Forces and Motion

Reference:

Prentice Hall

Physical Science: Concepts in Action

Chapter 12

What is Force?

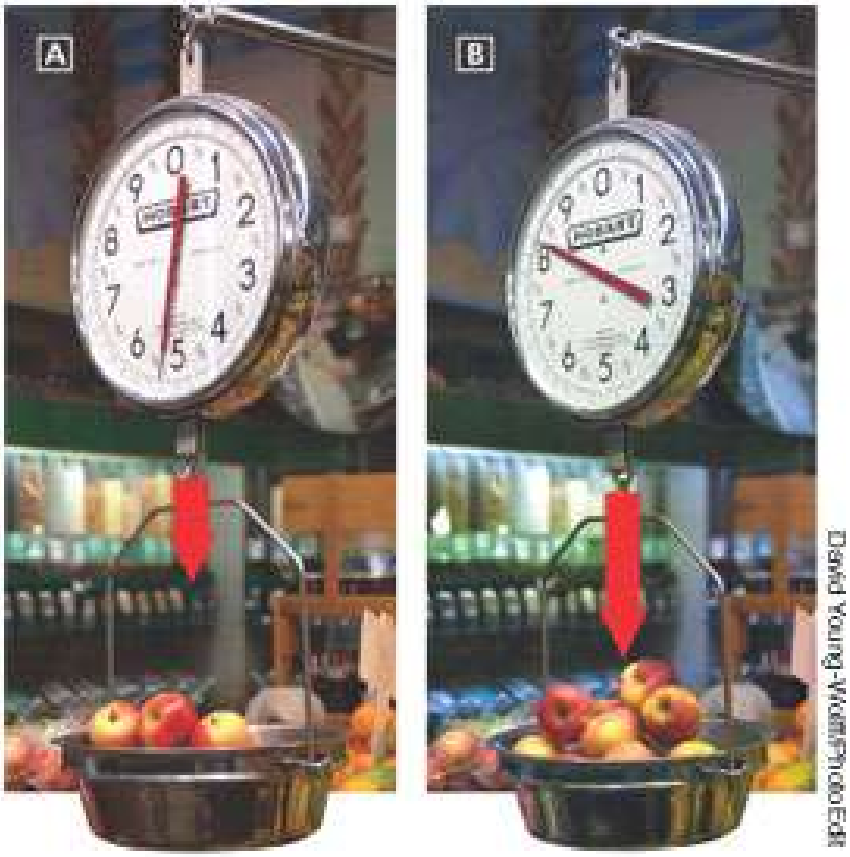
- A push or pull that acts on an object
- Can cause a resting object to move
- Can accelerate a moving object
  - By changing its speed or direction

How is force measured?

- Spring scale
  - Stretch of the spring depends on the mass of the object acting on it
- Unit of Force
  - Newton (N)
  - 1 kg to accelerate 1 m/s^2
  - $1N = \frac{kg \bullet m}{s^2}$

How is force represented?

- Use arrows
  - Direction
  - Strength
    - Length represents strength or magnitude



  - The scale with more apples, greater mass, has a longer arrow. The arrow is pointed downward due to mass is below the balance pulling downwards.

Combining Forces

- Forces in the same direction are added together
- Force in the opposite direction are subtracted
- Net Force
  - Overall force acting on an object

Balanced vs. Unbalanced Forces

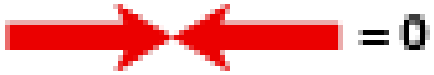
- Balanced
  - Combine to produce a net force of zero
  - No change in the object's motion
- Unbalanced
  - Net force equals the size of the larger force minus the size of the smaller force
  - Net force does not equal zero
  - Causes an object to accelerate

Representing Forces

A Adding forces

B Subtracting forces

C Equal and opposite forces

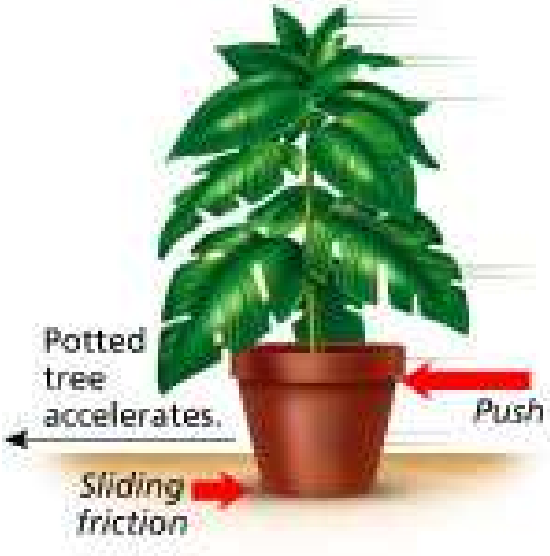


Friction

- Force that opposes the motion of objects that touch as they move past each other
- Acts at the surface where objects are in contact
- 4 types of friction

4 Types of Friction

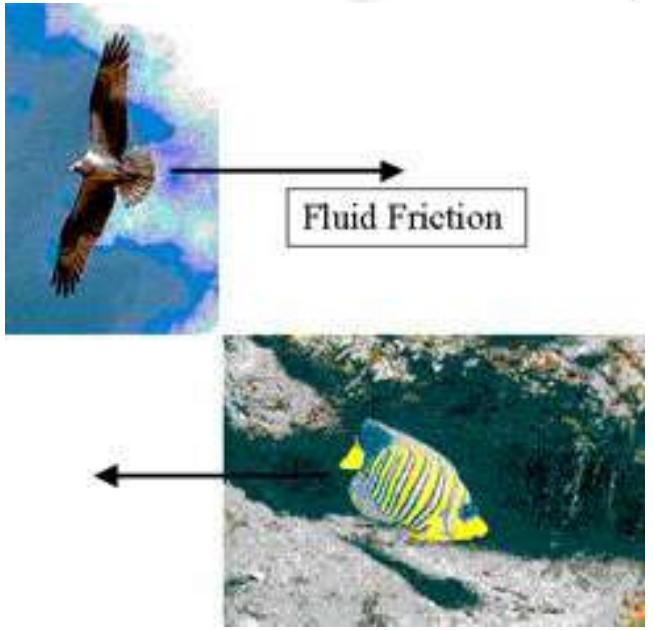
- Static friction
  - Force that acts on objects that are not moving
  - Always acts in the direction opposite to that of the applied force
- Sliding friction
  - Force that opposes the direction of motion of an object as it slides over a surface



4 Types of Friction

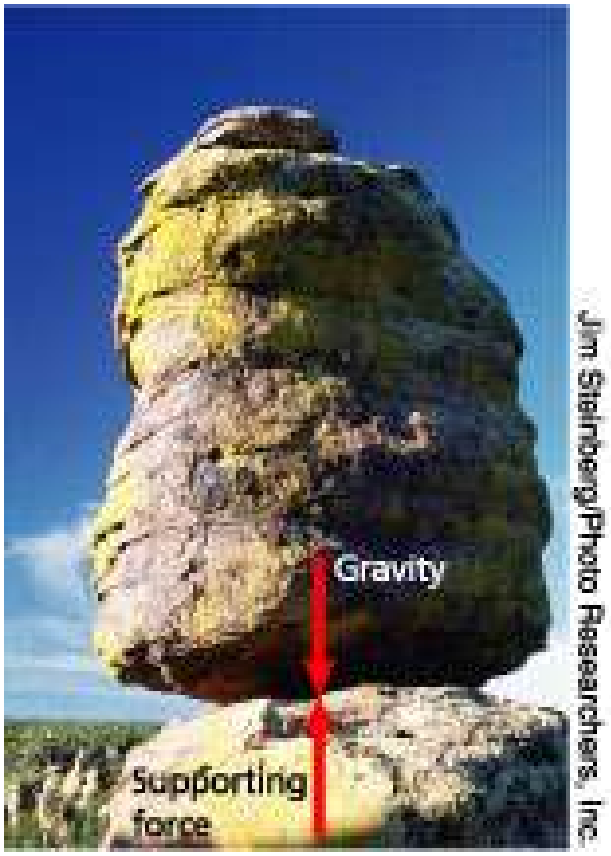
- Rolling friction
  - Change in shape at the point of rolling contact

- Fluid friction
  - Opposes the motion of an object through fluid
  - Increases the speed of the object moving through the fluid
  - Fluids (gas and liquids)



Gravity

- Force that acts between two masses
- Attractive force
  - Pulls objects together
- Earth's gravity
- Acts downwards towards the center of the earth



Gravity and Falling Objects

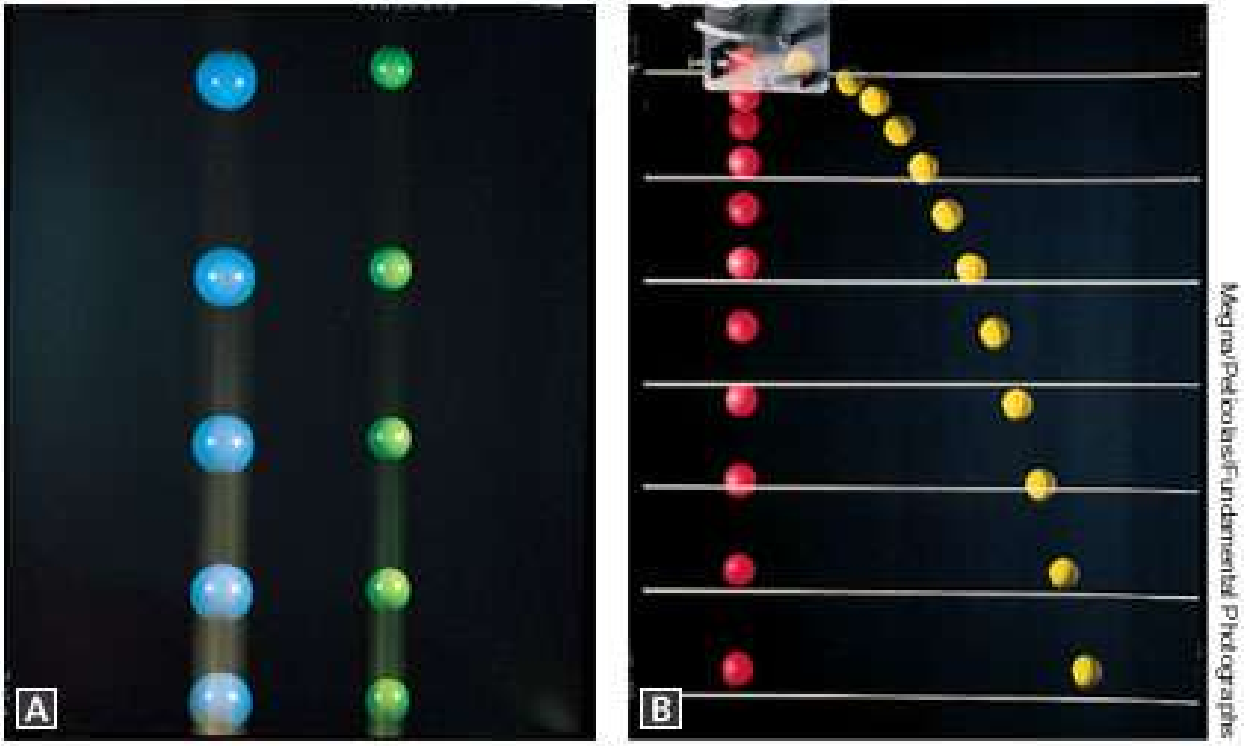
- Gravity causes objects to accelerate downward
- Air resistance (fluid friction) acts in the direction opposite to the motion and reduces acceleration

Gravity and Falling Objects

- Terminal velocity
  - Constant velocity of a falling object when force of resistance equals gravity

Projectile Motion

- Motion of a falling object after given an initial forward velocity
- Causes a curved path



Newton's 1st Law of Motion

- Law of inertia
  - Inertia
    - Tendency of an object to resist change in its motion
- State of an object does not change as long as the net force acting on it is zero
- An object at rest stays at rest, an object in motion stays in motion at the same direction and speed (until something acts on it)
- Inertia mini lab

Newton's 1st Law of Motion

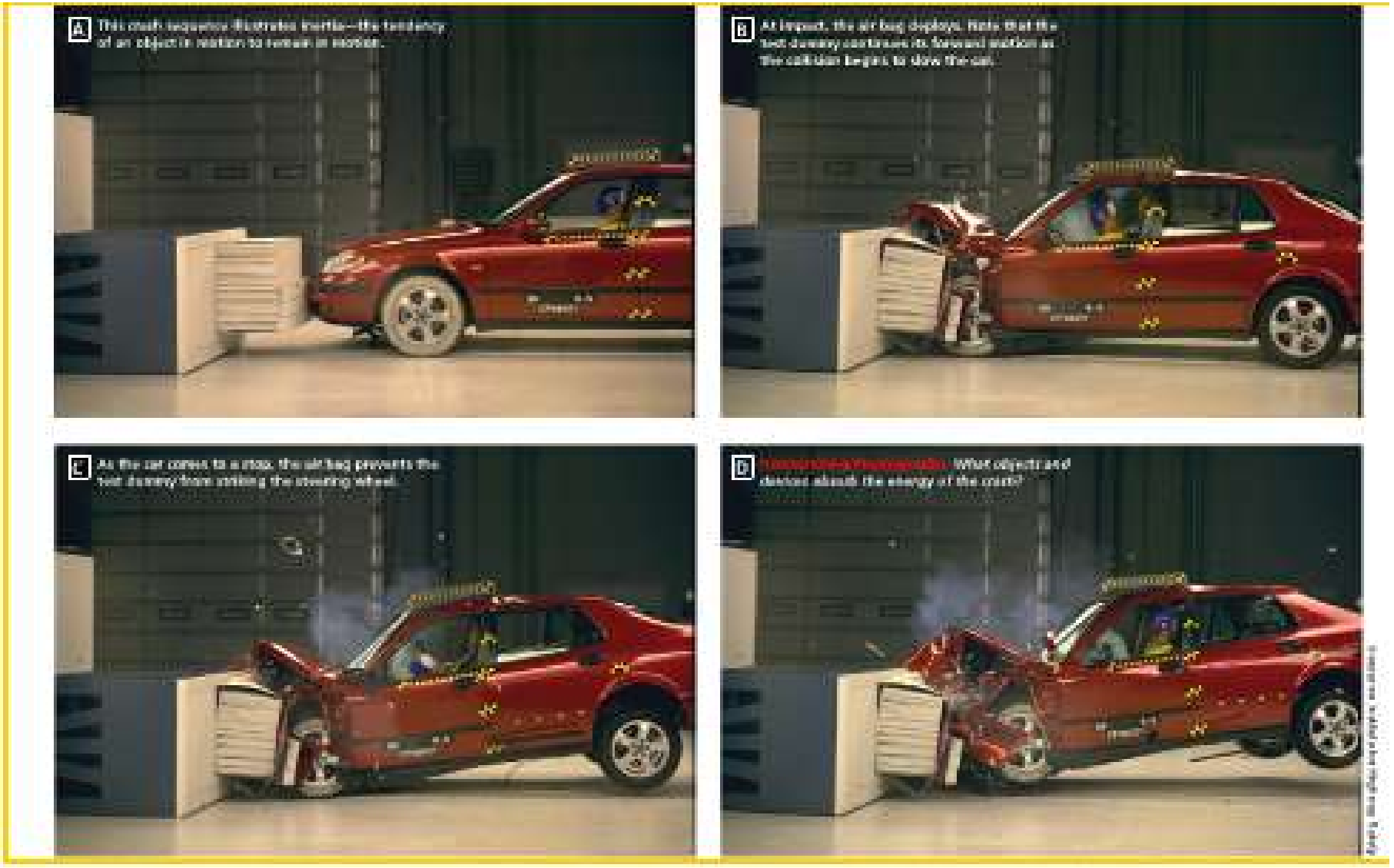


Figure 12

Videos

- animated videos
- real videos
- physics in sports

Newton's 2nd Law of Motion

- The acceleration of an object is equal to the net force acting on it divided by the objects mass
  - Mass
    - Measure of inertia of an object and depends on the amount of matter the object contains

F = ma

Force = mass * acceleration

Newton's 2nd Law of Motion

- The acceleration of an object is always in the same direction as the net force
- Net forces in the opposite direction of object's motion
  - Force produces deceleration and reduces speed
  - Ex. Seat belts
- Units for Acceleration are equivalent
  - $N/kg = m/s^2$

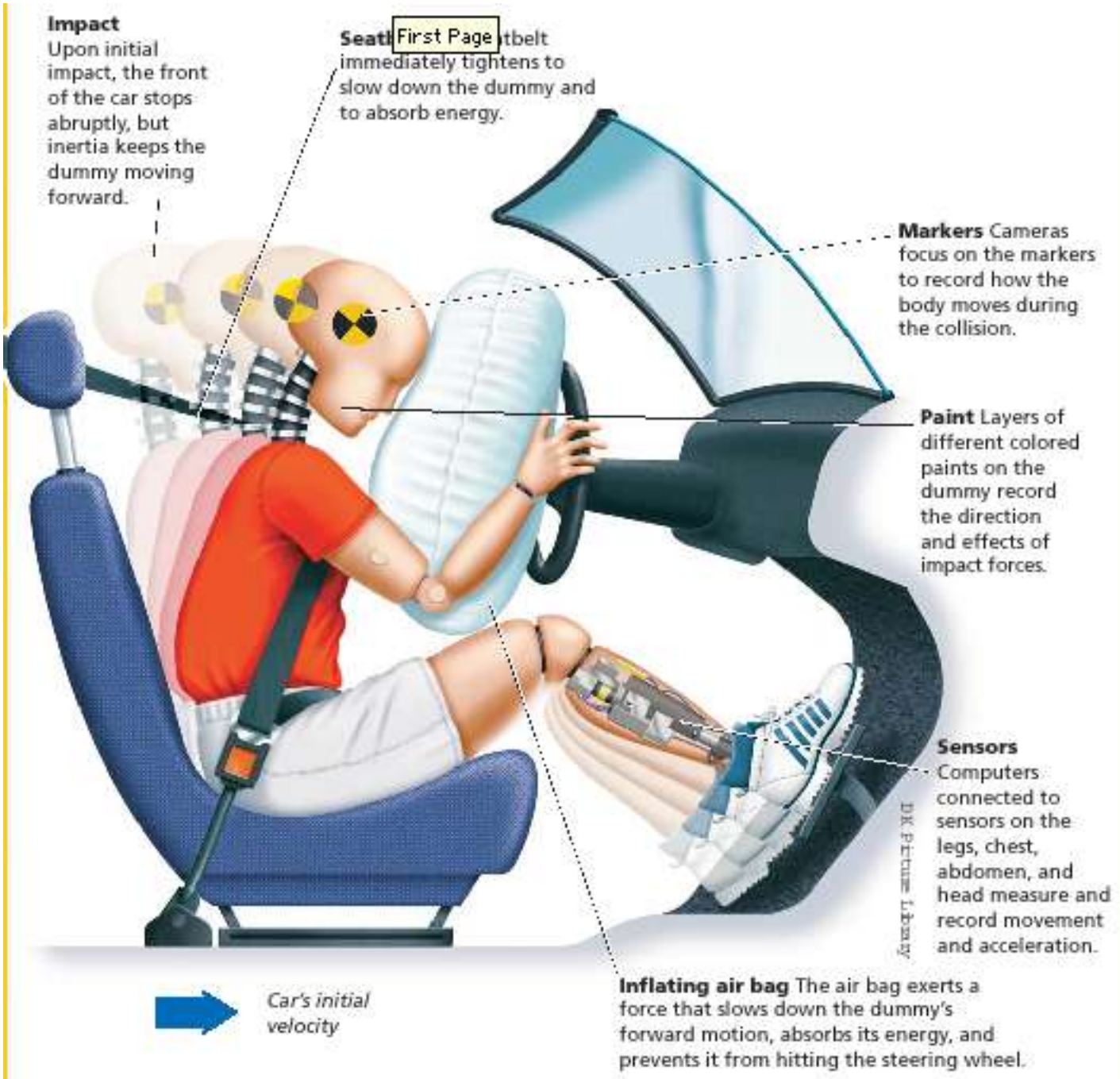
Newton's 2nd Law of Motion

Crash-Test Dummies

Dummies are used in simulated car crashes to study what might happen to passengers in a real crash. They are fitted with a range of measuring devices that track the motion of the dummies throughout the crash. By analyzing the data, scientists learn how injuries occur and how they can be prevented. **Interpreting Diagrams** ***What forces act on the crash-test dummy to slow its forward movement?***

Newton's 2nd Law of Motion

Corner collision
One standard test involves crashing a car into a solid concrete wall at nearly 60 kilometers an hour. Other tests involve crashing a sled into the side or corner of the car.


Impact
Upon initial impact, the front of the car stops abruptly, but inertia keeps the dummy moving forward.
Seatbelt immediately tightens to slow down the dummy and to absorb energy.
Markers Cameras focus on the markers to record how the body moves during the collision.
Paint Layers of different colored paints on the dummy record the direction and effects of impact forces.
Sensors Computers connected to sensors on the legs, chest, abdomen, and head measure and record movement and acceleration.
DK Picture Library
Car's initial velocity
Inflating air bag The air bag exerts a force that slows down the dummy's forward motion, absorbs its energy, and prevents it from hitting the steering wheel.

Weight and Mass

- Weight & Mass are Different
- Weight
  - The force of gravity acting on an object
  - Product of the mass and acceleration due to gravity
  - Unit is Newtons (N)

Weight Formula

$$\text{Weight} = \text{Mass} \times \text{Acceleration due to gravity}$$

$$W = mg$$

Weight and Mass

AP/ Wide World Photos

A **Astronaut on Earth**
Mass = 88.0 kg; Weight = 863 N

Bettmann/Corbis

B **Astronaut on Moon**
Mass = 88.0 kg; Weight = 141 N

Newton's 2nd Law of Motion

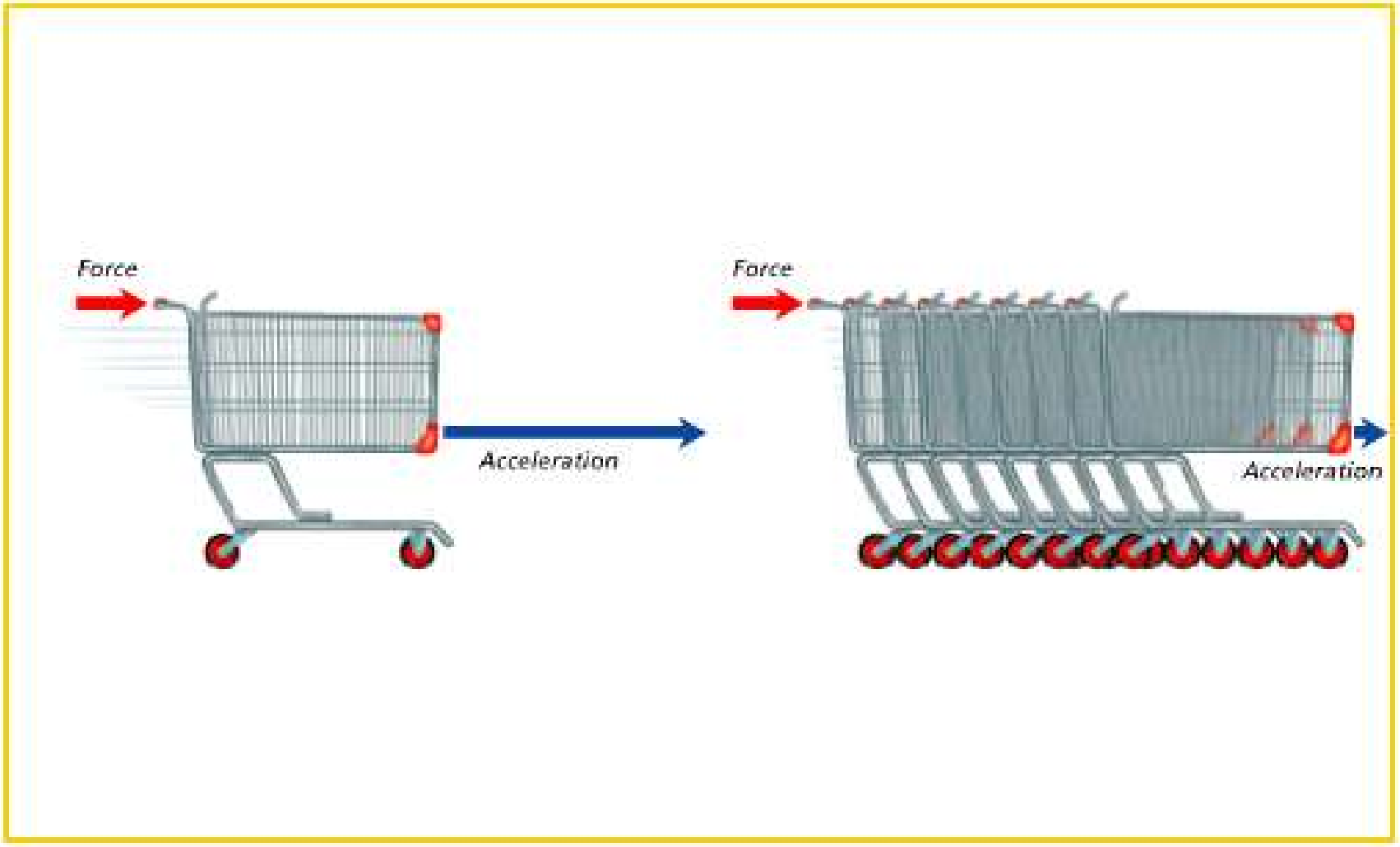


Figure 13 Acceleration depends directly on force and inversely on mass. Neglecting friction, when the same force acts, the single cart accelerates eight times faster than the chain of eight carts.

Newton's 2nd Law of Motion

1. A boy pushes forward a cart of groceries with a total mass of 40.0 kg. What is the acceleration of the cart if the net force on the cart is 60.0 N?

$a = F/m$

$= 60.0\ N/40.0\ kg$

$= 1.50\ m/s^2$

2. What is the upward acceleration of a helicopter with a mass of 5000 kg if a force of 10,000 N acts on it in an upward direction?

$a = F/m$

$= 10000\ N/5000\ Kkg$

$= 2\ m/s^2$

Newton's 2nd Law of Motion

3. An automobile with a mass of 1200 kg accelerates at a rate of 3.0 m/s^2 in the forward direction. What is the net force acting on the automobile? (*Hint:* Solve the acceleration formula for force.)

$a=F/m \quad F=ma$

$= 1200\ kg(3.0\ m/s^2)$

$= 3600\ N$

4. A 25-N force accelerates a boy in a wheelchair at 0.5 m/s^2 What is the mass of the boy and the wheelchair? (*Hint:* Solve Newton's second law for mass.)

$a=F/m \quad m=F/a$

$= 25\ N/0.50\ m/s^2$

$= 50\ k/=g$

Section 2 Practice Problems

6. During a test crash, an air bag inflates to stop a dummy's forward motion. The dummy's mass is 75 kg. If the net force on the dummy is 825 N toward the rear of the car, what is the dummy's deceleration?

$a = F/m$

$= 825\ N / 75\ kg$

$= 11\ m/s^2$

Section 2 Practice Problems

7. A bicycle takes 8.0 seconds to accelerate at a constant rate from rest to a speed of 4.0 m/s. If the mass of the bicycle and rider together is 85 kg, what is the net force acting on the bicycle? (*Hint:* First calculate the acceleration.)

$a=(v_f-v_i)/t$

$= (4.0\ m/s) / 8.0\ s$

$= 0.50\ m/s^2$

$F=ma$

$= 85\ kg \times 0.50\ m/s^2$

$= 43\ N$

Newton's 3rd Law of Motion & Momentum

- 3rd Law – when an object exerts a force on a second object, that object exerts an equal and opposite force on the first object
- Momentum
  - Product of an object's mass and its velocity
  - Objects momentum at rest is zero
  - Unit kg m/s

Momentum Formula

$$\text{Momentum} = \text{Mass} \times \text{Velocity}$$

Law of Conservation of Momentum

- If no net force acts on a system, then the total momentum of the system does not change
- In a closed system, loss of momentum of one object equals the gain in momentum of another object

Law of Conservation of Momentum

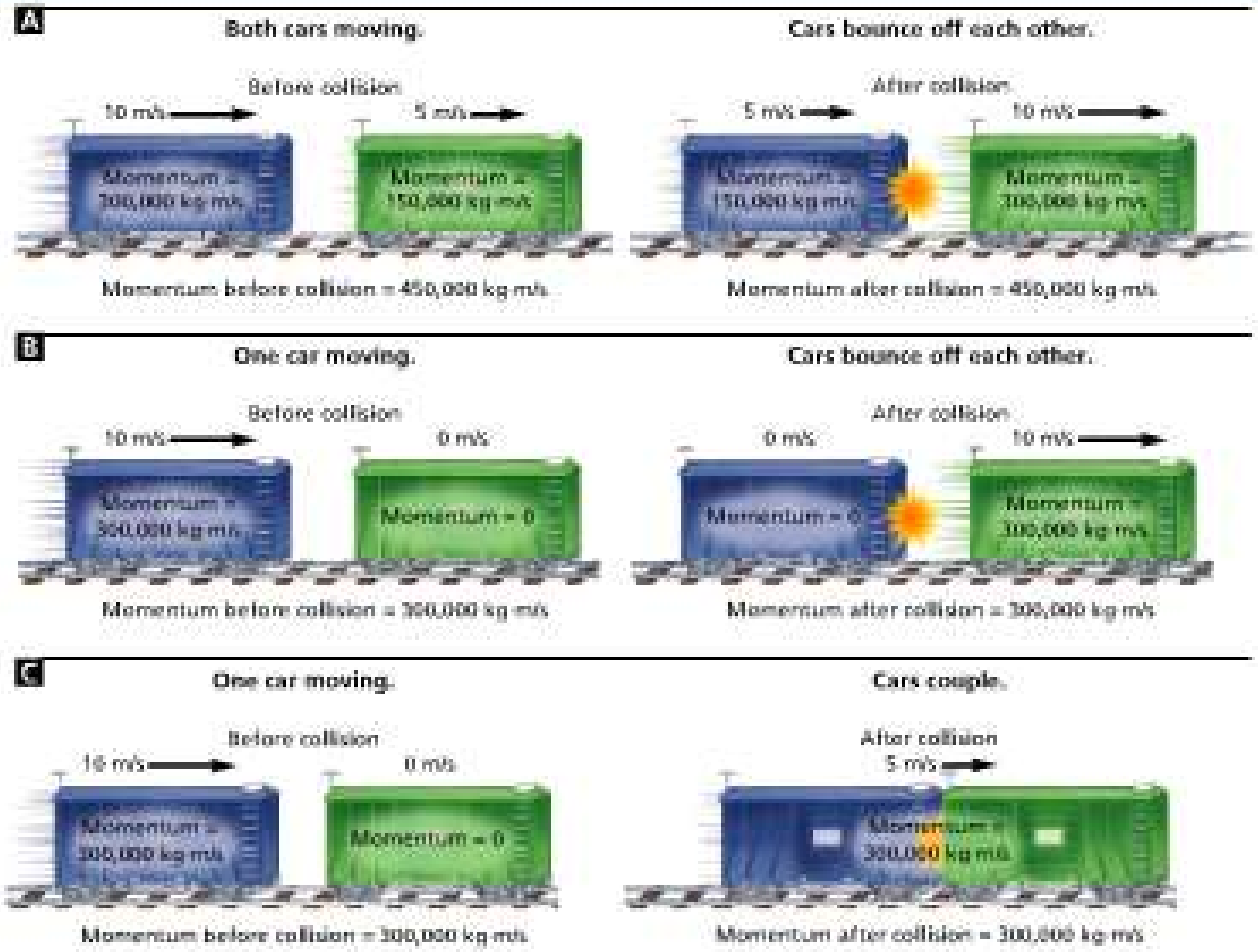


Figure 17 Three different collisions between equal-mass train cars are shown above. The different collisions between equal-mass train cars are shown above. In each collision, the total momentum of the train cars does not change—momentum is conserved.

Universal Forces

- Electromagnetic – associated with charged particles.
- Electric force and magnetic force are the only forces that can both attract and repel.
  - Electric forces act between charged objects or particles such as electrons or protons.
  - Magnetic forces act on certain metals, on the poles of magnets, and on moving charges.
  - **Universal forces = do not need to be in contact – forces act over a distance

Universal Forces

- Nuclear forces – one strong and one weak – hold the nucleus of atoms together and keep the positive protons from repelling each other and destroying the atom
  - Strong nuclear force acts only on neutrons and protons in a nucleus – holds them together. Acts at a longer range than weak nuclear forces.
  - Weak nuclear force acts only over a short range

Universal Forces

- Gravitational Force – an attractive force acting between any two masses
  - Gravitational force depends on two factors: mass and distance apart
  - More mass or less distance = more gravity
  - Gravity acts over LARGE distances
  - Weakest universal force

Universal Forces

- Centripetal force – center-directed force that continuously changes the direction of an object to make it move in a circle
- Centrifugal force (centrifuge) doesn't actually exist in science!
- Earth's gravitational attraction keeps the moon in an orbit around the Earth. This gives us tides. Similarly to how the moon orbits Earth, satellites are able to orbit!

Assignment

- On your own paper: answers only
- P. 367 #1-4
- P. 369 #1-3, 6, 7
- P. 377 #1-4
- P. 382 #1-4
- Due before you leave class
- STOP STEALING THE TEXTBOOKS (you will have to do assignments online if it happens one more time!)