Preview of Period 6:
Energy and Work

6.1 Work and Energy

How much energy is required to do work?

6.2 Potential Energy

How do objects gain potential energy?

How can we use their potential energy to do work?

6.3 & 6.4 Kinetic Energy ⟷ Potential Energy

What happens when potential energy is converted into kinetic energy?

6.5 & 6.6 Energy Conservation and Conversions

Does the amount of energy in the Universe increase, decrease, or remain constant?

6.7 Energy Storage

How is potential energy stored?

Act. 6.1: Work and Energy

Work is done when a force moves an object over some distance in the direction of the force.

Work = Force x Distance

$$W = F\ D$$

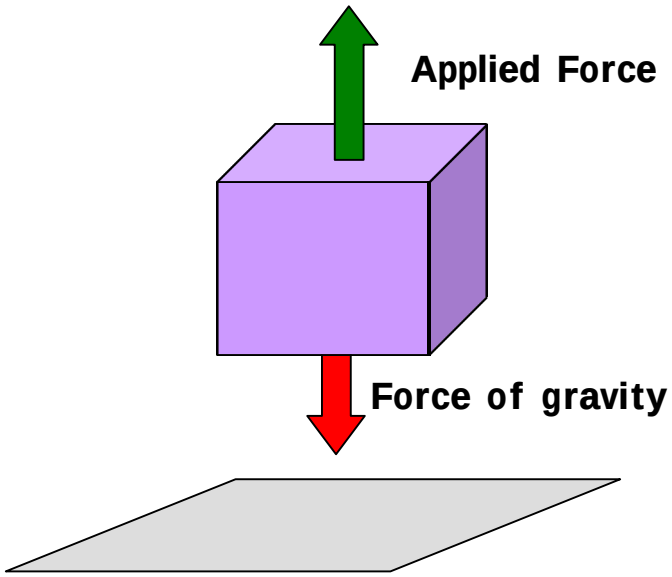
W **= work (joules or foot-pounds)**

F **= force applied (newtons or pounds)**

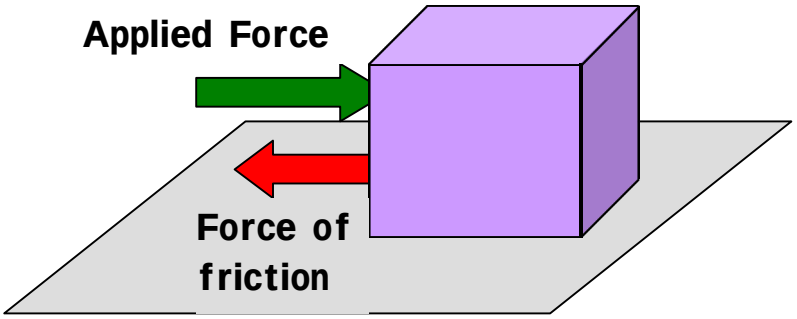
D **= distance moved in the direction of the force (meters or feet)**

Work and energy are measured in units of joules.

$$1 \text{ joule} = 1 \text{ kg m}^2/\text{s}^2$$



Work is done to raise a box vertically against the force of gravity.



Work is done to move a box horizontally against the force of friction.

Work Done to Lift a Box Vertically

The weight of an object equals the object's mass times the acceleration of gravity (g)

$$Weight = F = M g$$

The work required to lift an object equals the object's weight times the vertical distance it moves.

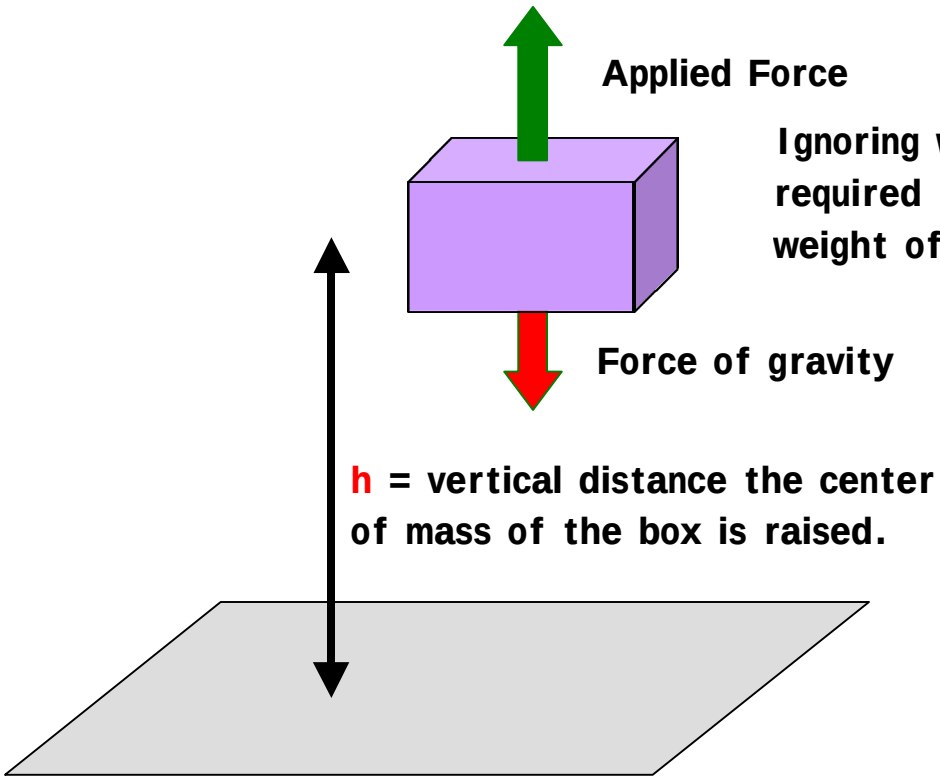
$$W = M g h$$

W **= work (joules)**

M **= mass of object (kilograms)**

g = acceleration of gravity = 9.8 m/s^2

h **= vertical height the object moves (meters)**

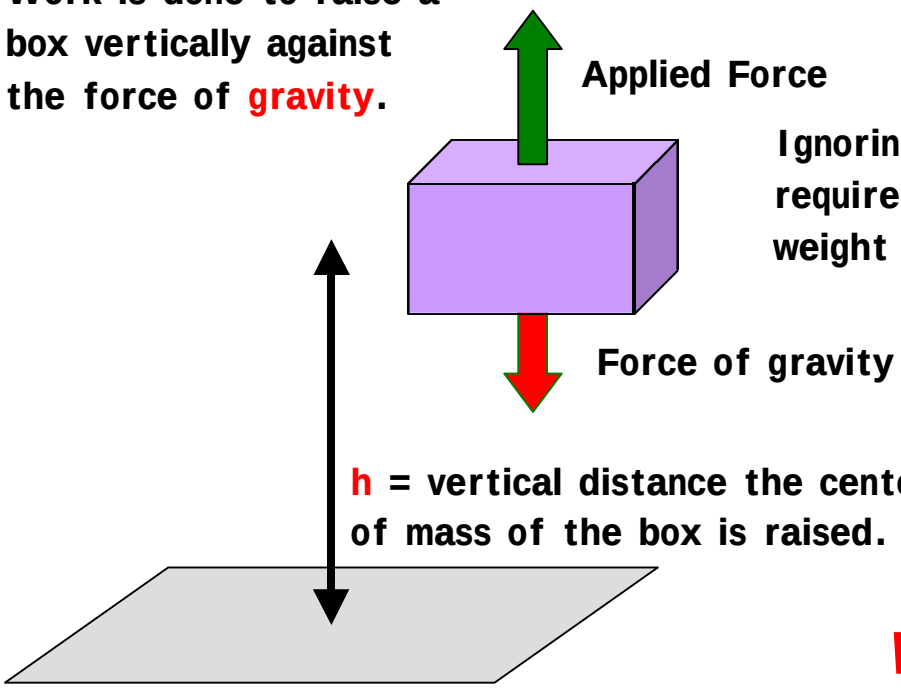


Ignoring wasted energy, the force required to lift the box is the weight of the box. weight = Mg

Work is done when a force moves an object over some distance in the direction of the force.

Work = Force x Distance

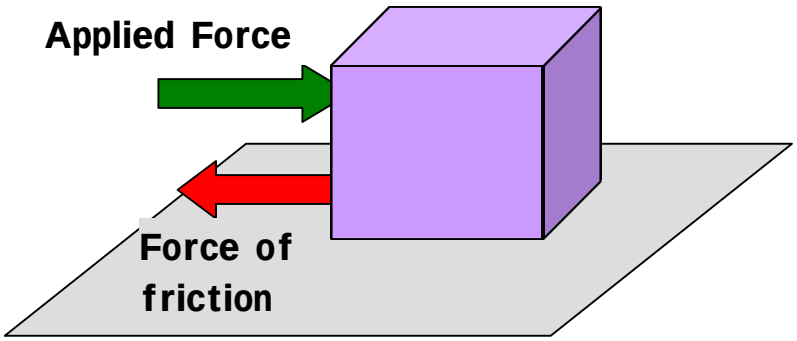
Work is done to raise a box vertically against the force of **gravity**.



Ignoring wasted energy, the force required to lift the box is the weight of the box. weight = Mg

h = vertical distance the center of mass of the box is raised.

$$W = M g h$$



Work is done to move a box horizontally against the force of **friction.**

$$W = F D$$

Act. 6.2: Work and Potential Energy

Potential energy is stored energy, which can be used to do work.

We use gravitational potential energy as an example of the many forms of potential energy.

Gravitational potential energy = weight of object times vertical change in its height

$$E_{pot} = M\ g\ h$$

M = mass of object (kilograms)

g = acceleration of gravity = 9.8 m/s^2

h = change in vertical height (meters)

Neglecting the energy wasted by friction, the gain in gravitational potential energy from raising an object equals the work done to raise it.

Act. 6.4: Kinetic ⟺ Potential Energy

Gravitational potential energy is most useful when it is converted into the kinetic energy of motion.

$$E_{kin} = \frac{1}{2} M v^2$$

E_{kin} = kinetic energy (joules)

M = mass (kilograms)

v = speed (meters/sec)

(Ex. 6.1)

What is the kinetic energy of a 1,000 kg car moving at 30 miles per hour?

Convert miles per hour into meters per second.

$$\frac{30\ \cancel{\text{miles}}}{1\ \cancel{\text{hour}}} \times \frac{1609\ \text{m}}{1\ \cancel{\text{mile}}} \times \frac{1\ \cancel{\text{hour}}}{3600\ \text{sec}} = \frac{13.4\ \text{m}}{1\ \text{sec}}$$

Next, substitute values into the equation.

$$E_{kin} = (1/2)\, M v^2 = \tfrac{1}{2} \times 1000\ \text{kg} \times (13.4\ \text{m/s})^2$$

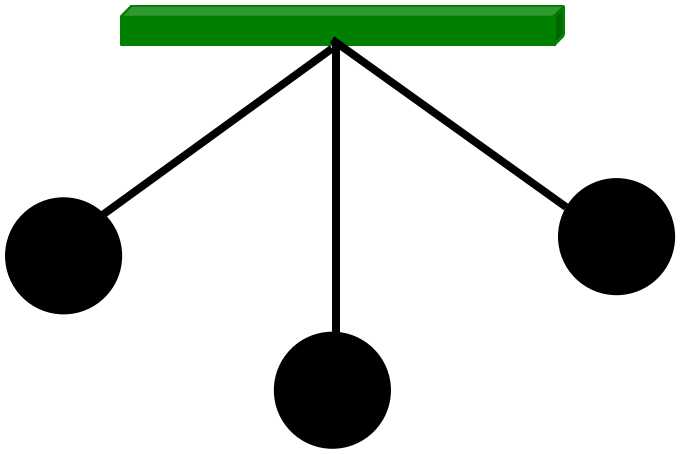
$$= 500\ \text{kg} \times 180\ \text{m}^2/\text{s}^2 = 90{,}000\ \text{kg m}^2/\text{s}^2$$

$$= 9 \times 10^4\ \text{J}$$

Act. 6.4: The swinging ball pendulum

As the ball swings, identify the point(s) at which its

- **Potential energy is at its MAXIMUM and at its MINIMUM**
- **Velocity is at its MAXIMUM, and at its MINIMUM**
- **Kinetic energy is at its MAXIMUM and at its MINIMUM**



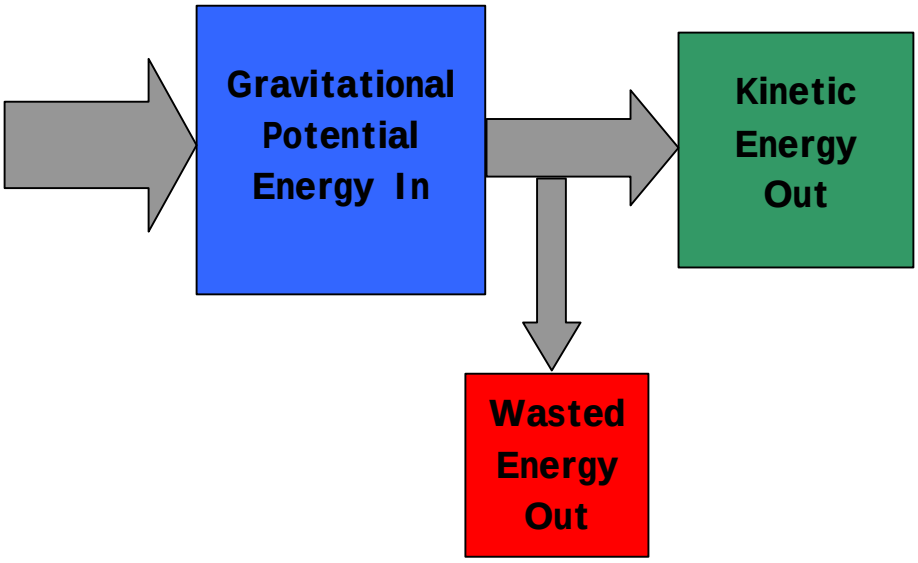
Act. 6.5: Energy Conservation

The law of conservation of energy:

- **Energy can be neither created nor destroyed.**
- **The total amount of energy we have now in the Universe is the same amount that existed at its beginning.**
- **All the energy that goes into a conversion process must come out – no energy can be lost or destroyed.**
- **In every energy conversion, some energy is wasted.**
- **Wasted energy is often in the form of thermal energy from the force of friction.**

Energy Conservation and Conversions

An Example of Conservation of Energy



Gravitational Potential Energy In =

Kinetic Energy Out + Wasted Energy Out

How is energy conserved in the rolling cart demonstration?

Act. 6.6: Work Done Against Friction

Work = Force x Distance

$$W = F\ D$$

W **= work (joules or foot-pounds)**

F **= force applied (newtons or pounds)**

D **= distance moved in the direction of the force (meters or feet)**

(Example 6.1)

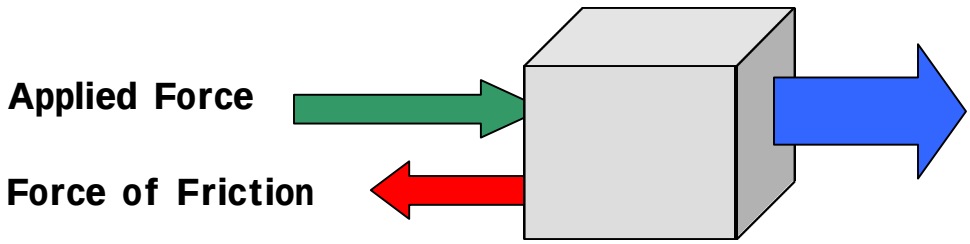
Once a box is moving, you must apply a force of 6 N to keep it moving at constant speed. How much work was done against the force of sliding friction to move the box a distance of 0.5 meters?

Force moving the box = Force of friction = 6 N

$$W = F\,D = 6\text{ N} \times 0.5\text{ m} = 3\text{ N m} = 3\text{ joules}$$

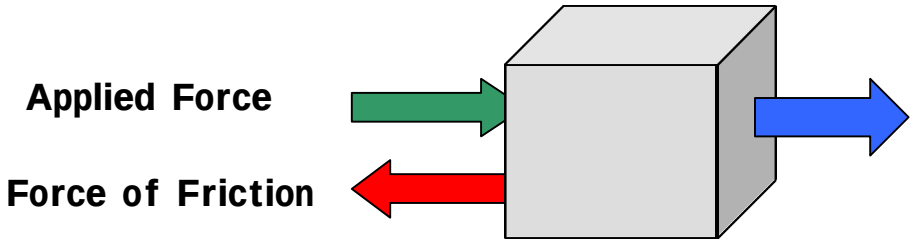
Moving an Object with An Applied Force

An Applied Force Larger than the Force of Friction Accelerates a Box



The box accelerates across a level floor in the direction of the applied force.

An Applied Force Equal to the Force of Friction Moves the Box at a Constant Speed

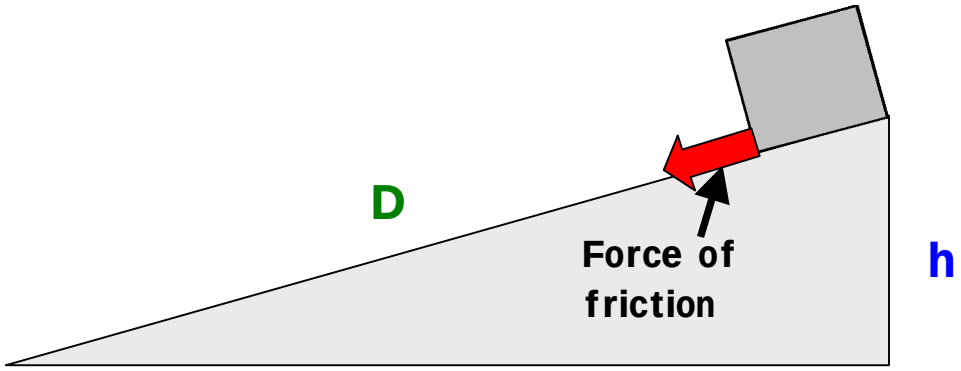


The box moves with constant speed across a level floor in the direction of the applied force.

The work done to move the box equals the amount of the applied force times the distance the box moves.

$$W = F\ D$$

Work Has Been Done to Move a Box Up an Incline



The work done to move a box up an incline

= the work needed to raise it to a height h against the force of gravity

+ the work needed to move it a distance D against the force of friction.

$$W = M g h + F D$$

Period 6 Summary

6.1: Work is done when a force moves an object over a distance in the direction of the force. Work = Force x Distance, or

$$W = F\ D$$

One joule of work is done when a 1 newton weight is lifted vertically 1 meter.

6.2: Potential energy is stored energy, which is available to do work.

The gravitational potential energy stored in a raised object is proportional to the height it is raised and to the mass of the object.

$$E_{pot} = M\ g\ h$$

6.3: Kinetic energy is the energy of motion. The amount of kinetic energy depends on the mass and the square of the speed of an object.

$$E_{kin} = \tfrac{1}{2}\ M\ v^2$$

Period 6 Summary, Continued

6.4: Law of conservation of energy: Energy can be converted from one form into another, but cannot be created or destroyed.

Some of the gravitational potential energy stored when an object is lifted is converted into kinetic energy as the object falls.

As in all energy conversion processes, some gravitational potential energy is wasted, usually as thermal energy from friction.

6.5 Moving an object horizontally usually involves doing work against the force of friction.

For an object moving at constant velocity across a level surface, all of the energy is used to do work against the force of friction.

For an accelerating object, some energy goes into doing work against the force of friction and some energy goes into increasing the kinetic energy of the object.

Period 6 Review Questions

R.1 How is work done? What can happen when a force is applied to an object that experiences a frictional force with the surfaces it touches?

R.2 What is potential energy? Give examples.

R.3 When gravitational potential energy is converted into kinetic energy, how does the amount of potential energy put into the process compare to the amount of kinetic energy out? What happens to the remaining energy?

R.4 What is the law of conservation of energy? How do energy conversion processes affect the total amount of energy in the Universe?

R.5 Jennifer pushes a 25 newton box up a ramp to a vertical height of 2 meters. Peter lifts a 25 newton box from the ground to a height of 2 meters. Who has done more work to lift the box? Why?

R.6 How is the amount of kinetic energy of an object related to its mass and its velocity? How much kinetic energy does a 5,000 kg truck traveling at 20 m/s have?