Physics 2A
Chapter 4: Forces and Newton's Laws of Motion

"There is nothing either good or bad, but thinking makes it so." **–** William Shakespeare

"It's not what happens to you that determines how far you will go in life; it is how you handle what happens to you." – Zig Ziglar

Reading: pages 102 – 124

Outline:

⇒ Newton's 1st law
  inertia and mass
⇒ forces
  what is a force?
  different kinds of forces
⇒ identifying forces
⇒ Newton's 2nd law
  units of force
⇒ free-body diagrams (FBDs)
⇒ Newton's 3rd law

Problem Solving

Definite procedures has been devised for identifying the forces acting on an object and then drawing a free-body diagram. These procedures are given in Tactics Box 4.2 on page 111 and Tactics Box 4.3 on page 118. The list below gives a simplified version of these procedures.

1. Identify the object to be considered. It is usually the object on which the given forces act or about which a question is posed.
2. Draw a sketch of the situation that includes the object of interest and all other objects (ropes, surfaces, …) that touch it. Identify all contact and long-range forces that act on the object. The hard part is getting all the forces. If appropriate, don't forget to include the gravitational force on the object, the normal force of a surface on the object, any frictional forces, and the forces of any strings or rods attached to the object. (Some students erroneously include forces that are not acting on the object. For each force you include you should be able to point to something in the environment that is exerting the force. This simple procedure should prevent you from erroneously including a normal force, for example, when the object you are considering is not in contact with a surface.)
3. Draw a coordinate system and represent the object by a dot at the origin of the coordinate axes.
4. Draw vectors that represent each of the identified forces. Place the tail of each force vector on the object, which is represented as a dot. Be sure to label each force vector.
5. Draw and label the net force vector $\vec{F}_{net}$ next to the free-body diagram. Check that $\vec{F}_{net}$ points in the same direction as the acceleration vector $\vec{a}$, or, if appropriate, write $\vec{F}_{net} = 0$.

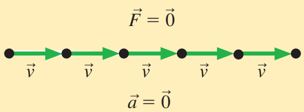
SUMMARY

The goal of Chapter 4 has been to establish a connection between force and motion.

GENERAL PRINCIPLES

Newton's First Law

Consider an object with no force acting on it. If it is at rest, it will remain at rest. If it is in motion, then it will continue to move in a straight line at a constant speed.



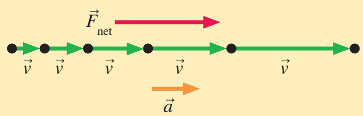
The first law tells us that no "cause" is needed for motion. Uniform motion is the "natural state" of an object.

Newton's Second Law

An object with mass m will undergo acceleration

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

where the net force $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$ is the vector sum of all the individual forces acting on the object.



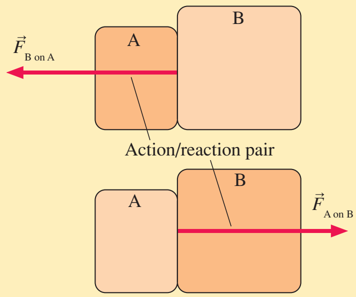
The second law tells us that a net force causes an object to accelerate. This is the connection between force and motion. The acceleration points in the direction of $\vec{F}_{net}$.

Newton's Third Law

Every force occurs as one member of an **action/reaction** pair of forces. The two members of an action/reaction pair:

- act on two *different* objects.
- point in opposite directions and are equal in magnitude:

$$\vec{F}_{A\ on\ B} = -\vec{F}_{B\ on\ A}$$



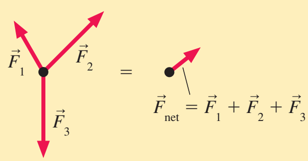
IMPORTANT CONCEPTS

Force is a push or pull on an object.

- Force is a vector, with a magnitude and a direction.
- A force requires an agent.
- A force is either a contact force or a long-range force.

The SI unit of force is the **newton** (N). A 1 N force will cause a 1 kg mass to accelerate at 1 m/s^2.

Net force is the vector sum of all the forces acting on an object.



Mass is the property of an object that determines its resistance to acceleration.

If the same force is applied to objects A and B, then the ratio of their accelerations is related to the ratio of their masses as

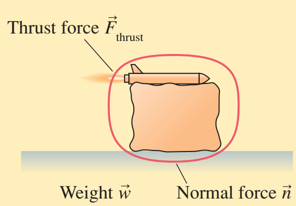
$$\frac{a_A}{a_B} = \frac{m_B}{m_A}$$

The mass of objects can be determined in terms of their accelerations.

APPLICATIONS

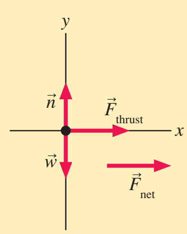
Identifying Forces

Forces are identified by locating the points where other objects touch the object of interest. These are points where contact forces are exerted. In addition, objects feel a long-range weight force.



Free-Body Diagrams

A free-body diagram represents the object as a particle at the origin of a coordinate system. Force vectors are drawn with their tails on the particle. The net force vector is drawn beside the diagram.

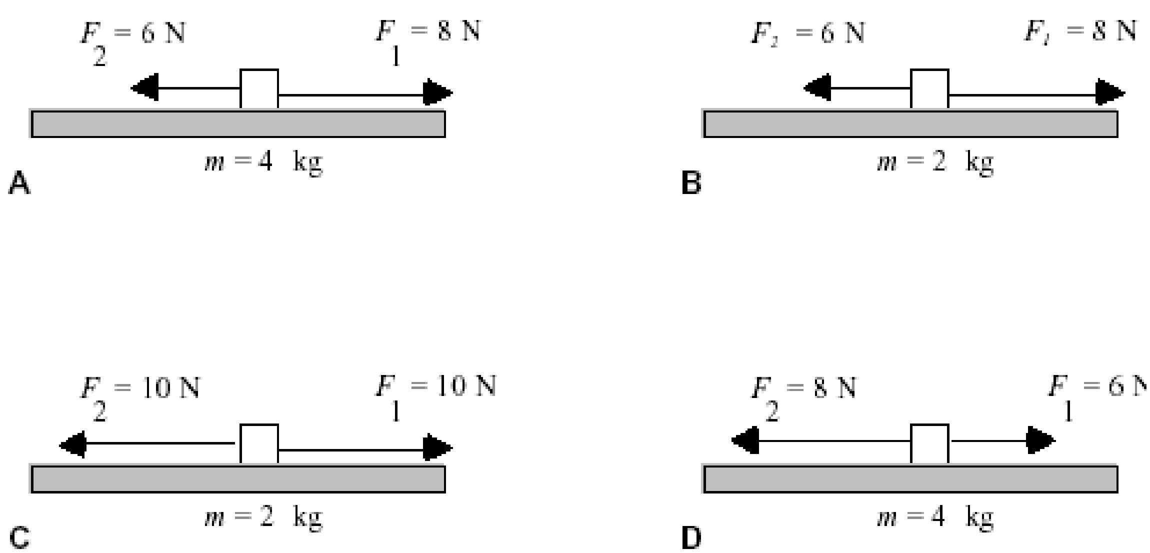


Questions and Example Problems from Chapter 4

Question 1
Why do you lung forward when your car suddenly comes to a halt? Why are you pressed backward against the seat when your car rapidly accelerates?

Question 2
A person sits on a sloped hillside. Is it ever possible to have the static friction force on this person point down the hill? Explain.

Question 3
Two forces act on an object that is on a frictionless surface, as shown below. Rank these situations from greatest acceleration to least acceleration. (Note: All vectors directed to the right are positive, and those to the left are negative. Also, 0 m/s^2 > -10 m/s^2.)



Greatest 1__________ 2___________ 3__________ 4__________ Least

Problem 1
A baseball player is sliding into second base. Identify the forces on the baseball player.

Problem 2
A constant force is applied to an object, causing the object to accelerate at 8.0 m/s^2. What will the acceleration be if

a) The force is doubled?

b) The object's mass is doubled?

c) The force and the object's mass are both doubled?

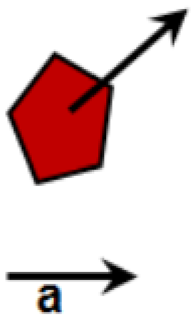
d) The force is doubled and the object's mass is halved?

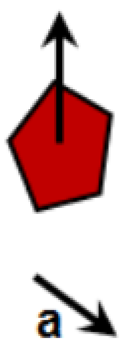
Problem 3
Two children fight over a 200 g stuffed bear. The 25 kg boy pulls to the right with a 15 N force and the 20 kg girl pulls to the left with a 17 N force. Ignore all other forces on the bear (such as its weight).

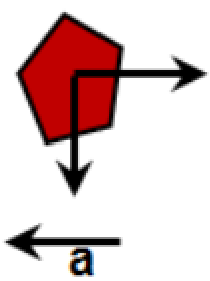
a) At this instant, can you say what the velocity of the bear is? If so, what are the magnitude and direction of the velocity?

b) At this instant, can you say what the acceleration of the bear is? If so, what are the magnitude and direction of the acceleration?

Problem 4
In the figures below, one force is missing. Use the given direction of acceleration to determine the missing force and draw it on object.



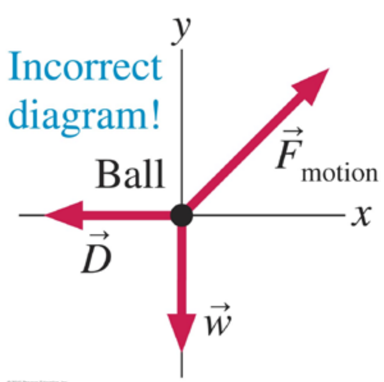




Problem 5
Very small forces can have tremendous effects on the motion of very small objects. Consider a single electron, with a mass of 9.1×10^{-31} kg, subject to a single force equal to the weight of a penny, 2.5×10^{-2} N. What is the acceleration of the electron?

Problem 6
When a 58-g tennis ball is served, it accelerates from rest to a speed of 45 m/s. The impact with the racket gives the ball a constant acceleration over a distance of 44 cm. What is the magnitude of the net force acting on the ball?

Problem 7
A student draws the flawed free-body diagram shown in the figure below to represent the forces acting on a golf ball that is traveling upward and to the right a very short time after being hit off the tee. Air resistance is assumed to be relevant. Identify the errors in the diagram, then draw a correct free-body diagram for this situation.



Problem 8
For each situation, draw a sketch of the situation, a motion diagram, and a FBD.

a) An elevator, suspended by a single cable, has just left the tenth floor and is speeding up as it descends toward the ground floor.

b) A heavy box is in the back of a truck. The truck is accelerating to the right. Apply your analysis to the box.

Problem 9
For each situation, draw a sketch of the situation, a motion diagram, and a FBD.

a) A rocket is being launched straight up. Air resistance is not negligible.

b) You've slammed on the brakes and your car is skidding to a stop while going down a 20° hill.