

## Chapter 12 Forces

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### CHAPTER OUTLINE

#### Section 1 Newton's First and Second Laws

##### Key Idea questions

- > What makes an object speed up, slow down, or change directions?
- > What determines how much an object speeds up or slows down?

#### Newton's First Law

- > What makes an object speed up, slow down, or change directions?
- > Objects change their state of motion only when a net force is applied.
  - This principle is *Newton's first law*.
  - Objects tend to maintain their state of motion.
  - Inertia is related to an object's mass.
    - inertia: the tendency of an object to resist a change in motion unless an outside force acts on the object
  - Seat belts and car seats provide protection.
    - When a car comes to a stop, your seat belt and the friction between you and the seat provide the unbalanced backward force that is needed to bring you to a stop as the car stops.

#### Newton's Second Law

- > What determines how much an object speeds up or slows down?
- > Net force is equal to mass times acceleration. The unbalanced force on an object determines how much an object speeds up or slows down.
  - This principle is *Newton's second law*.
  - *net force = mass × acceleration, or  $F = ma$*
  - Force is measured in newtons (N):  $1 \text{ N} = 1 \text{ kg} \times 1 \text{ m/s}^2$
  - For equal forces, a larger mass accelerates less.

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- For equal masses, a greater force produces a greater acceleration.
- Newton's second law can also be stated as follows:
  - The acceleration of an object is proportional to the net force on the object and inversely proportional to the object's mass.

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### Section 2 Gravity

#### Key Idea questions

- > How are weight and mass related?
- > Why do objects fall to the ground when dropped?
- > What is the relationship between free-fall acceleration and mass?
- > Why does a projectile follow a curved path?

### Weight and Mass

- > How are weight and mass related?
- > Weight is equal to mass times free-fall acceleration.
  - weight: a measure of the gravitational force exerted on an object
  - *weight = mass x free-fall acceleration, or  $w = mg$*
  - Weight is measured in newtons.
  - Weight is different from mass.
    - mass = a measure of the amount of matter in an object
    - weight = the gravitational force an object experiences because of its mass

### Law of Universal Gravitation

- > Why do objects fall to the ground when dropped?
- > All objects in the universe attract each other through the force of gravity.
  - Newton's *law of universal gravitation* gives the size of the gravitational force between two objects:
$$F_g = G \frac{m_1 m_2}{d^2}$$
  - All matter is affected by gravity.
    - Two objects, whether large or small, always have a gravitational force between them.
    - When something is very large, like Earth, the force is easy to detect.

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- Gravitational force increases as mass increases.
- Gravitational force decreases as distance increases.

### Free Fall

- > What is the relationship between free-fall acceleration and mass?
- > In the absence of air resistance, all objects falling near Earth's surface accelerate at the same rate regardless of their mass.
  - free fall: the motion of a body when only the force of gravity is acting on the body
  - Air resistance can balance weight.
    - terminal velocity: the constant velocity of a falling object when the force of air resistance is equal in magnitude and opposite in direction to the force of gravity
  - Astronauts in orbit are in free fall.

### Projectile Motion

- > Why does a projectile follow a curved path?
- > Projectile motion has two components—horizontal and vertical. When the two motions are combined, they form a curved path.
  - projectile motion: the curved path that an object follows when thrown, launched, or otherwise projected near the surface of Earth
  - Projectile motion has a horizontal component.
    - After you have thrown a ball, no horizontal forces are acting on the ball (if air resistance is ignored). So, the horizontal component of velocity of the ball is constant after the ball leaves your hand.

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- Projectile motion also has a vertical component.
  - When you throw a ball, gravity pulls it downward, which gives the ball vertical motion. In the absence of air resistance, gravity on Earth pulls objects that are in projectile motion downward with an acceleration of  $9.8 \text{ m/s}^2$ , just as it pulls down all falling objects.
- Orbiting is projectile motion.

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### Section 3 Newton's Third Law

#### Key Idea questions

- > What happens when an object exerts a force on another object?
- > How do you calculate the momentum of an object?
- > What is the total momentum after objects collide?

### Action and Reaction Forces

- > What happens when an object exerts a force on another object?
- > When one object exerts a force on a second object, the second object exerts a force equal in size and opposite in direction on the first object.
  - This is *Newton's third law*.
  - Forces always occur in pairs.
    - For every *action* force, there is an equal and opposite *reaction* force.
  - Forces in a force pair do not act on the same object.
  - Equal forces don't always have equal effects.
    - Example: The action force of Earth pulling on an object and causing it to fall is much more obvious than the equal and opposite reaction force of the falling object pulling on Earth.

### Momentum

- > How do you calculate the momentum of an object?
- > For movement along a straight line, momentum is calculated by multiplying an object's mass and velocity.
  - *momentum = mass x velocity, or  $p = mv$*
  - momentum: a quantity defined as the product of the mass and velocity of an object
    - SI units of momentum = kilograms times meters per second (kg•m/s).
    - Momentum and velocity are in the same direction.

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- Momentum increases as mass and velocity increase.
- Force is related to change in momentum.
  - As the period of time of the momentum's change becomes longer, the force needed to cause this change in momentum becomes smaller.

### Conservation of Momentum

- > What is the total momentum after objects collide?
- > The total momentum of two or more objects after a collision is the same as it was before the collision. In other words, the total amount of momentum in an isolated system is conserved.
  - This principle is the *law of conservation of momentum*.