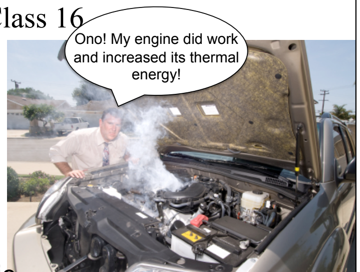
PHY131H1F - Class 16



Today:

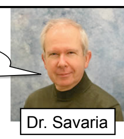
- Work and Force
- Work and Potential Energy
- The Work-Kinetic Energy Theorem
- Thermal Energy
- Power

Ch.11 Reading Quiz:

- For conservative forces, **Force** can be found as being –1× the derivative of

A. impulse.
B. kinetic energy.
C. momentum.
D. potential energy.
E. work.

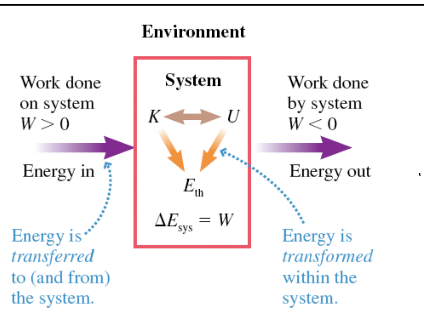
Announcement



- Test 2 will be on Tuesday, Nov. 22 from 8:00 to 9:30pm [note late start!]
- If you have a conflict at that time, and you were registered for the alternate sitting for test 1, you must send an email to April Seeley requesting an alternate sitting for test 2 by Thursday Nov. 17 by 5:00pm.
- If you have a conflict at that time, and you were ***not*** registered for the alternate sitting for test 1, you must visit MP129 and fill out a conflict form for test 2 by Thursday Nov. 17 by 5:00pm.
- The alternate sitting will take place on Wednesday Nov. 23 at 7:40am.

Last day I asked at the end of class:

- If one object does work on another object, does energy always get transferred from one object to the other?
- ANSWER:
- *Yes*!
- When object 1 does positive work on object 2, then object 1 loses some form of energy, and object 2 gains this energy.
- Equivalently, during this process, we can say that object 2 does negative work on object 1. Again, object 1 loses energy and object 2 gains it.



$W > 0$: The environment does work on the system and the system's energy increases.
$W < 0$: The system does work on the environment and the system's energy decreases.

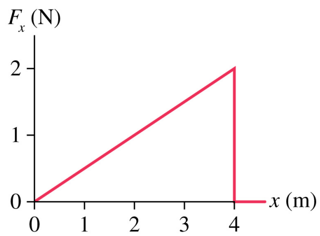
Chapter 11: Work

- Consider a force acting on a particle as the particle moves along the s-axis from s_i to s_f
- The force component F_s *parallel* to the s-axis causes the particle to speed up or slow down, thus transferring energy to or from the particle
- We say that the force does **work** on the particle:

$$W = \int_{s_i}^{s_f} F_s \, ds$$

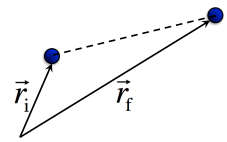
- The unit of work is J, or Joules.

A particle moving along the x-axis experiences the force shown in the graph. The particle starts at $x_i = 0$. What is the work done by this force on the particle as it moves to $x_f = 4$ m?



A. 0 J
B. 1 J
C. 2 J
D. 4 J
E. 8 J

Work Done by a Constant Force

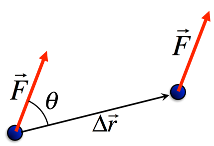


- Consider a particle which moves along a straight line
- The particle's displacement over the time interval $\Delta t = t_f - t_i$ is:

$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i$$

- As the particle moves it is subject to a constant force

Work Done by a Constant Force



- As the particle moves it is subject to a constant force
- The angle between the force $\vec{F}$ and the displacement vector $\Delta\vec{r}$ is θ
- The work done on the particle is:

$$W = \int_{s_i}^{s_f} F_s\,ds = \int_{r_i}^{r_f} F\cos\theta\,dr$$

- Both F and θ are constant, so they can be taken outside the integral. Thus:

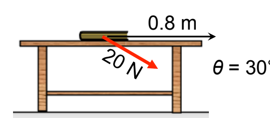
$$W = F\cos\theta\int_{r_i}^{r_f} dr = F\cos\theta(\Delta r)$$

Example

- Harlow pushes a book with a force of 20 Newtons, at an angle of 30° below horizontal.
- As he is pushing, the book slides forward a distance of 0.8 m.
- How much work does Harlow do on the book as it slides?

Answer:

W = F·cosθ·Δr
W = (20)·cos(30°)·0.8
W = 14 Joules

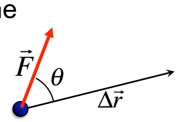


Work

- 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:

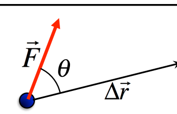
$$W = \vec{F}\cdot\Delta\vec{r}$$

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



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.

- Leo 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 Leo do on the bar?

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

- Leo 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 Leo do on the bar?

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

- Leo slowly carries a barbell sideways 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 sideways movement, how much **work** does Leo do on the bar?

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

Calories

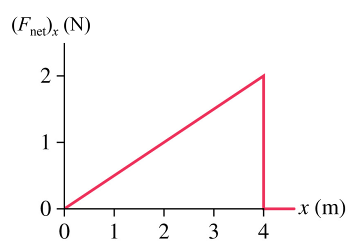
- One food Calorie (note the capital "C", also sometimes called a kilocalorie) is equal to 4186 Joules.
- Fat is a good form of energy storage because it provides the most energy per unit mass.
- 1 gram of fat provides about 9.4 (food) Calories.
- **Example:** Your mass is 70 kg. You climb the stairs of the CN Tower, a vertical distance of 340 m. How much energy does this take (minimum)?
- [answer = 230,000 Joules]
- How much fat will you burn doing this?
- [answer = 0.01 lbs of fat]

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:

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

A particle moving along the x-axis experiences the *net* force shown in the graph. The particle starts *at rest* at $x_i = 0$. What is the *kinetic energy* of the particle when it reaches $x_f = 4$ m?



A. 0.0 J
B. 1.0 J
C. 2.0 J
D. 4.0 J
E. 8.0 J

Finding Force from Potential Energy

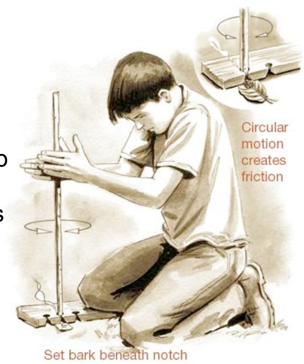
- When you plot Force versus distance, the area under the curve is a form of energy called work.
- When you plot Potential Energy versus distance, the slope of the curve is related to Force.

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

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:

$$\Delta E_{th} = f_k \Delta s$$



The Work – Kinetic Energy Theorem:

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

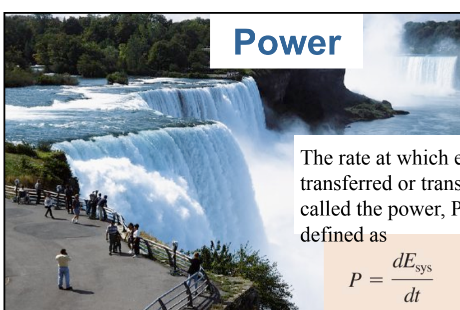
$$\Delta K = W_{net} = W_c + W_{diss} + W_{ext}$$

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

A child slides down a playground slide at ***constant speed***.
The energy transformation is

A. $U \rightarrow K$.
B. $U \rightarrow E_{th}$.
C. $K \rightarrow U$.
D. $K \rightarrow E_{th}$.
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".

Before Class 17 on Monday

- Please read the Part III Overview, and Chapter 12 of Knight, sections 12.1-12.7
- Problem Set 8 on Chapter 11 is due Friday
- Something to think about: Why is a door easier to open when the handle is far from the hinge, and more difficult to open when the handle is in the middle?