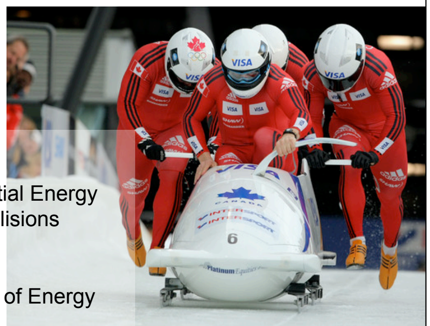
PHY131H1F Summer – Class 9



Today:
- Hooke's Law
- Elastic Potential Energy
- Energy in Collisions
- Work
- Calories
- Conservation of Energy
- Power
- Dissipative Forces and Thermal Energy

Ch.10 Reading Quiz 1 of 3:
- Two objects collide. All external forces on the objects are negligible.
- If the collision is "perfectly elastic", that means it conserves

A. Momentum $p=mv$
B. Kinetic energy $E = ½ mv^2$
C. Both
D. Neither

Ch.10 Reading Quiz 2 of 3:
- Two objects collide. All external forces on the objects are negligible.
- If the collision is "inelastic", that means it conserves

A. Momentum $p=mv$
B. Kinetic energy $E = ½ mv^2$
C. Both
D. Neither

Ch.10 Reading Quiz 3 of 3:

- Two objects collide. All external forces on the objects are negligible.
- If the collision is "perfectly inelastic", that means

A. momentum is not conserved.
B. the final kinetic energy is zero.
C. the objects stick together.
D. one of the objects ends with zero velocity.

Ch.11 Reading Quiz:

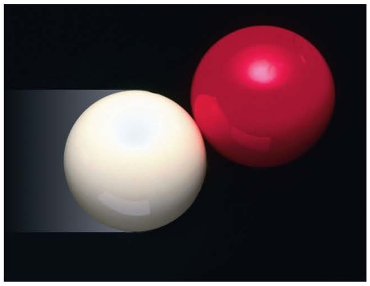
- For conservative forces, **Force** can be found as being –1× the derivative of

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

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.

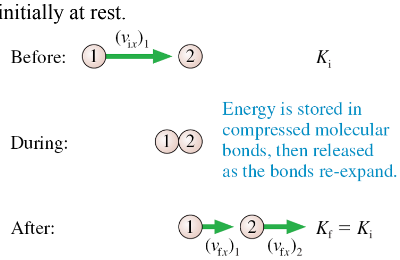
Elastic Collisions



A perfectly elastic collision conserves both momentum and mechanical energy.

1D Elastic Collision when ball 2 is initially at rest.

Consider a head-on, perfectly elastic collision of a ball of mass m_1 having initial velocity $(v_{ix})_1$, with a ball of mass m_2 that is initially at rest.



The balls' velocities after the collision are $(v_{fx})_1$ and $(v_{fx})_2$.

1D Elastic Collision when ball 2 is initially at rest.

momentum conservation: $m_1(v_{fx})_1 + m_2(v_{fx})_2 = m_1(v_{ix})_1$

energy conservation: $\frac{1}{2}m_1(v_{fx})_1^2 + \frac{1}{2}m_2(v_{fx})_2^2 = \frac{1}{2}m_1(v_{ix})_1^2$

There are two equations, and two unknowns: v_{fx1} and v_{fx2}.
You can solve this! Don't be afraid!

Eq. 10.43:

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1$$

$$(v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$

(perfectly elastic collision with ball 2 initially at rest)

Elastic Collision when ball 2 is initially at rest.

Eq. 10.43:

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1$$
$$(v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$
(perfectly elastic collision with ball 2 initially at rest)

These equations come in especially handy, because you can always switch into an inertial reference frame in which ball 2 is initially at rest!

Demonstration and Example

- A 0.50 kg basketball and a 0.05 kg tennis ball are stacked on top of each other, and then dropped from a height of 0.82 m above the floor.
- How high does the tennis ball bounce?
- Assume all perfectly elastic collisions.

Demonstration and Example

- Divide motion into segments.
- Segment 1: free-fall of both balls from a height of h = 0.82 m. Use conservation of energy: $U_f + K_f = U_i + K_i$

$0 + ½\, m\, v_f^2 = mgh + 0$

$v_f = [2gh]^{½} = -4.0$ m/s, for both balls.

- Segment 2: basketball bounces elastically, so its new velocity is +4.0 m/s.

Demonstration and Example

- Segment 3: A 0.50 kg basketball moving upward at 4.0 m/s strikes a 0.05 kg tennis ball, initially moving downward at 4.0 m/s.
- Their collision is perfectly elastic.
- What is the speed of each ball immediately after the collision?

Demonstration and Example

- Segment 4: freefall of tennis ball on the way up. vi = +10.5 m/s.
- Use conservation of energy: $U_f + K_f = U_i + K_i$

$mgh + 0 = 0 + ½\, m\, v_i^2$

$h = v_i^2/(2g) = 5.6$ m.

- So the balls were dropped from 0.82 m, but the tennis ball rebounds up to 5.6 m! (Assuming no energy losses.)

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.

Work Done by a Constant Force

Consider a particle which experiences a constant force which makes an angle θ with respect to the particle's displacement.

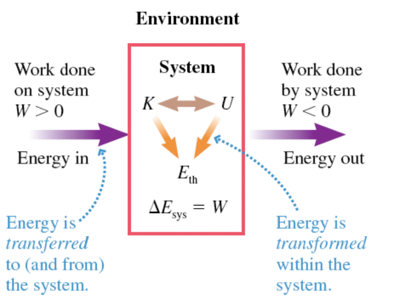
The work done on the particle is

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

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

$$W = F\cos\theta \int_{s_i}^{s_f} ds = F\cos\theta(s_f - s_i) = F(\Delta r)\cos\theta$$

or: $W = \vec{F}\cdot\Delta\vec{r}$ (work done by a constant force)



***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.

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.

- 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 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 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)?
- How much fat will you burn doing this?

In-Class Discussion Question.
A crane raises a steel girder into place at a construction site.
The girder moves with constant speed, *v*, upward.
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.

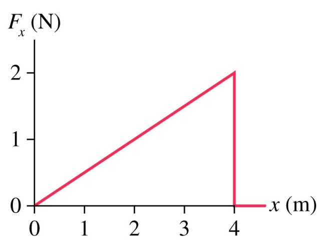
The Work Done by a Variable Force

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.

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?



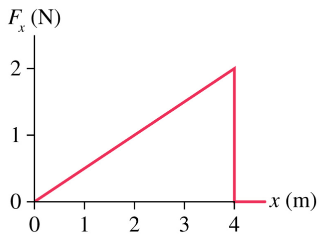
A. 0.0 J
B. 1.0 J
C. 2.0 J
D. 4.0 J
E. −2.0 J

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:

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

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?



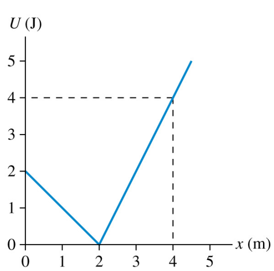
A. 0.0 J
B. 1.0 J
C. 2.0 J
D. 4.0 J
E. −2.0 J

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.

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

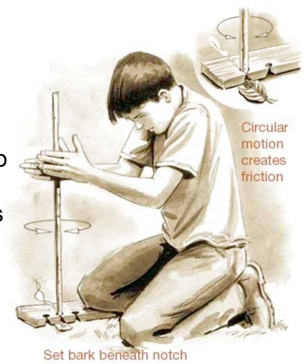
Example.
A particle moves along the x-axis with the potential energy shown.
Draw the corresponding graph of force on the particle versus distance.



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:

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



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.

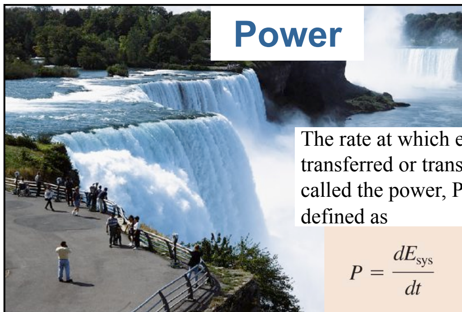
$W_{diss} = -\Delta E_{th}$ is the work done by dissipative forces, and is equal to the negative of the thermal energy created.

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". They charge about $0.10 per kWh. How many Joules is this?

Before Next Class:

- Read Chapter 12.
- Complete MasteringPhysics.com Problem Set 7 due tomorrow at 11:59pm
- 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?

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