Momentum and Energy

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Momentum

Momentum is inertia in motion.

Momentum = mass x velocity

Unit kg meters/second

Momentum is changed by force. The amount of momentum change is also affected by how long the force acts. The product of force and time is called <u>impulse</u>.

Impulse = force x time

force x time = change in momentum

Units Newton x seconds [=] kg meters/second

- $Ft = D(mv) = m\,Dv$
  - This equation shows that when you want the force of impact to be small, extend the time of impact.
  - Examples: safety net of acrobats, boxer “rolling with the punch”, truck hitting a haystack and not a solid wall
  - On the other hand, if you want the force of impact to be large, have a small time of impact
  - Example: karate expert breaking a stack of bricks
- Bouncing
  - Impulses are greater when “bouncing” takes place. This is because you have to stop the motion and then give the object motion in the other direction – increasing the impulse.

Conservation of momentum

Whenever a physical quantity remains unchanged during a process, that quantity is said to be *conserved*. Momentum is such a quantity.

This idea is especially useful in analyzing collisions.

Collisions can be elastic (objects hit and bounce off each other without deformation or generation of heat) or inelastic (objects hit and deform, generate heat, stick together or all of the above). Momentum is always conserved in all collisions.

Momentum before collision = momentum after collision

Example: Consider a cart that has a mass of 0.50 kg and velocity 4.0 m/s that collides with a stationary cart of mass 1.5 kg. If the carts stick together after impact, what is the resulting velocity of the coupled carts?

Work

Force x time (impulse) tells us how much momentum is changed.

Force x distance (work) tells us how much the energy of the object is changed. Thus we define work as:

Work = force x distance

Units Joule [=] Newton x meter

Example: How much work is done when a force of 5.0 N moves a 10.0 kg object a distance of 2.0 m?

Mechanical energy

Energy is difficult to define – it is a property of all matter just like inertia. It allows for work to be done. There are many forms. For now we will focus on energy that is due to the positions of the interacting bodies (potential) or their motion (kinetic). This what we call *mechanical energy*.

Units - If work changes energy and is measured in Joules, then it makes sense that the Joule is the official energy unit. It is not a vector.

Gravitational potential energy

When work is done to elevate objects against the Earth's gravity an object gains gravitational potential energy. Examples: raising a book, water in a water tower.

Potential energy = weight x height

$$PE = mgh$$

Problem: How much work is done in lifting a 100. N block of ice a vertical distance of 3.00 m?

How much work is done in pushing the same block of ice up a 6.00 m long ramp if the force needed is 50.0 N?

What is the increase in PE in each case?

Kinetic energy

Energy of motion is called kinetic energy.

$$\text{Kinetic energy} = \tfrac{1}{2}\ \text{mass} \times \text{velocity}^2$$

$$KE = \tfrac{1}{2} m v_f^2$$

Notice that KE is proportional to the square of the velocity!

Problem: A 5.0 kg object is dropped from a height of 100.0 m. What is the PE and KE when it is dropped? Make a chart showing the PE and KE after 2.0 sec, 4.0 sec, and when it hits the ground.

Work-Energy Theorem

The kinetic energy of an object moving at a given speed is equal either to the work done in bringing the object from rest to that speed or to the work the object can do in being brought to rest.

$$\text{Work} = \Delta KE$$

This can also apply to the sum of PE and KE so

$$\text{Work} = \Delta E$$

Questions: When the brakes of a car going 90. km/h lock, how much farther will it skid than when the brakes lock at 30. km/h?

Compare the destruction from a 50. mi/h windstorm and a 100. mi/h windstorm.

Conservation of Energy

Law of conservation of energy - Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.

Power

Power is the rate at which work is done.

$$\text{Power} = \frac{\text{work done}}{\text{time}}$$

$$\text{Unit: watt } [=] \frac{\text{Joule}}{\text{second}}$$

Power is not a vector.

Although we are not officially on the SI (metric) system we do buy light bulbs and buy electrical energy using an SI unit!

Questions: How much time does it take for a 100. watt light bulb to use 5,000. Joules of energy?

How many Joules of energy are in one kilowatt- hour?

Machines

A machine multiplies/divides force or changes the direction of a force.

- If we multiply/divide force we must do it at the expense of distance. The law of conservation of energy limits what a machine can do. Levers and inclined planes are two basic simple machines. The principle of the lever can be used to analyze the wheel and axle and the pulley. The inclined plane can be used to understand the wedge and screw.

If friction is small:

work input (energy used) = work output (work done)

In many machines friction is not small so that these two are not equal. This means the efficiency is not 100%.

$$\% \text{ Efficiency} = \frac{\text{work done}}{\text{energy used}} \times 100$$

Question: What is the % efficiency of an automobile if 50. Joules of work is done for every 200. Joules of chemical gasoline energy used?