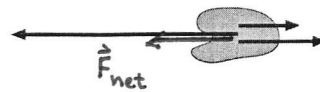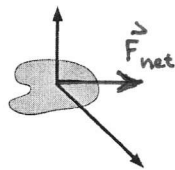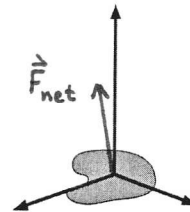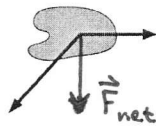# 5 Force and Motion

5.1 Force

1. Two or more forces are shown on the objects below. Draw and label the net force $\vec{F}_{net}$.

2. Two or more forces are shown on the objects below. Draw and label the net force $\vec{F}_{net}$.

5.2 A Short Catalog of Forces

5.3 Identifying Forces

Exercises 3–8: Follow the six-step procedure of Tactics Box 5.2 to identify and name all the forces acting on the object.

3. An elevator suspended by a cable is descending at constant velocity.
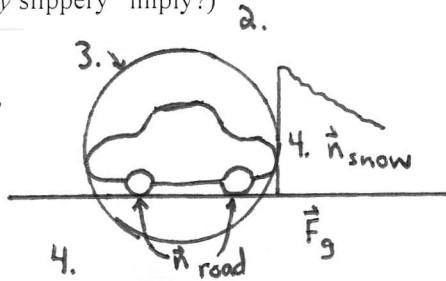
1. System: elevator
   Environment: cable

2.

5. Cable exerts a tension force $\vec{T}$

4.

←3.

6. Weight $\vec{F}_g$

4. A car on a *very* slippery icy road is sliding headfirst into a snowbank, where it gently comes to rest with no one injured. (Question: What does "*very* slippery" imply?)

1. System : Car
   Environment : Road, Snowbank
5. The snowbank and road each exert normal forces $\vec{n}_i$.
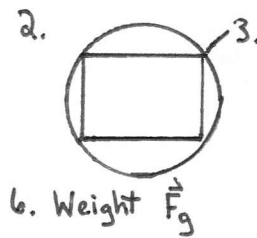6. Weight $\vec{F}_g$

5. A compressed spring is pushing a block across a rough horizontal table.

1. System : Black
   Environment : spring, table
5. Spring exerts $\vec{F}_{sp}$.
   Table exerts normal force $\vec{n}$ and kinetic friction $\vec{f}_k$
6. Weight $\vec{F}_g$
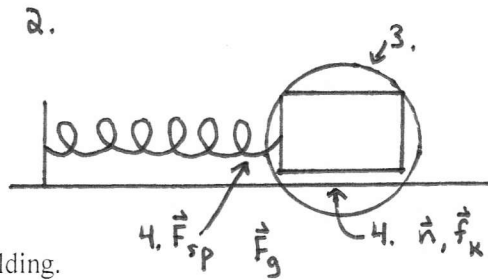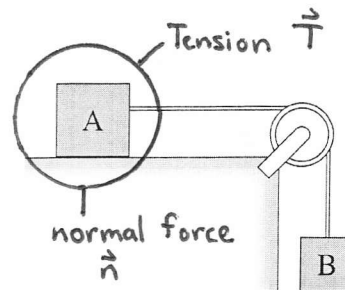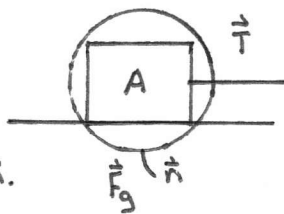
6. A brick is falling from the roof of a three-story building.

1. System: Brick
   Environment : none

6. Weight $\vec{F}_g$

7. Blocks A and B are connected by a string passing over a pulley. Block B is falling and dragging block A across a frictionless table. Analyze block A.
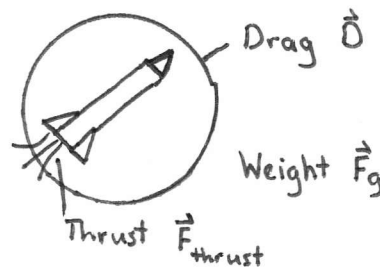
1. System: Block
   Environment: Table, String

Table exerts normal force, $\vec{n}$.
String exerts tension $\vec{T}$.

Tension $\vec{T}$
normal force $\vec{n}$
6. Weight $\vec{F}_g$

8. A rocket is launched at a 30° angle. Air resistance is not negligible.

1. System : Rocket
   Environment : Air, exhaust

Drag $\vec{D}$
Weight $\vec{F}_g$
Thrust $\vec{F}_{thrust}$

5.4 What Do Forces Do? A Virtual Experiment

9. The figure shows an acceleration-versus-force graph for an object of mass m. Data have been plotted as individual points, and a line has been drawn through the points.

   Draw and label, directly on the figure, the acceleration-versus-force graphs for objects of mass

   a. $2m$ b. $0.5m$

   Use triangles ▲ to show four points for the object of mass $2m$, then draw a line through the points. Use squares ■ for the object of mass $0.5m$.

Acceleration

Force (rubber bands)
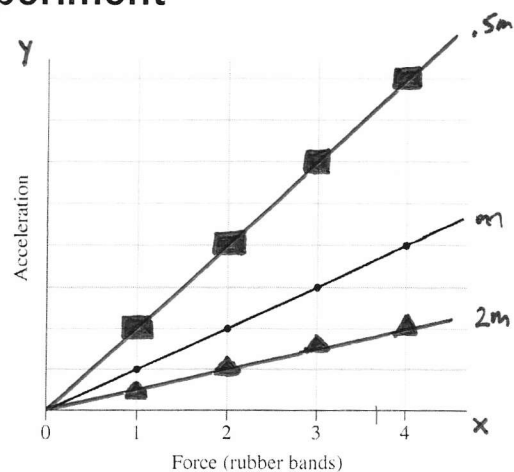
10. A constant force applied to object A causes A to accelerate at 5 m/s². The same force applied to object B causes an acceleration of 3 m/s². Applied to object C, it causes an acceleration of 8 m/s².

    a. Which object has the largest mass? **B**
    b. Which object has the smallest mass? **C**
    c. What is the ratio of mass A to mass B? $(m_A/m_B) =$ **3/5**

11. A constant force applied to an object causes the object to accelerate at 10 m/s². What will the acceleration of this object be if

    a. The force is doubled? $20\frac{m}{s^2}\left(=\frac{2F}{m}\right)$ b. The mass is doubled? $5\frac{m}{s^2}\left(=\frac{F}{2m}\right)$
    c. The force is doubled *and* the mass is doubled? Same, $10\frac{m}{s^2}\left(=\frac{2F}{2m}\right)$
    d. The force is doubled *and* the mass is halved? $40\,{}^m/s^2\left(=\frac{2F}{m/2}\right)$

12. A constant force applied to an object causes the object to accelerate at 8 m/s². What will the acceleration of this object be if

    a. The force is halved? $4\,{}^m/s^2$ b. The mass is halved? $16\,{}^m/s^2\left(=\frac{F}{m/2}\right)$
    c. The force is halved *and* the mass is halved? $8\,{}^m/s^2\left(=\frac{F/2}{m/2}\right)$
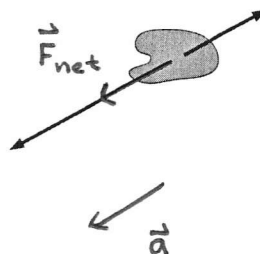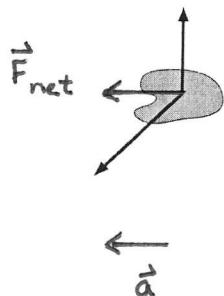   d. The force is halved *and* the mass is doubled? $2\,{}^m/s^2 = \left(\frac{F/2}{2m}\right)$

5.5 Newton's Second Law
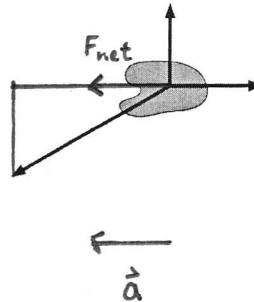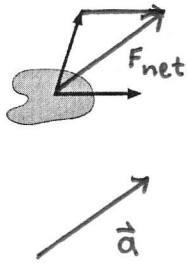
13. Forces are shown on two objects. For each:
    a. Draw and label the net force vector. Do this right on the figure.
   b. Below the figure, draw and label the object's acceleration vector.

14. Forces are shown on two objects. For each:
    a. Draw and label the net force vector. Do this right on the figure.
    b. Below the figure, draw and label the object's acceleration vector.

15. In the figures below, one force is missing. Use the given direction of acceleration to determine the missing force and draw it on the object. Do all work directly on the figure.
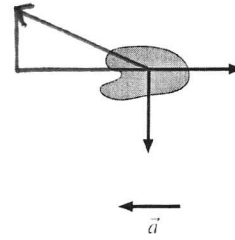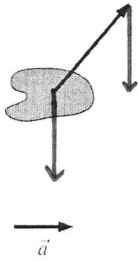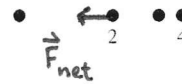
16. Below are two motion diagrams for a particle. Draw and label the net force vector at point 2.
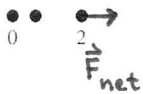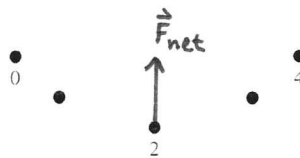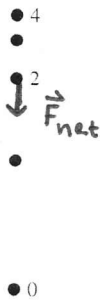
17. Below are two motion diagrams for a particle. Draw and label the net force vector at point 2.

5.6 Newton's First Law

18. If an object is at rest, can you conclude that there are no forces acting on it? Explain.

> No. The object's state of rest only tells us about the net force or vector <u>sum</u> of the forces, which must be zero. There may be any number of counter-balancing forces.

19. If a force is exerted on an object, is it possible for that object to be moving with constant velocity? Explain.

> If there is a <u>net</u> force on the object, it must have a changing velocity vector. The object will move at constant velocity if the vector sum of the forces acting on it is zero.

20. A hollow tube forms three-quarters of a circle. It is lying flat on a table. A ball is shot through the tube at high speed. As the ball emerges from the other end, does it follow path A, path B, or path C? Explain your reasoning.
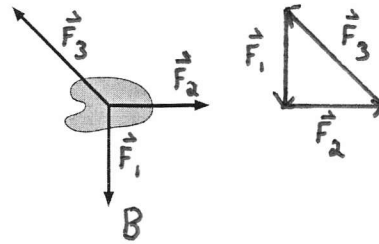
> The ball will follow path C. After leaving the tube, the ball no longer is in contact with the wall of the tube and, with no net force, will continue in a straight line.

View from above
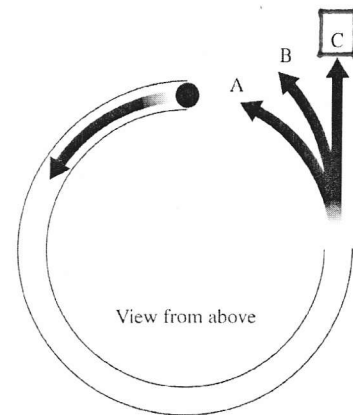
21. Which, if either, of the objects shown below is in equilibrium? Explain your reasoning.
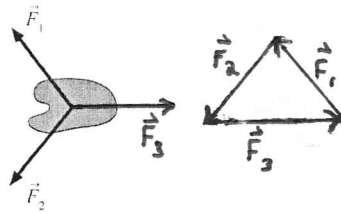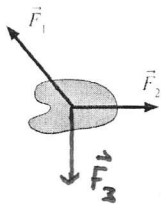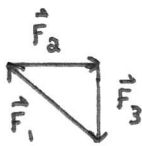

A
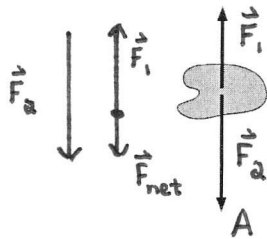
The above object A is not in equilibrium. $|F_2| > |F_1|$ so there is a net downward force on A.

B

Object B is in equilibrium. The vector sum of forces $\vec{F_1} + \vec{F_2} + \vec{F_3} = 0$.

22. Two forces are shown on the objects below. Add a third force $\vec{F_3}$ that will cause the object to be in equilibrium.

23. Are the following inertial reference frames? Answer Yes or No.

   a. A car driving at steady speed on a straight and level road.   Yes

   b. A car driving at steady speed up a 10° incline.   Yes

   c. A car speeding up after leaving a stop sign.   No

   d. A car driving at steady speed around a curve.   No

   e. A hot air balloon rising straight up at steady speed.   Yes

   f. A skydiver just after leaping out of a plane.   No

   g. The space shuttle orbiting the earth.   No

5.7 Free-Body Diagrams

Exercises 24–29:
- Draw a picture and identify the forces, then
- Draw a complete free-body diagram for the object, following each of the steps given in Tactics Box 5.3. Be sure to think carefully about the direction of $\vec{F}_{net}$.

Note: Draw individual force vectors with a **black** or **blue** pencil or pen. Draw the *net* force vector $\vec{F}_{net}$ with a **red** pencil or pen.
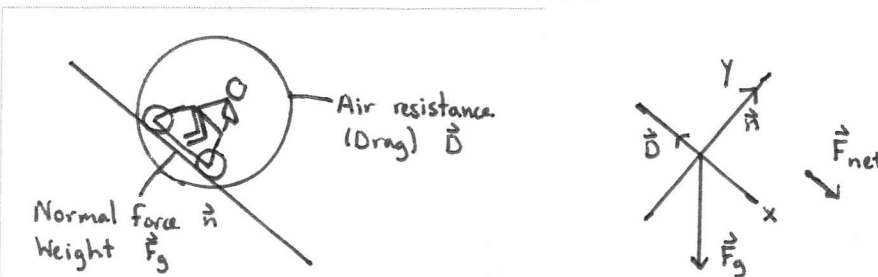
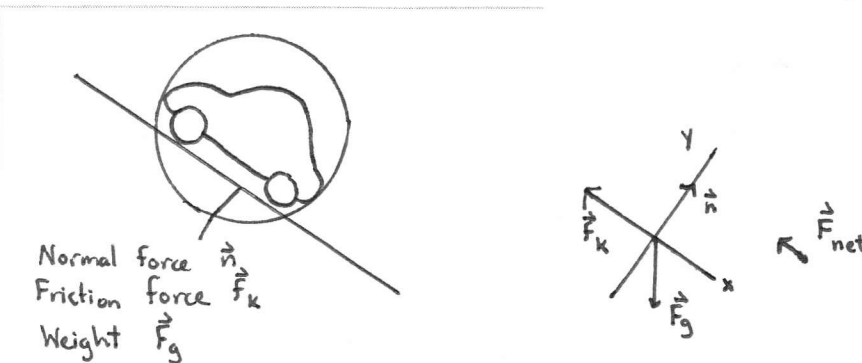24. A heavy crate is being lowered straight down at a constant speed by a steel cable.
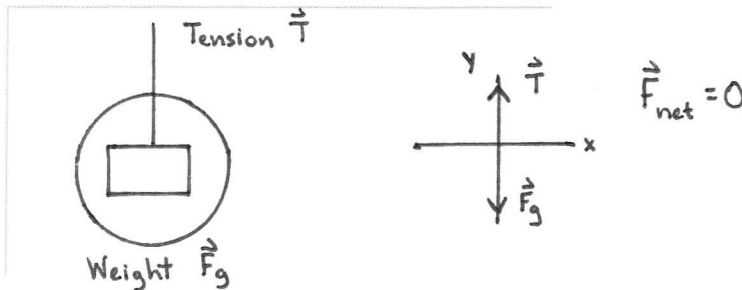
25. A boy is pushing a box across the floor at a steadily increasing speed. Let the box be "the system" for analysis.
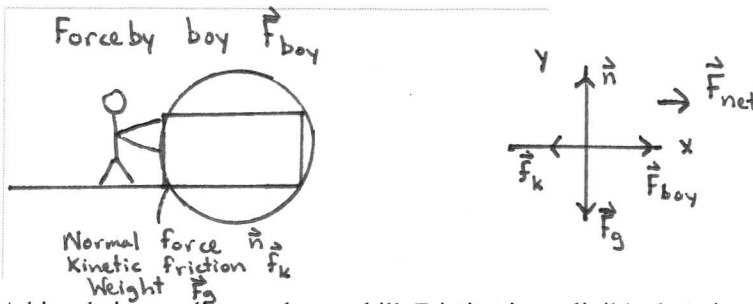
26. A bicycle is speeding up down a hill. Friction is negligible, but air resistance is not.

27. You've slammed on your car brakes while going down a hill. You're skidding to a halt.

28. You are going to toss a rock *straight up* into the air by placing it on the palm of your hand (you're not gripping it), then pushing your hand up very rapidly. You may want to toss an object into the air this way to help you think about the situation. The rock is "the system" of interest.

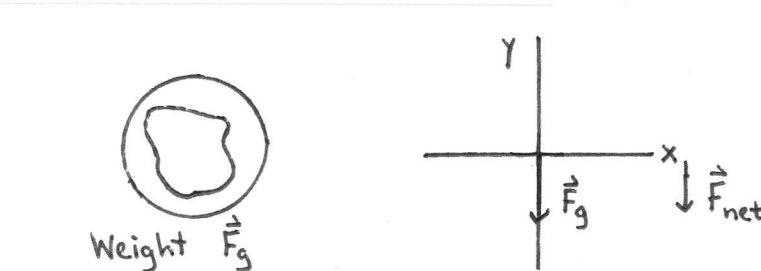a. As you hold the rock at rest on your palm, before moving your hand.
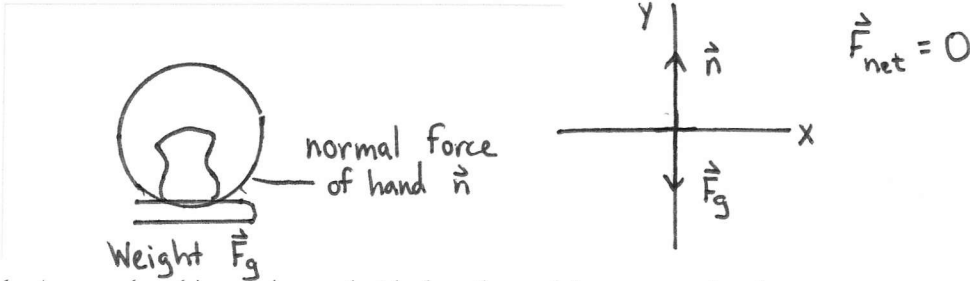
b. As your hand is moving up but before the rock leaves your hand.
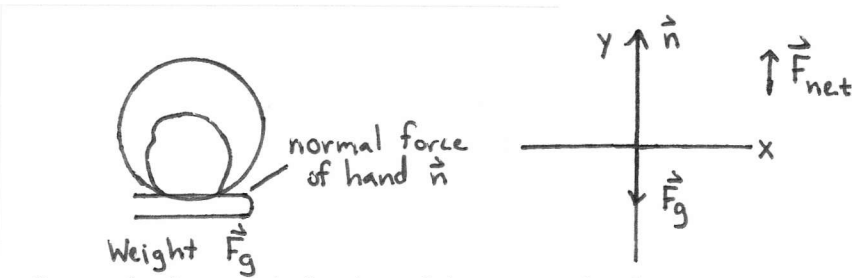
c. One-tenth of a second after the rock leaves your hand.

d. After the rock has reached its highest point and is now falling straight down.

29. Block B has just been released and is beginning to fall. The table has friction. Analyze block A.