Basic Mechanics

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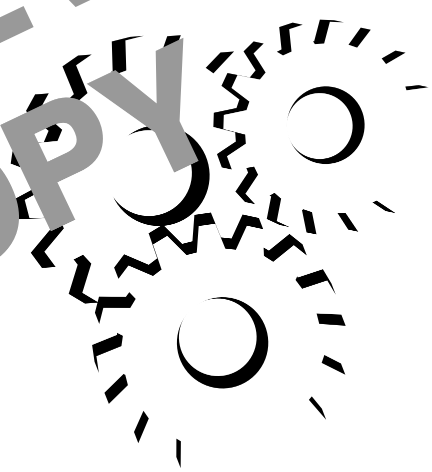
BASIC MECHANICS

Lesson One

Forces and Motion



TPC Training Systems

30101

Lesson

1 Forces and Motion

TOPICS

Definition of Force
Sources of Forces
Measuring Forces
Forces Applied to Stationary Objects
Normal Forces
Describing Motion
Acceleration
Types of Motion
Newton's Law of Motion

OBJECTIVES

After studying this lesson, you should be able to…

- Name five ways forces originate.
- Explain how forces are measured.
- Define *velocity*, *acceleration*, and *elastic distortion*.
- Define *rotary motion* and *reciprocating motion*.
- State and explain Newton's Laws of Motion

KEY TECHNICAL TERMS

Distortion 1.15, 1.16 any change in the shape of a solid object caused by the application of a force

Vector 1.19 an arrow showing size and direction of a force

Elasticity 1.21 the ability of a solid object to recover its original shape after a distorting force is withdrawn

Resilience 1.27 the ability to recover quickly from an elastic impact

Torsion 1.29 distortion produced by twisting

Mechanics is the branch of engineering concerned with forces and motion. Even the most complex machinery can be broken down into simpler components that transmit forces and change motions. Skilled mechanics have a practical knowledge of forces and motion, which they use every time they apply a wrench to a nut or move material from one place to another. Through experience, they have learned how to look for signs of misplaced forces or unwanted motions when troubleshooting breakdowns in equipment. When they clearly understand what is happening in a particular machine, they have no trouble adapting to a similar machine when required to do so. And their knowledge of forces and motion helps them work safely.

This lesson begins with a discussion of forces—how they originate, how they are measured, and what they do to stationary objects. The lesson then covers motion, how forces affect it, and why Newton's Laws are important to the mechanic. In later lessons, you should be able to relate each new topic to the ideas covered in this lesson on forces and motion.

Definition of Force

1.01 When you attempt to describe something you have seen or felt, you must use words that are as simple as possible. You hope that they mean the same thing to your listener as they do to you. If there is a chance that you might not be understood, you try to explain it in even simpler terms. But eventually you must use terms that cannot be explained in any simpler words. In mechanics, three such terms are length, time, and force

1.02 Length, time, and force are not easily definable. You can point and say, "Length is from here to there." But that is not a definition. You have a similar problem in defining force and time. They can be experienced, however. A force can be experienced by feeling or seeing its effects: an object is distorted or its motion is changed. These effects are shown in Fig. 1-1.

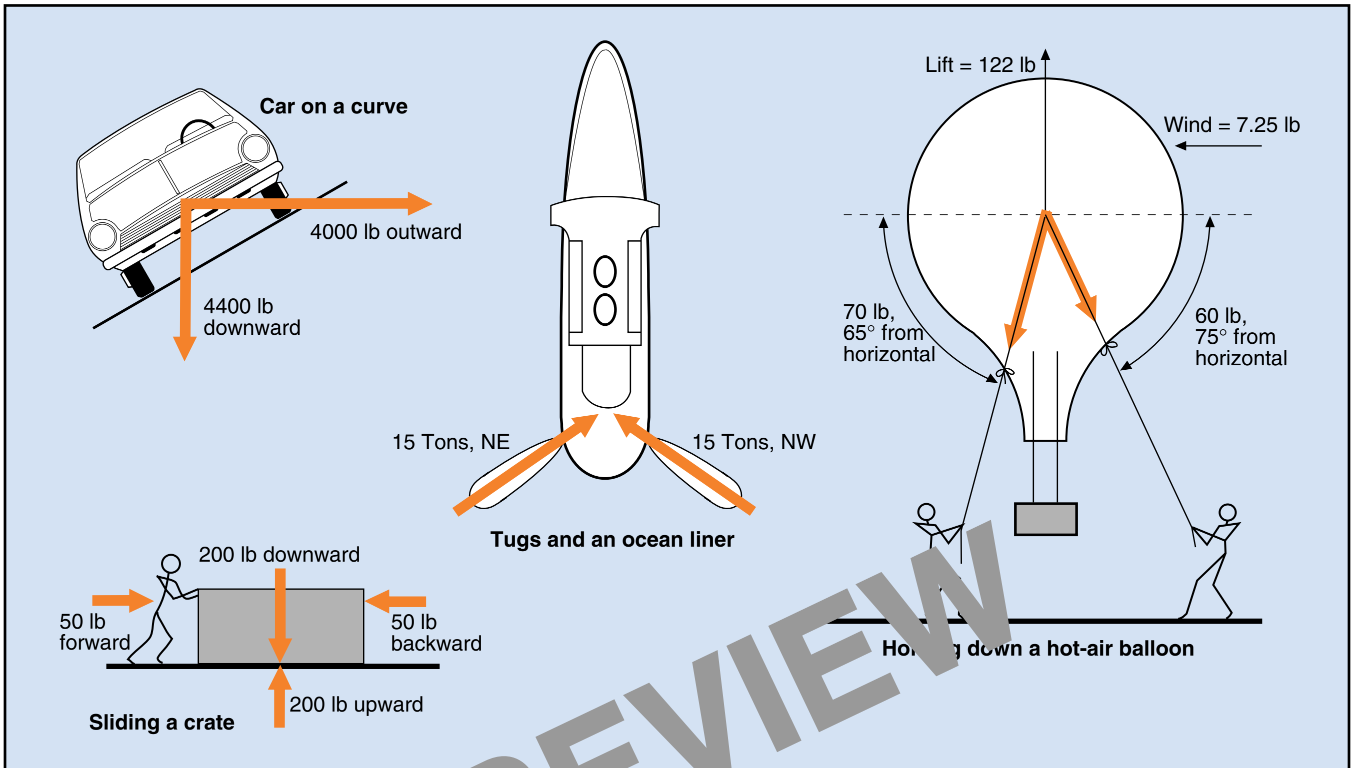
1.03 You know that forces cause these effects. Everyone has had these experiences and knows what you are talking about. But you still do not have a definition. About the best you can do instead is to describe force by using words that mean the same as force: a force is a push or a pull. A push or a pull is a force.

Sources of Forces

1.04 Forces do not come in different kinds. One force does not have different qualities from another

Fig. 1-1. Evidence of forces

Fig. 1-2. Vectors representing measured forces



force. However, forces arise in different ways. That is, they have different origins.

1.05 The source closest to you is your own body. Living muscles can create forces. You pull on a wrench, a horse pulls on a buggy. The source of both forces is the contraction of thousands of coordinated muscle cells.

1.06 Another source of forces is the expansion of confined materials when they get hot. An example is the force that develops inside the cylinders of your car's engine. This force originates from the expansion of confined hot gases. The expansion of materials due to heat is called *thermal expansion*. When materials expand in enclosed spaces, forces result.

1.07 You can see another result of thermal expansion on a hot day, when the roadway buckles. The buckling occurs because of strong sideward forces caused by the expansion of the concrete or asphalt. Conversely, in a few materials, the removal of heat (cooling) causes thermal expansion. When water freezes, the ice that forms takes up more space, causing tremendous forces.

1.08 A third source of forces is gravity. Gravitational forces are mutual attractions among all objects in the universe. The gravitational force you are most familiar with, however, exists between earthbound objects and the earth itself. This force is referred to as *weight*.

1.09 Forces also can arise because of the electrical and magnetic properties of matter. Wires carrying electric current have magnetic fields around them. This fact allows us to build electric motors that make use of magnetic attraction in order to produce forces. Electromagnets work on the same principle.

1.10 The motion of an object also can cause a force. You know that when a moving object collides with another object, forces are produced. Sometimes the forces are strong enough to damage both objects.

1.11 Forces originate in response to other forces. In fact, you cannot produce a force unless you have an opposite force to push against. To put it another way, an object must offer a resistance to your force, or you would not be able to generate a force. It would be like pushing on nothing. If you push on an object, it always pushes back at you with an equal force, but in the opposite direction.

1.12 Forces of *containment* are response forces. An iron ball heated without any containment will not create thermal expansion forces. If the ball is confined within a cooler steel ring, however, the expanding ball pushes outward against the ring, and the ring pushes back against the ball. In a gasoline engine, the cylinder walls and pistons provide the containment forces in response to the forces of the hot, expanding gases.

1.13 Another responding force is *friction*. Friction force arises when you move an object across a surface or through a fluid. Friction occurs between two surfaces and is equal and opposite to the applied force, as long as the object's motion is a constant speed (no acceleration or deceleration). Lesson Ten of this course covers friction force in more detail.

1.14 All responding forces are due to the forces of *cohesion* that keep the molecules of material together. Cohesion is the name given to the force of attraction that molecules have for other molecules like themselves. Cohesion gives materials strength, rigidity, and endurance.

Measuring Forces

1.15 Various devices have been created for measuring forces. They are all *comparing* instruments. They compare a given force with the pull of the earth on some standard object. This comparison is made by using one of the observable effects of a force, such as *distortion*.

1.16 For example, a spring is distorted when a force is applied. To make a spring scale for measuring forces, you merely need to see how far the spring is stretched (or compressed) when a standard weight is placed on it. Place a mark at that point. Add more standard weights, making another mark each time, and you have your force-measuring instrument.

1.17 Forces, then, are measurable, even though they are not very describable. In the English system, forces are measured in pounds (lb). In the metric system, they are measured in newtons (N). Also in the metric system, if the force is a weight, you will see kilograms and grams used as the units of measurement.

1.18 Not only does each force have a measurable size, but it also has a specific direction in which it acts. For example, you can say that a force of 100 lb is directed against the side of a tank. Or you can say that a 300 lb load of wet cement pushes down on the wheelbarrow, or that a force of 30 N is applied to the crank in a clockwise direction. Because a force has both size and direction, it can be represented with an arrow. The relative length of the arrow stands for the size of the force. The direction it points is the direction of the force.

1.19 The arrow symbol is called a *vector*. It can be used on a drawing to show a number of different forces in action, how large they are, and in what direction each is being applied. Figure 1-2 shows several vector diagrams and lists the forces represented.

Forces Applied to Stationary Objects

1.20 One of the effects of applying a force to an object, as mentioned earlier, is that the object will deform or distort. The distortion may be large or small, depending on the material and the size of the force. But the material will always distort by some amount. The distortion may be much too small to be seen with a high-powered microscope, but even the smallest applied force distorts the hardest surface it acts upon.

1.21 When the applied force is withdrawn from an object, the distortion usually disappears. Cohesive forces pull the molecules back into their original alignment. The object then goes back to its original shape, provided that the applied force was not too large. This quality of being able to spring back to the original condition is called *elasticity*.

1.22 If the applied force exceeds a certain limit, a permanent distortion occurs. This limiting force is called the *elastic limit*. A spring that has exceeded its elastic limit will never go back to its original length. An automobile fender that has received a blow larger than its elastic limit must be pounded back to its original shape.

1.23 Below the elastic limit, all materials behave in a very predictable way. Their distortions will be proportional to the amount of applied force. That is, if the force is increased by 50%, the amount of distortion will also increase by 50%. If the force is dou-

Fig. 1-3. Progressive stretch and breaking point for an iron wire

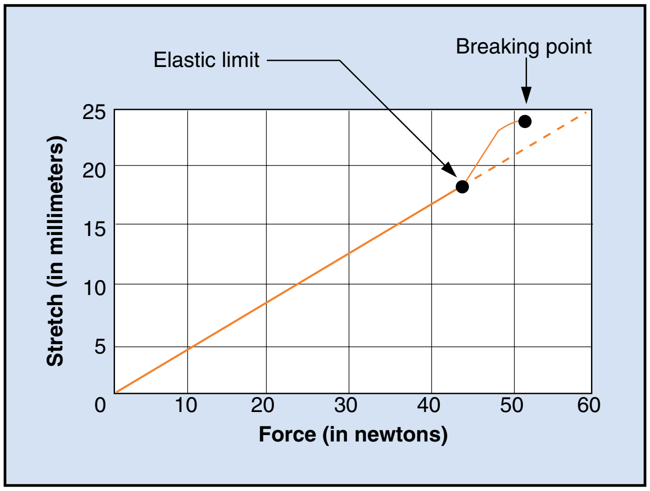
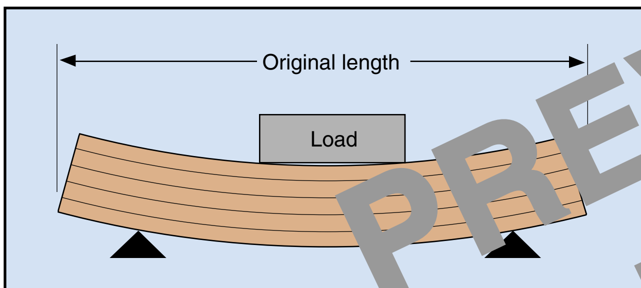


Fig. 1-4. Bent plank showing compression and tension



bled, the distortion is doubled, and so on. This holds true right up to the elastic limit.

1.24 This relationship was first discovered by Robert Hooke in the seventeenth century. It is now known as *Hooke's Law*. It describes the property of matter that allows us to build spring scales, such as the one described in paragraph 1.16. To restate Hooke's Law:

> *For forces less than the elastic limit, the amount of distortion produced on an object is proportional to the force applied to it.*

1.25 Beyond the elastic limit, things are not so predictable. Consider how an iron wire stretches. Figure 1-3 shows a graph that compares the amount of stretch to the amount of force it took to produce that stretch. Notice that the straight-line portion demonstrates Hooke's Law. But above the elastic limit, the wire begins to stretch irregularly until it breaks. The same kind of graph can be drawn for a bolt that is tightened beyond its recommended load.

1.26 Hooke's Law applies not only to stretching (also called *tension*), but to any kind of distortion. This includes compressing, bending, twisting, and shearing. The following paragraphs examine each of these distortions, one at a time.

1.27 *Compression* is the reverse of stretching or tension. The coil springs in your car distort by compressing. Rubber bumpers do too. So do golf balls, basketballs, baseballs, footballs, tennis balls, and anything else you hit, bat, or kick. This distortion may be invisible to the naked eye. The ability of a material to recover quickly from a compressive impact is called *resilience*. Golf balls have a great deal of resilience. The opposite property, or inability to recover, is called *brittleness*.

1.28 *Bending* distortion is a bit more complex than it looks. It is a combination of stretching and compressing. Figure 1-4 shows a wooden plank bending in the middle under an applied force. Imagine that the plank is made of many parallel layers. The layers at the bottom of the plank are stretching, while the layers at the top are compressing. Somewhere in the middle is a surface that is neither stretching nor compressing.

1.29 *Twisting* distortion occurs when one end of a rod, cylinder, or beam is held rigid while the other is made to rotate slightly, as shown in Fig. 1-5. This type of distortion is also known as *torsion*. The angle through which the free end rotates is proportional to the amount of twisting force applied to that end. Torsion springs work on this principle. You can get a feel for this effect by twisting on a length of rubber hose.

1.30 You can demonstrate *shear* distortion by piling up a stack of magazines, as in Fig. 1-6. Imagine that you push on the top magazine and it moves a certain distance. The top magazine drags the next magazine with it, but not quite as far. The second magazine drags along a third magazine part of the way, and so on down the pile. With your slanting stack of magazines, you have created a rough model of shear distortion.

1.31 The magazines represent the molecular layers in a material. Molecular layers will stay in this distort-

Fig. 1-5. Torsion distortion

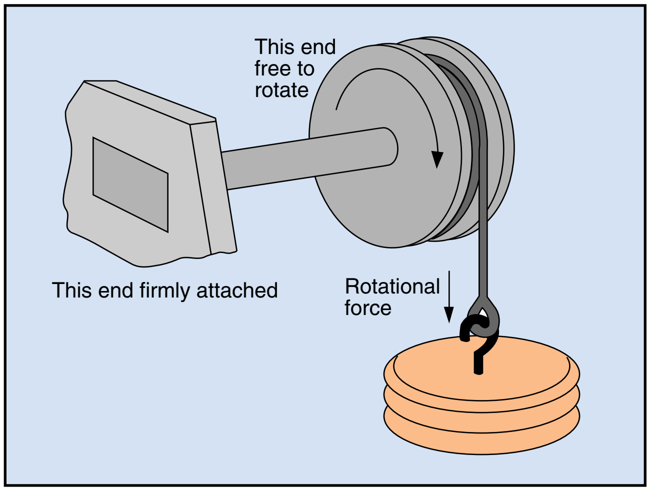
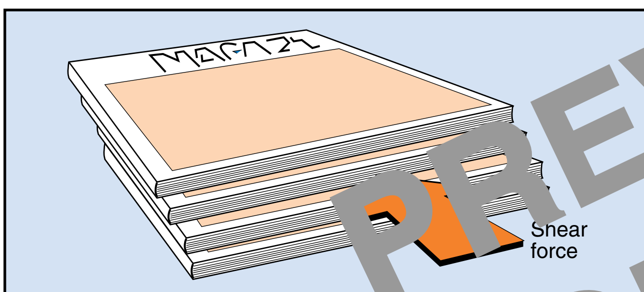
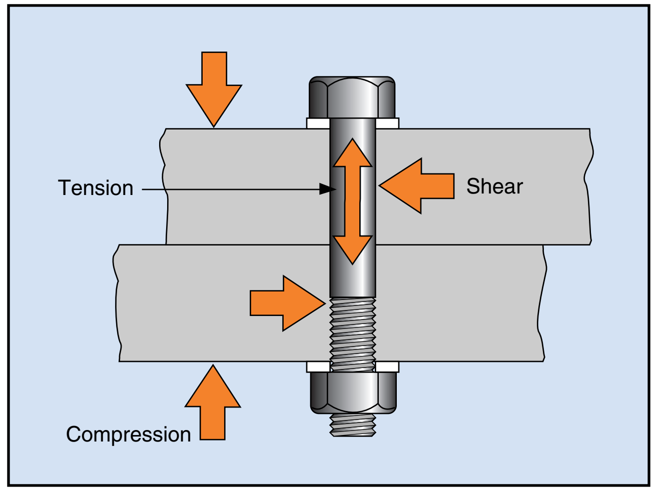


Fig. 1-6. Shear force on a stack of magazines



ed position as long as the applied force remains. When the force is released, the layers spring back to their original positions and the block is restored. If the elastic limit is reached, the block is permanently deformed.

Fig. 1-7. Compound distortion within and adjacent to a threaded fastener



1.32 In the real world, you often find combinations of these distortions occurring at the same time. A good example is shown in Fig. 1-7. The bolt is under tension after having been tightened. The two pieces of sheet metal have been compressed by the bolt and nut. If the metal sheets are under tension horizontally, the edges of the bolt holes apply shear distortion to the bolt.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. A force is a(n) ________ or a(n) ________.	1-1. PUSH; PULL Ref: 1.03
1-2. Humans produce forces by contraction of their _________.	1-2. MUSCLES Ref: 1.05
1-3. Electric motors use ________ attraction to produce forces.	1-3. MAGNETIC Ref: 1.09
1-4. The strength and rigidity of materials come from forces of ________.	1-4. COHESION or MOLECULAR ATTRACTION Ref: 1.14
1-5. A vector is used to represent the ________ and ________ of a force.	1-5. SIZE (AMOUNT); DIRECTION Ref: 1.19
1-6. If a force exceeds the elastic limit of an object, the object will have a permanent ________.	1-6. DISTORTION Ref: 1.22
1-7. Hooke's Law states that below the elastic limit, the amount of distortion is proportional to the ________.	1-7. FORCE or APPLIED FORCE Ref: 1.24
1-8. Bending is a combination of two other distortions, ________ and ________.	1-8. STRETCHING (TENSION); COMPRESSION Ref: 1.28

Normal Forces

1.33 Forces may be directed at the surface of an object from any angle or any direction. When a force is perpendicular to a surface, it is said to be normal to the surface. If an object rests on a flat, level floor, for example, the weight of the object is normal to the floor. The responding force in the floor boards is also normal to the floor. Normal forces, then, are simply forces acting at a 90° angle to a surface.

Describing Motion

1.34 You have seen how forces affect stationary objects. One way to observe a force is to see how it distorts a stationary object. The other way to observe a force is by noticing a change in an object's motion. Motion can be described in three levels of detail.

1.35 **Displacement.** First of all, in simplest terms, motion is *displacement*. That means if an object was "here" and now it is "there," it has moved from here to there. It has been displaced from its original position.

1.36 **Speed.** Suppose you also want to know how fast the object moved from here to there. You now enter the next level of detail—you are talking about speed. *Speed* is the amount of displacement per unit of time. If "from here to there" is 100 ft, and it took 50 seconds for the displacement to occur, the speed was 2 feet per second (ft/s).

1.37 **Velocity.** You can go to still another level of detail. You can add the direction of movement. You now have a *velocity*. You can say that the object moved 2 ft/s northward. That is a velocity, and so is 2 ft/s "toward the loading dock."

Acceleration

1.38 In the study of mechanics, you often deal with velocities. The reason is simple. Forces change velocities. A change in velocity is evidence that a force has been applied. No velocity can change without a force being applied. Any change in velocity is called *acceleration*. Figure 1-8 shows a typical example.

1.39 Forces cause accelerations. An object can be accelerated in two ways. Either its speed is changed or its direction is changed. Either way, it is an acceleration. Even if the speed is decreased, it is still an acceleration. (You may prefer to call it a deceleration.)

1.40 Here are a few examples. You are driving a car 50 mph west, and you increase your velocity to 55 mph west. This is an acceleration. If you round a curve in the road, you also accelerate, even though you maintain a constant speed through the curve. In other words, 55 mph west changing to 55 mph south is also an acceleration. If you slow down to 45 mph south, this is also an acceleration.

1.41 Strictly speaking, when describing acceleration, you must also include the time it took to accomplish the acceleration. For instance, if you went from 50 mph west to 55 mph west in 5 seconds, your acceleration was 1 mile per hour per second west. This may be written as 1 mph/s west.

1.42 Similarly, when you slowed down from 55 mph south to 45 mph south, you did it in 5 seconds, and your acceleration at that time was –2 mph/s. Thus, you have a more accurate definition of acceleration as a change in velocity per unit of time. Table 1-

Fig. 1-8. An acceleration

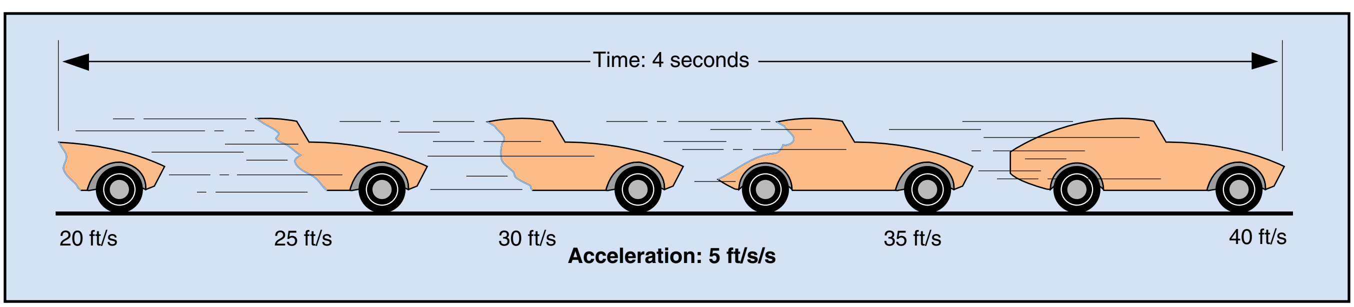


Table 1-1. Commonly used units for speed and acceleration

	Speed units	Acceleration units
English system	feet per second (ft/s) feet per minute (ft/min) miles per second (mi/s) miles per hour (mph) inches per year (in/yr)	feet per second per second (ft/s/s) feet per minute per second (ft/min/s) miles per second per second (mi/s/s) miles per hour per second (mph/s)
Metric system	millimeters per day centimeters per second (cm/s) centimeters per minute (cm/min) meters per second (m/s) kilometers per second (km/s) kilometers per hour (km/hr)	centimeters per second per second (cm/s/s) centimeters per minute per second (cm/min/s) meters per second per second (m/s/s) kilometers per hour per second (km/hr/s)

1 gives the common measurement units for speed and acceleration in both the English and metric systems.

Types of Motion

1.43 **Linear motion.** So far, you have studied only motion in a straight line. Examples include an object moving across the floor or a car traveling down the road. This type of motion is called *linear motion*.

1.44 **Rotary motion.** Another type of motion to consider is *rotary motion*. Anytime an object spins on an axis, it has rotary motion. Rotary speed is measured in revolutions per unit of time, such as revolutions per minute (rpm) or revolutions per second (rps). If the rotary speed is extremely slow, it can be measured in degrees of rotation per unit of time (360° = 1 revolution). For example. the rotary speed of the earth is one revolution per day, which translates to 15° per hour.

1.45 Rotary velocities include a direction of rotation, usually clockwise or counterclockwise. Thus, an example of a rotary velocity would be 3000 rpm clockwise. A rotary acceleration also has a direction included, plus another unit of time. A shaft velocity of 3000 rpm clockwise increasing to 4500 rpm clockwise in 15 seconds has an acceleration of 100 rpm/s clockwise, as shown below:

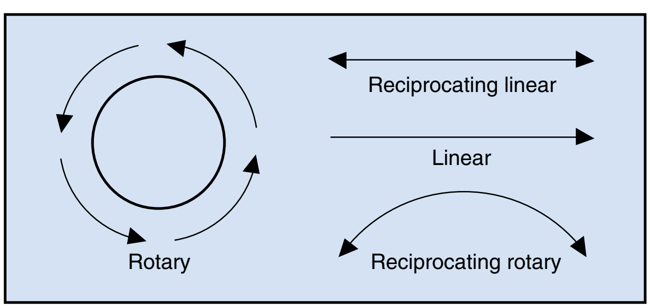
$$\frac{4500-3000}{15}=100$$

1.46 **Reciprocating motion.** A special modification of the two types of motion described above is *reciprocating motion*. Reciprocating motion is back-and-forth motion, and it may be either linear or rotary. In reciprocating motion, an object has its direction completely reversed twice in every cycle.

1.47 A ping-pong ball, batted back and forth by player A and player B, is a rough example of linear reciprocating motion. The ball approaches player A, who bats it back to player B, who bats it back to player A. Each time a player hits the ball, its direction of motion is reversed. As a result, the ball undergoes two accelerations in each complete cycle.

1.48 Many parts of industrial machines operate with reciprocating linear motion. A piston moves back and forth in a cylinder. A support frame slides back and forth on a pair of guide rails. But reciprocating rotary motion is also common. Usually this motion occurs through only a fraction of a circle, often less than 90°. This motion is referred to as *rocker motion*. Again, in this type of motion, a directional change occurs at the end of each half cycle. Figure 1-9 summarizes the types of motion.

Fig. 1-9. Types of motion



Newton's Laws of Motion

1.49 Isaac Newton was the first to figure out exactly how forces and motion are related. In particular, he studied how forces change the velocities of objects. His ideas apply very well to industrial operations, where forces and motion are so much a part of the daily scene. The following paragraphs examine each of his three laws of motion.

1.50 **The First Law of Motion.** Newton's first observation had to do with the property of materials that today is called *inertia*. Inertia is usually referred to as a tendency. It is the tendency of all objects at rest to stay at rest, and of all objects in motion to stay in motion in a straight line.

1.51 But Newton saw that an applied force would counteract the tendency. If you apply a strong enough force to an object at rest, it begins to move. If you apply a force to a moving object, you can stop it. He stated his First Law of Motion in roughly these words:

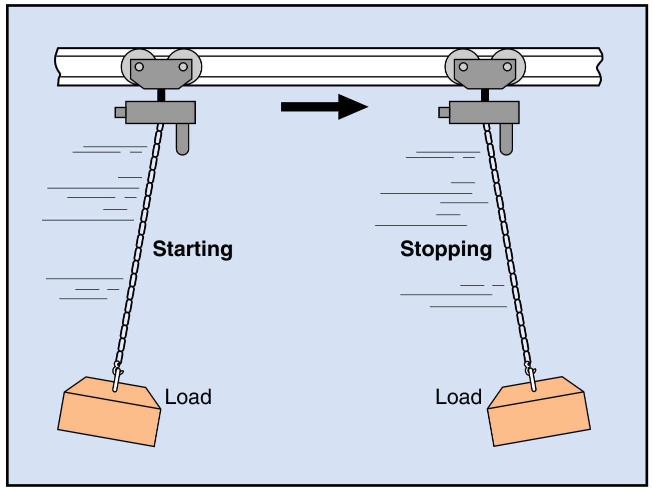
> *A body at rest will remain at rest, and a body in motion will continue in motion, with its velocity unchanging, unless acted upon by some external force.*

1.52 There are many ways to demonstrate Newton's First Law of Motion. You can pull a sheet of newspaper out from under a lunch bucket, without disturbing the lunch bucket, if you pull the paper fast enough. A bartender can slide a mug of beer down the entire length of a wet bar surface, if he gives it a sharp enough push. A car can skid off the road if it travels around a curve too fast, because of its tendency to travel in a straight line and not have its velocity changed.

1.53 In handling materials, you find many examples of this physical principle. A skate wheel conveyor allows cartons and crates to continue in motion for a great distance because of the low friction of the conveyor. Material-handling chutes that bend around corners must be banked in order to keep the material from flying off the curves in the chute. The material continues in motion after it reaches the end of the chute, also because of inertia.

1.54 Another graphic example of Newton's First Law is shown in Fig. 1-10. An overhead crane lifts a heavy object. As the crane starts forward, the load tends to remain in place, and the crane gets a little ahead of its load. At the end of its travel, the opposite situation occurs. The crane stops, but the load tends to keep on going. To keep the load from swinging out of control, it often needs to be guided or tethered from below.

Fig. 1-10. Starting and stopping an overhead crane



1.55 The First Law also applies to rotary motion. A fan or a circular saw blade continues to rotate for a long time after the power is turned off. Here, inertia can be a definite hazard. But it also can work to your benefit. Any rotary equipment that has a flywheel makes good use of this physical fact.

1.56 **The Second Law of Motion.** Newton's Second Law gives measurement to inertia. Measured inertia is called *mass*. Newton established exactly how force, acceleration, and mass are related. In effect, he made two statements.

- The larger the mass of an object, the smaller the acceleration it receives from a specific applied force.
- For any given object, the larger the applied force, the more the object will be accelerated.

1.57 Newton combined these two ideas into a single equation:

$$a = \frac{F}{m}$$

where a = acceleration

F = applied force

m = mass.

Table 1-2. Table of matching units for F = ma

If force (F) is measured in...	then mass (m) is measured in...	and acceleration (a) is measured in...
pounds	slugs	feet/s/s
newtons	kilograms*	meters/s/s
dynes	grams*	cm/s/s

*Note: These are *mass* units, not to be confused with kilograms and grams used as units of *weight*.

As you can see from this equation, as *F* gets larger, *a* also gets larger. We say that *F* and *a* are *directly* proportional. Also from the equation, as *m* gets larger, *a* becomes smaller. That is, *m* and *a* are *inversely* proportional.

1.58 After reviewing these two mathematical definitions of "proportional," you can now state Newton's Second Law:

> *A body acted upon by an applied force will accelerate in the direction of the applied force, and its acceleration will be directly proportional to the applied force and inversely proportional to the body's mass.*

1.59 The more massive an object is, the more force it takes to accelerate it. Being extremely massive, an ocean liner requires an enormous force to get it moving away from a dock. Furthermore because of its huge mass, its acceleration will be quite small.

1.60 Stopping a massive object is also a problem for the same reason. A large force is required to give the object negative acceleration (deceleration). Stopping a car with a great deal of mass takes more force than stopping a car with little mass. If two barrels come rolling at you, which one will be easier to stop: the empty one or the full one? (Which one has the smaller mass?)

1.61 Newton's equation is often rearranged into this form: $F = m \times a$. This equation expresses exactly the same relationship as the other equation. But it probably points out more clearly why it takes an exceedingly great force to give a high acceleration rate to a very massive object, such as a NASA space vehicle. The equation also gives you a new definition of force. If $F = ma$, then force is the product of mass times acceleration. Measurement units used in this equation are shown in Table 1-2.

1.62 Remember that mass and weight are not the same thing. If a body travels to the moon or to another planet, its weight changes, but not its mass. As stated in the equation above, weight (F) is the product of mass (m) times the acceleration caused by gravity (a).

1.63 You can see why forklift trucks should be operated at very low speeds in confined spaces. For

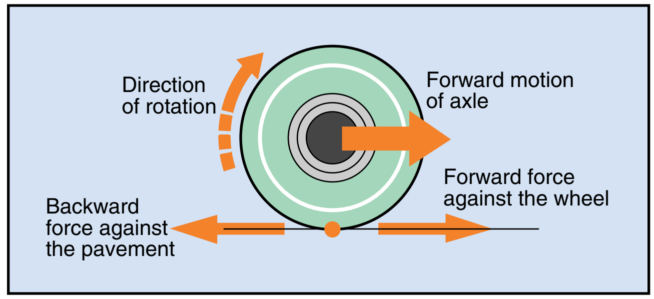
Fig. 1-11. Action and reaction

the same reason, operation of an overhead crane by an unskilled worker can be extremely hazardous. You can imagine how difficult it is to stop a massive, fast-moving vehicle in a very limited stopping distance. A short stopping distance requires a high acceleration, which requires a large stopping force. These vehicles can apply only so much stopping force. You can easily exceed their capability.

1.64 **The Third Law of Motion.** Newton's Third Law simply states that *for every action force, an equal and opposite reaction force is produced.* This is actually a restatement of what was said earlier about forces originating in response to other forces (paragraph 1.11). You push on a desk top, the desk top pushes back on you.

1.65 A classic example of Newton's Third Law is the man who steps from an unsecured rowboat onto a pier. The man pushes away from the boat, the boat pushes away from the man, as shown in Fig. 1-11. Both move in opposite directions. The same thing happens with a wheeled vehicle. The wheels push backward on the pavement, and the pavement pushes forward on the wheels, as in Fig. 1-12, causing the driving axle and the entire vehicle to move forward.

Fig. 1-12. Action-reaction forces



1-9. Velocity is made up of both ________ and ________.	1-9. SPEED, DIRECTION Ref: 1.36, 1.37
1-10. A change in velocity is called a(n) ________.	1-10. ACCELERATION Ref: 1.38
1-11. "4000 rpm clockwise" is an example of a(n) ________ velocity.	1-11. ROTARY Ref: 1.45
1-12. Reciprocating motion can be either rotary or ________.	1-12. LINEAR Ref: 1.46
1-13. Newton's First Law describes the property of matter known as ________.	1-13. INERTIA Ref: 1.50
1-14. If two different objects receive the same applied force, the one with the greater ________ receives the smaller acceleration.	1-14. MASS Ref: 1.56
1-15. An object acted upon by an applied force will always accelerate ________.	1-15. IN THE DIRECTION OF THE APPLIED FORCE Ref: 1.58
1-16. Stopping an object in a short distance requires a large force, because the ________ has to be great.	1-16. ACCELERATION or DECELERATION Ref: 1.63

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Thermal expansion causes outward forces only if the expanding material is

- ☐ a. confined
- ☐ b. dry
- ☐ c. hot
- ☐ d. moist

1-2. In the English system, forces are measured in

- ☐ a. grams (g)
- ☐ b. kilograms (kg)
- ☐ c. newtons (N)
- ☐ d. pounds (lb)

1-3. Forces can be measured using elastic objects, because

- ☐ a. acceleration is inversely proportional to force
- ☐ b. changes in the elastic limit are proportional to the amount of force
- ☐ c. distortion is proportional to the amount of force
- ☐ d. normal force is proportional to the distortion

1-4. Bending is a combination of

- ☐ a. compressing and stretching
- ☐ b. shearing and turning
- ☐ c. tension and stretching
- ☐ d. twisting and turning

1-5. Another name for twisting distortion is

- ☐ a. compression
- ☐ b. inertia
- ☐ c. tension
- ☐ d. torsion

1-6. A description of motion that includes both speed and direction is a

- ☐ a. displacement
- ☐ b. distortion
- ☐ c. revolution
- ☐ d. velocity

1-7. Which of the following is *not* an acceleration?

- ☐ a. A car heading west turns north
- ☐ b. A car is driving along at 50 mph
- ☐ c. A car slows from 25 to 20 mph
- ☐ d. A car speeds up from 30 to 40 mph

1-8. A special type of motion that can be either linear or rotary is ________ motion.

- ☐ a. harmonic
- ☐ b. reciprocating
- ☐ c. translational
- ☐ d. vibratory

1-9. A heavy vehicle is difficult to stop because of its

- ☐ a. friction force
- ☐ b. horsepower
- ☐ c. inertia
- ☐ d. resilience

1-10. Acceleration is directly proportional to the

- ☐ a. applied force on an object
- ☐ b. distortion of an object
- ☐ c. mass of an object
- ☐ d. velocity of an object

SUMMARY

You have seen that forces can change motion, and changes in motion create forces. Some common origins of forces are muscle movement, gravity, electromagnetism, and thermal expansion. Forces also originate in response to other forces. Isaac Newton provided the foundation for our understanding of the relation of forces and motion.

You can measure a force by comparing how far the force you want to measure distorts an elastic object to how far a standard force distorts the same object. Five kinds of elastic distortion are: tension, compression, bending, torsion, and shear.

Velocity is speed in a given direction. A change in velocity is called an acceleration. Only forces can cause accelerations. Velocities and accelerations may be linear or rotary. A special kind of linear or rotary motion often seen in equipment is called reciprocating motion, in which the direction of motion is reversed twice per cycle.

Answers to Self-Check Quiz

1-1. a. Confined. Ref: 1.12

1-2. d. Pounds (lb). Ref: 1.17

1-3. c. Distortion is proportional to the amount of force. Ref: 1.24

1-4. a. Compressing and stretching. Ref: 1.28

1-5. d. Torsion. Ref: 1.29

1-6. d. Velocity. Ref: 1.37

1-7. b. A car is driving along at 50 mph. Ref: 1.39, 1.40

1-8. b. Reciprocating. Ref: 1.46

1-9. c. Inertia. Ref: 1.56, 1.60

1-10 a. Applied force on an object. Ref: 1.58