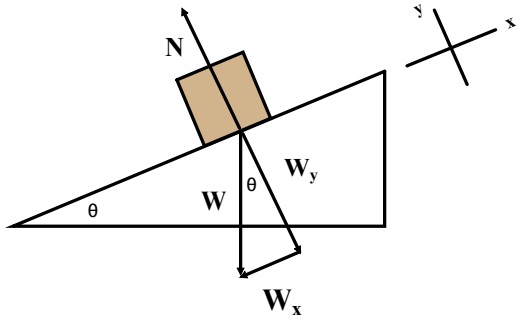
A picture hangs on a wall suspended by two strings, as shown. The magnitude of the tension in string 1 is 1.7 N.

a) What is the magnitude of the tension in string 2? (0.85 N)

b) What is the weight of the picture? (-2.0 N)



Type III - Inclined Planes, Hills, Ramps



REMEMBER:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t} \qquad \vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d} \qquad \vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

Simulation

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Examples

1. A 1975 kg car is rolling down a hill inclined at an angle of 15^{o}. What is the acceleration of the car? Neglect friction. ($2.5\ m/s^2$ down the hill)

2. A skier coasts down a 3.5^{o} slope at a constant speed. Find the coefficient of kinetic friction between the skis and the snow covering the slope. (0.061)

Sample Problems - **Inclined Planes**

1. A trunk weighing 562 N is resting on a plane inclined at 30.0° from the horizontal. Find the components of the trunk's weight parallel and perpendicular to the plane.

2. A 562 N trunk is placed on a frictionless plane inclined at 30.0° from the horizontal. Find the magnitude and direction of the trunk's acceleration.

3. A worker places a large plastic waste container with a mass of 84 kg on the ramp of a loading dock. The ramp makes an angle of 22° with the horizontal. The worker turns to pick up another container before pushing the first one up the ramp. If the coefficient of static friction is 0.47, will the crate slide down the ramp?

4. A 1975 kg car is rolling down a hill inclined at an angle of 15°. What is the acceleration of the car? Neglect friction.

5. A skier coasts down a 3.5° slope at a constant speed. Find the coefficient of kinetic friction between the skis and the snow covering the slope.

6. You slide a 325 N trunk up a 20.0° inclined plane with a constant velocity by exerting a force of 211 N parallel to the inclined plane.

   a) What is the sum of your applied force, friction and the parallel component of the trunk's weight? Justify your answer.

   b) What is the magnitude and direction of the force of friction?

   c) What is the coefficient of friction?

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Page 194, #27, 28

Handout - Problems I, II and III

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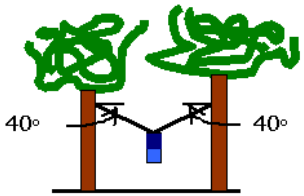
Handout: Problems I, II and III

1. On a camping trip you stretch a rope between two trees and hang your backpack from the middle of it to keep it safe from bears. The mass of your backpack is 36.0 kg and each half of the rope makes an angle of 40.0° with the horizontal.
    a) Find the amount of weight supported by each half of the rope.
    b) Find the magnitude of the tension in each rope.



2. A 2.5 kg brick is pulled at a constant speed across a table by a cord that makes an angle of 20° with the horizontal. There is 7.0 N of force in the cord.
    a) Calculate the force of friction between the brick and the table.
    b) Calculate the normal force.

3. Joey moves a 26 kg wagon at a constant speed by pushing on the handle that makes an angle, theta, with the horizontal. Joey exerts a force of 54 N on the handle and the force of friction on the wagon is 34 N.
    a) Calculate the angle the handle of the wagon makes with the horizontal.
    b) What is the magnitude of the normal force acting on the wagon?

4. A 10 N block is held motionless on a frictionless inclined plane which makes an angle of 30° with the horizontal. What force would be needed to hold the block in position?

5. An object weighing 600 N is pulled up a frictionless incline at a constant speed using a rope. If the incline makes an angle of 42.0° with the horizontal, what is the magnitude of the force that is applied to the rope?

6. A 10 kg object, starting from rest, slides down a frictionless incline with a constant acceleration of 2.0 m/s^2. What angle does the incline make with the horizontal?

7. An object with a mass of 7.2 kg is allowed to slide from rest down an inclined plane. The plane makes an angle of 30° with the horizontal and is 65 m long. The coefficient of friction between the plane and the object is 0.45. What is the velocity of the object at the bottom of the plane?

8. A piano is accelerating down a ramp that is inclined at an angle of 38.5° above the horizontal. The acceleration is 4.62 m/s^2. What is the coefficient of friction between the piano and the ramp?

Answers

1. a)Each half of the rope supports half of the weight of the backpack, 176 N.
   b)The tension in each rope is 274 N.

2. a)The force of friction is 6.6 N, in a direction opposite to the motion of the brick.
   b)The magnitude of the normal force is 22 N.

3. a)The handle makes an angle of 51° with the horizontal.
   b)The normal force is 3.0×10^{2} N, up.

4. A 5.0 N force exerted up the incline would be needed.

5. It is 401 N.

6. The incline makes an angle of 12°.

7. The velocity of the object is –12 m/s.

8. The coefficient of friction is 0.19.