Physics 2514

Lecture 10

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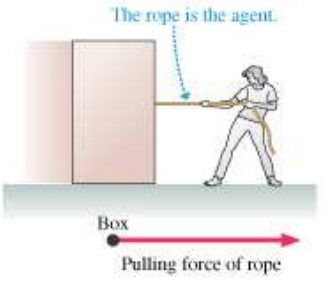
Goals

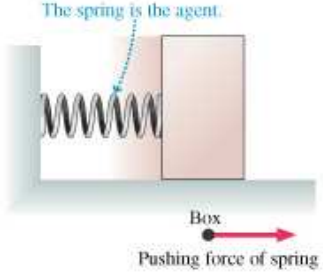
Finish the qualitative discussion of force, and start quantitative discussion.

Introduce Newton's first and second laws of motion.

Force–Qualitative Description

- Qualitative description
  - Force pushes or pulls on an object;
  - Force has a magnitude and direction (it's a vector);
  - A force requires an agent, something to pull or push;
  - Forces can be either contact or long range:
    - Long range forces include gravity, electric and magnetic forces.
- Conclusion, a force causes an objects motion to change.





Observations

We start with a series of observations that we wish to describe in order to define force quantitatively:

- An object is released and falls toward the Earth at a constant acceleration independent of its size (mass);
- An object is hung from a spring, the spring stretches by greater amounts as more objects are hung;
- An object is pushed along a surface, sometimes the object has a constant velocity other times not.

We wish to explain each of these phenomena with a single definition for force

Conclusions

Based on our simple demonstrations we can draw the following conclusions

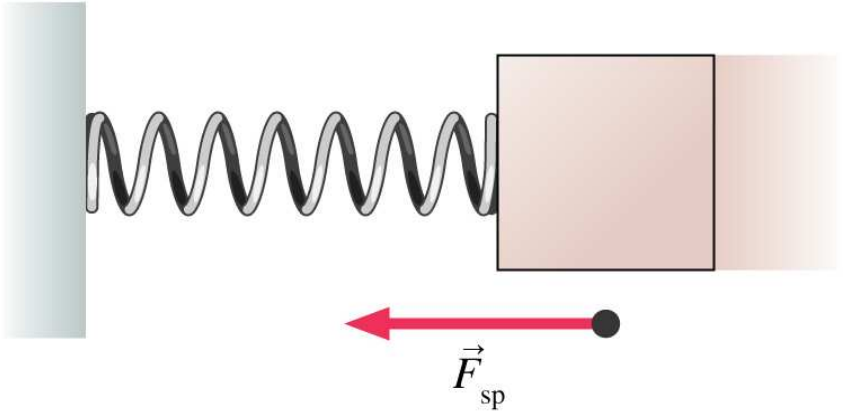
- An object that experiences a net force will accelerate;
- The greater the force, the larger the acceleration;
- A smaller (lighter) object experiences a smaller force due to gravity;
- All objects experience the same acceleration due to gravity.

We can draw the following two conclusion, *an object at rest has zero net force acting on it, an object moving with a constant velocity has zero net force acting on it*.

Force and Motion

Now we consider what happens when a single constant (non-gravitational) force is applied on an object

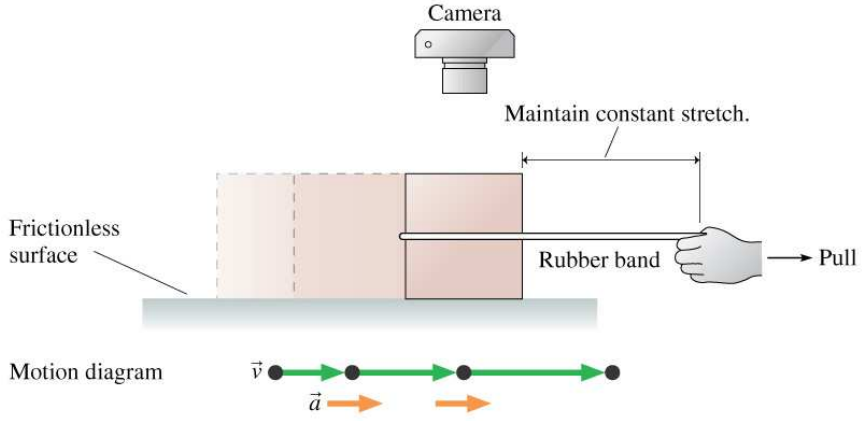
- Consider a spring (rubber band) stretched by a constant amount acting on an object
  - Object accelerates to return spring to unstretched length changes motion of object.



Force and Motion

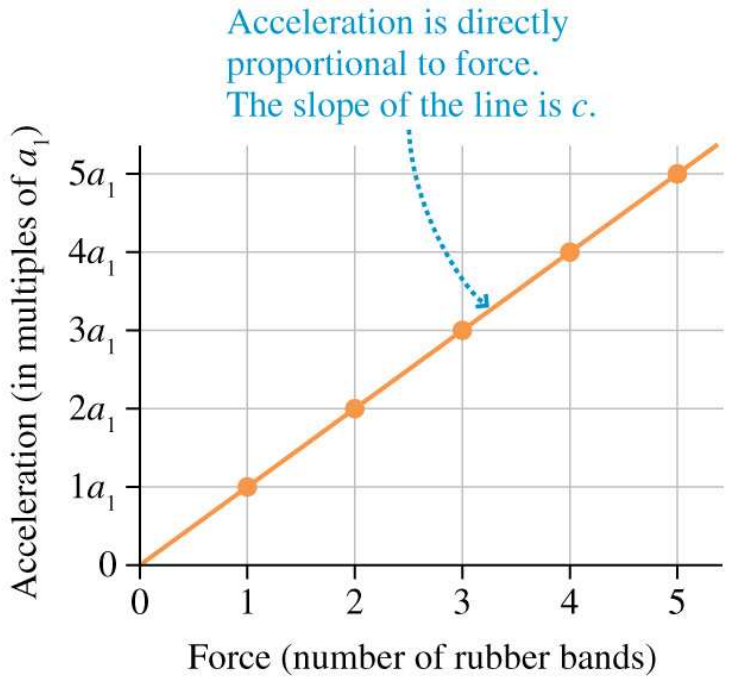
Stretching by different amounts causes different accelerations
spring causes non-constant acceleration.

- To define force consider a spring (rubber band) stretched by a constant amount
  - Accelerate spring by the same value as it wants to accelerate object for a fixed stretched amount

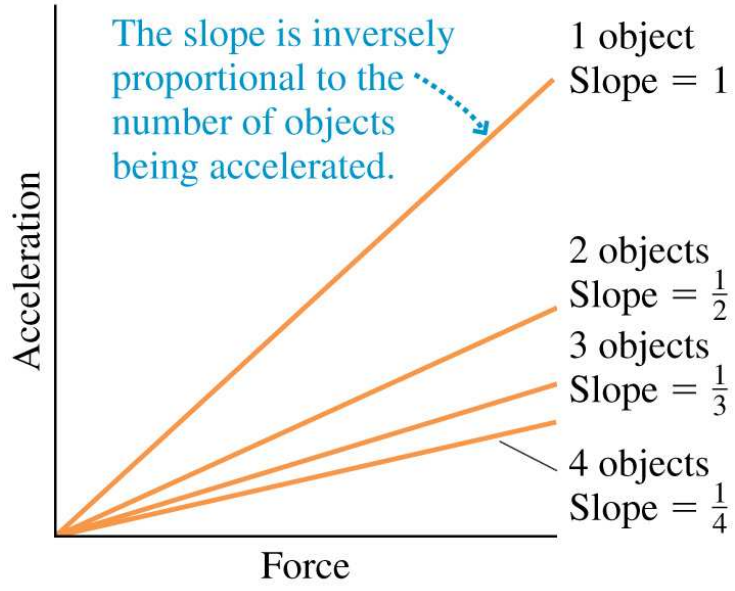


Mass

one object variable force



multiple objects variable force



The force is given by $\vec{\mathbf{F}} = m\vec{\mathbf{a}}$ with m being defined as the mass

Clicker

An object is moving to the right, and experiencing a net force to the right. The magnitude of the force is decreasing with time. The speed of the object is:

1. increasing
2. decreasing
3. constant in time

Solution

An object is moving to the right, and experiencing a net force to the right. The magnitude of the force is decreasing with time. The speed of the object is:

1. increasing
2. decreasing
3. constant in time

The force is always to the right, therefore object always accelerates to the right, ie the velocity is always increasing.

Newton's Second Law of Motion

We start with Newton's second law of motion:

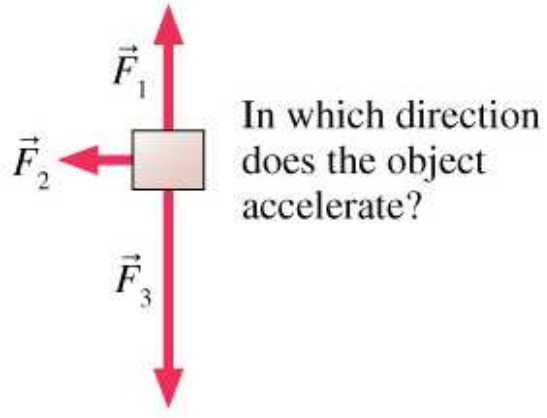
An object of mass m subjected to forces $\vec{\mathbf{F}}_1, \vec{\mathbf{F}}_2, \vec{\mathbf{F}}_3, \ldots$ will undergo an acceleration $\vec{\mathbf{a}}$ given by

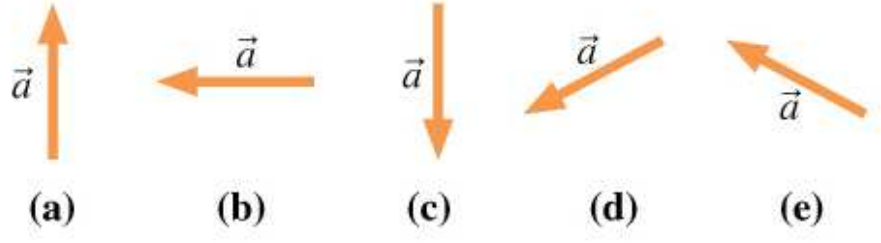
$$\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}_{\text{net}}}{m} \quad \text{where} \quad \vec{\mathbf{F}}_{\text{net}} = \sum_{i=1}^{n} \vec{\mathbf{F}}_i$$

The acceleration vector $\vec{\mathbf{a}}$ points in the same direction as the net force vector $\vec{\mathbf{F}}_{\text{net}}$.

Clicker

Three forces act on an object. In which direction does the object accelerate.





Units

Units of force are given by $\vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}} =$ Mass*Length/Time^2

Therefore in the SI system of units, force has the units:

$$\vec{\mathbf{F}} = \frac{\text{kg} \times \text{m}}{\text{s}^2} = \text{newtons}$$

In the English system of units

$$\vec{\mathbf{F}} = \frac{\text{ft} \times \text{slugs}}{\text{s}^2} = \text{pounds}$$

where the unit for mass is the slug 1 lb $= 4.45$ N

Newton's First Law of Motion

An object that is at rest will remain at rest, or an object that is moving will continue to move in a straight line with constant velocity, if and only if the net force acting on the object is zero.

This defines what we mean by a force.

Clicker

The space shuttle orbits the Earth while traveling at a constant speed in 90.35 minutes at an altitude of 290 km. Which of the following statements is true:

A) The shuttle astronauts experience a net force directed away from the Earth;

B) The shuttle astronauts experience a net force directed toward the Earth;

C) The shuttle astronauts experience no net force;

D) The space shuttle experiences a net force directed toward the Earth, while the astronauts experience no net force;

E) None of the above.

Assignment

Read section on inertial reference frames. Start reading Chapter 5 for the next lecture

Monday will apply Newton's second law to a variety of problems.