Momentum and Collisions

Momentum and ImpulseConservation of Momentum Elastic and Inelastic Collisions

MCHS Honors Physics 2014-15

Kinetic Energy

- Kinetic energy is energy associated with an object in motion.
- Remember our Work Equation:
- We can say that because of Newton's second law.
- We also know that: $v_f^2 = v_i^2 + 2a\Delta x$
- If we solve this equation for *a* Δ *x, we get:*

$$a\Delta x = \frac{v_f^2 - v_i^2}{2}$$

- Substituting this result into the W_{net} equation gives:

Kinetic Energy

$$W_{net} = m\left(\frac{v_f^2 - v_i^2}{2}\right)$$

$$W_{net} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

- Kinetic energy depends on speed and mass
- The quantity ½ mv^2 has a special name in physics: kinetic energy.
- The kinetic energy of an object with mass *m* and speed *v*, when treated as a particle, is given by the expression shown on the next page.

Kinetic Energy

- The kinetic energy of an object with mass *m* and speed *v*, when treated as a particle, is given by the expression:

KINETIC ENERGY

$$KE = \frac{1}{2} mv^2$$

$$\textbf{kinetic energy} = \frac{1}{2} \times \textbf{mass} \times (\textbf{speed})^2$$

- Kinetic energy is a scalar quantity, and the SI unit for kinetic energy (and all other forms of energy) is the joule, just like the basic unit for work.

(let's do an example…)

Kinetic Energy

- The net work done on a body equals its change in kinetic energy.
- The equation $W_{net} = ½\, m\, v_f^2 – ½\, m\, v_i^2$ derived at the beginning of this section says that the net work done by a *net* force acting on an object is equal to the *change* in the kinetic energy of the object.
- This important relationship, known as the:

WORK–KINETIC ENERGY THEOREM

$$W_{net} = \Delta KE$$

$$\textbf{net work} = \textbf{change in kinetic energy}$$

Kinetic Energy

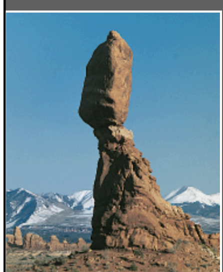
- When you use this theorem, you must include all the forces that do work on the object in calculating the net work done.
- From this theorem, we see that the speed of the object increases if the net work done on it is positive, because the final kinetic energy is greater than the initial kinetic energy.
- The object's speed decreases if the net work is negative, because the final kinetic energy is less than the initial kinetic energy.

Kinetic Energy

- The work–kinetic energy theorem allows us to think of kinetic energy as the work that an object can do while the object changes speed or as the amount of energy stored in the motion of an object.

(let's do another example…)

Potential Energy



- Consider the balanced boulder shown below.
- As long as the boulder remains balanced, it has no kinetic energy.
- If it becomes unbalanced, it will fall vertically to the desert floor and will gain kinetic energy as it falls.
- What is the origin of this kinetic energy?

Potential Energy

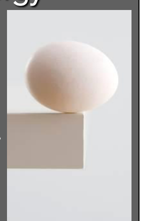
- Potential energy is stored energy
- Potential energy is associated with an object that has the potential to move because of its position relative to some other location.
- Unlike kinetic energy, potential energy depends not only on the properties of an object but also on the object's interaction with its environment.

Gravitational Potential Energy

- Gravitational potential energy depends on height
- We already know that, if an object is thrown up in the air, the force of gravity will eventually cause the object to fall back down.
- Similarly, the force of gravity will cause the unbalanced boulder in the previous example to fall.
- The energy associated with an object due to the object's position relative to a gravitational source is called gravitational potential energy.

Gravitational Potential Energy

- As an egg falls off the edge of a table, it gains kinetic energy.
- That gained energy comes from the potential energy due to the egg's initial position on the table relative to the floor.
- Gravitational potential energy can be determined using the following equation:



GRAVITATIONAL POTENTIAL ENERGY

$$PE_g = mgh$$

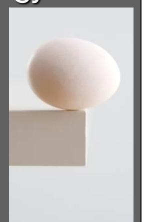
gravitational potential energy = mass × free-fall acceleration × height

Gravitational Potential Energy

- The SI unit for gravitational potential energy, like for kinetic energy, is the joule.
- Along with mass, gravitational potential energy also depends on both the height and the free-fall acceleration, neither of which is a property of an object.

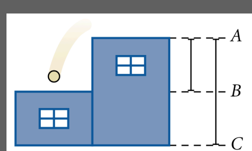
Gravitational Potential Energy

- Height, *h,* is measured from an arbitrary zero level.
- If the floor is the zero level, then *h* is the height of the table, and *mgh* is the gravitational potential energy relative to the floor.
- If the table is the zero level, then *h* is zero. Thus, the potential energy associated with the egg relative to the table is zero.



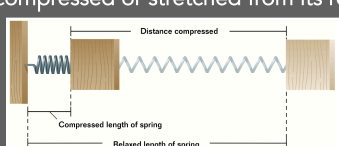
Gravitational Potential Energy

- The zero level is the vertical coordinate at which gravitational potential energy is defined to be zero.
- This zero level is arbitrary, and it is chosen to make a specific problem easier to solve.
- In many cases, the statement of the problem suggests what to use as a zero level.



Elastic Potential Energy

- Elastic potential energy depends on distance compressed or stretched.
- Elastic potential energy is stored in a spring by either compressing it or stretching it from it's relaxed length.
- The amount of energy depends on the distance the spring is compressed or stretched from its relaxed length



Elastic Potential Energy

- Elastic potential energy can be determined using the following equation:

ELASTIC POTENTIAL ENERGY

$$PE_{elastic} = \frac{1}{2}kx^2$$

$$\text{elastic potential energy} = \frac{1}{2} \times \text{spring constant} \times \left(\begin{array}{c}\text{distance compressed} \\ \text{or stretched}\end{array}\right)^2$$

- The symbol *k* is called the spring constant.
- The spring constant indicates how stiff a spring is.
- Spring constants have units of newtons divided by meters (N/m).

Conservation of Energy

- When we say that something is *conserved*, we mean that it remains constant.
- If we have a certain amount of a conserved quantity at some instant of time, we will have the same amount of that quantity at a later time.
- The quantity can change form during that time but there is always the same amount.
- An example of a conserved quantity is mass.

Mechanical Energy

- We have seen examples of objects that have either kinetic or potential energy. The description of the motion of many objects, however, often involves a combination of kinetic and potential energy as well as different forms of potential energy.
- Situations involving a combination of these different forms of energy can often be analyzed simply.
- Analyzing situations involving kinetic, gravitational potential, and elastic potential energy is relatively simple.

Mechanical Energy

- We can ignore these other forms of energy if their influence is negligible or if they are not relevant to the situation being analyzed.
- In most situations that we are concerned with, these forms of energy are not involved in the motion of objects.
- In ignoring these other forms of energy, we will find it useful to define a quantity called mechanical energy.

Mechanical Energy

- The mechanical energy is the sum of kinetic energy and all forms of potential energy associated with an object or group of objects.

$$ME = KE + \Sigma PE$$

- Mechanical energy is often conserved (if we neglect friction).

(do egg example on the board)

- Adding the kinetic and potential energy gives the total mechanical of an object.

Conservation of Energy

- Although the amount of mechanical energy is constant, mechanical energy itself can change form.
- The conservation of mechanical energy can be written symbolically as follows:

CONSERVATION OF MECHANICAL ENERGY

$$ME_i = ME_f$$

initial mechanical energy = final mechanical energy (in the absence of friction)