PHY131H1S – Class 17

Today:

- Work
- Calories
- The Work-Kinetic Energy Theorem.
- Dissipative Forces and Thermal Energy
- Power

Pre-class Reading Quiz 1. The transfer of energy to a system by the application of a force is called

A. dot product.
B. power.
C. work.
D. watt.
E. energy transformations.

Work

- A force is applied to an object.
- The object moves while this force is being applied.
- The work done by a constant force is the dot-product of the force and the displacement.

$$W = F\, r \cos\theta$$

Work

$$W = F\, r \cos\theta$$

- If the force has a component in the direction of the displacement, the work is positive.
- If the force has a component opposite the direction of the displacement, the work is negative (energy is removed from the object by the force)
- If the force is perpendicular to the displacement, work=0 and the object's energy does not change. Normal force often has this property.

In Class Discussion Question 1

- Adeel is doing a bench press, and he slowly pushes the bar up a distance of 0.30 m while pushing upwards on the bar with a force of 200 N. The bar moves with a constant velocity during this time.
- During the upward push, how much **work** does Adeel do on the bar?

A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J

In Class Discussion Question 2

- Adeel is doing a bench press, and he slowly lowers the bar down a distance of 0.30 m while pushing upwards on the bar with a force of 200 N. The bar moves with a constant velocity during this time.
- During the downward lowering, how much **work** does Adeel do on the bar?

A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J

In Class Discussion Question 3

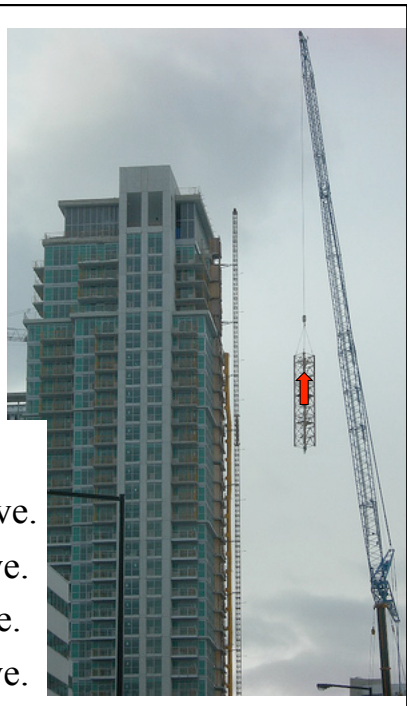
- Adeel is doing a bench press, and he slowly lowers the bar down a distance of 0.30 m while pushing upwards on the bar with a force of 200 N. He then pushes it up slowly the same distance of 0.30 m back to its starting position, also pushing upwards on the bar with a force of 200 N.
- During the complete downward and upward motion, how much total **work** does Adeel do on the bar?

A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J

Calories

- One food Calorie (note the capital "C", also sometimes called a kilocalorie) is equal to 4186 Joules.
- Fat is a good form of energy storage because it provides the most energy per unit mass.
- 1 gram of fat provides about 9.4 (food) Calories.
- Example. Your mass is 70 kg. You climb the stairs of the CN Tower, a vertical distance of 340 m. How much energy does this take (minimum)?
- How much fat will you burn doing this?

In-Class Discussion Question 4.
A crane raises a steel girder into place at a construction site.
The girder moves with constant speed, *v*.
Consider the work W_g done by gravity and the work W_T done by the tension in the cable.
Which of the following is correct?



A. W_g and W_T are both zero.
B. W_g is negative and W_T is negative.
C. W_g is negative and W_T is positive.
D. W_g is positive and W_T is positive.
E. W_g is positive and W_T is negative.

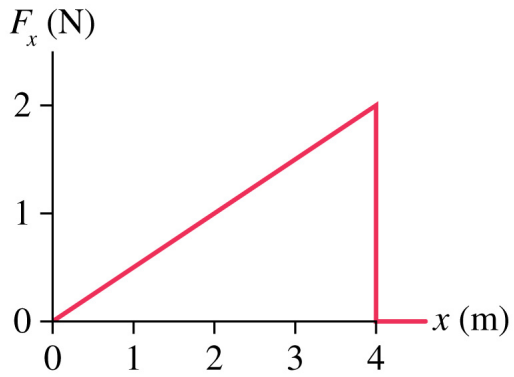
The Work Done by a Variable Force

To calculate the work done on an object by a force that either changes in magnitude or direction as the object moves, we use the following:

$$W = \int_{s_i}^{s_f} F_s \, ds = \text{area under the force-versus-position graph}$$

We must evaluate the integral either geometrically, by finding the area under the cure, or by actually doing the integration.

In Class Discussion Question 5.
A particle moving along the *x*-axis experiences the force shown in the graph.
How much work is done on the particle by this force as it moves from $x = 0$ to $x = 2$ m?



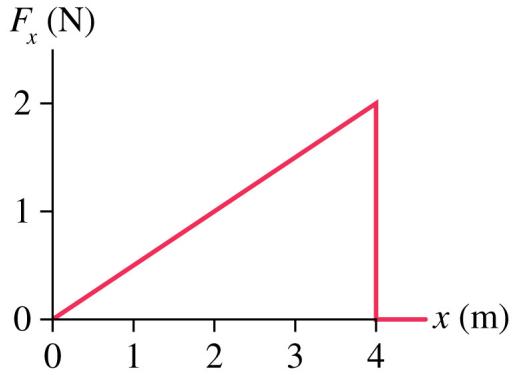
A. 0.0 J
B. 1.0 J
C. 2.0 J
D. 4.0 J
E. −2.0 J

The Work – Kinetic Energy Theorem:

- The work done by the net force on an object as it moves is called the "net work", W_{net}.
- The the net work causes the object's kinetic energy to change by:

$$\Delta K = W_{\text{net}}.$$

In Class Discussion Question 6.
A particle moving along the *x*-axis experiences the force shown in the graph. The particle starts at rest at *x* = 0. What is the kinetic energy of the particle when it reaches *x* = 2 m?



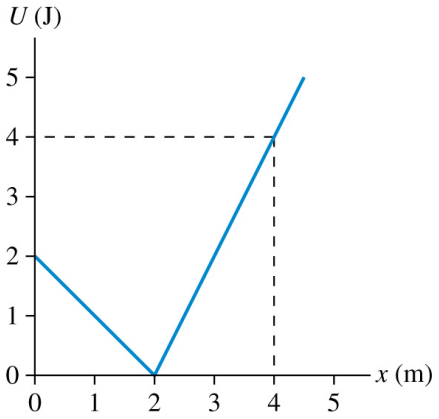
A. 0.0 J
B. 1.0 J
C. 2.0 J
D. 4.0 J
E. −2.0 J

Finding Force from Potential Energy

- When you plot Force versus distance, the area under the curve is a form of energy called work.
- When you plot Potential Energy versus distance, the slope of the curve is related to Force.

$$F_x = -\frac{dU}{dx}$$

Example Test Question.
A particle moves along the *x*-axis with the potential energy shown.
Draw the corresponding graph of force on the particle versus distance.



Thermal Energy

- Dissipative forces transform macroscopic energy (kinetic), into thermal energy.
- Thermal energy is the microscopic energy due to random vibrational and rotational motion of atoms and molecules.
- For friction:

$$\Delta E_{\text{th}} = f_{\text{k}} \Delta s$$

The Work – Kinetic Energy Theorem:

- The the net work causes the object's kinetic energy to change by:

$$\Delta K = W_{\text{net}} = W_{\text{c}} + W_{\text{diss}} + W_{\text{ext}}$$

$W_{\text{c}} = -\Delta U$ is the work done by conservative forces, and is equal to the negative of the change in potential energy.

$W_{\text{diss}} = -\Delta E_{\text{th}}$ is the work done by dissipative forces, and is equal to the negative of the thermal energy created.

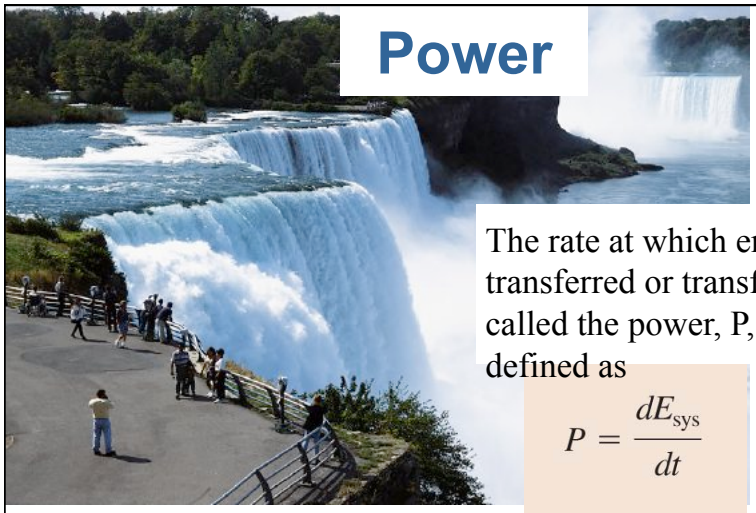
W_{ext} is the work done by other external forces.

In Class Discussion Question 7.

A child slides down a playground slide at ***constant speed***.

The energy transformation is

A. $U \rightarrow K$.
B. $U \rightarrow E_{\text{th}}$.
C. $K \rightarrow U$.
D. $K \rightarrow E_{\text{th}}$.
E. There is no transformation because energy is conserved.



Power

The rate at which energy is transferred or transformed is called the power, P, and it is defined as

$$P = \frac{dE_{sys}}{dt}$$

The unit of power is the watt, which is defined as 1 watt = 1 W = 1 J/s. Energy is measured by Ontario Hydro in kWh = "kiloWatt•hours". They charge about $0.10 per kWh.
How many Joules is this?