4.7.1 Kinetic and potential energy

Kinetic energy

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Kinetic energy is the energy that a moving object possesses. The faster the object moves the more kinetic energy it has. A more massive object has a greater kinetic energy than a less massive object moving at the same speed. The kinetic energy (E_k) of an object with mass m moving at a speed v is given by the expression:

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

(1)✏What happens to the kinetic energy if the speed (v) doubles?

(2)✏What happens to the kinetic energy if the mass doubles?

Gravitational potential energy

Gravitational potential energy (E_{gp}) is the energy stored when an object is lifted up in a uniform gravitational field. We usually talk about the change in gravitational energy (ΔE_{gp}) when something is lifted up. This allows us to ignore (for the time being!) the issue of where gravitational potential energy is actually zero. The change in gravitational potential energy (ΔE_{gp}) for an object with mass m lifted through a height Δh is given by the expression:

$$\Delta E_{gp} = mg\Delta h$$

where g = the gravitational field strength (=9.8Nkg^{-1} at the surface of the Earth)

(3)✏This formula only works for changes of height near the Earth's surface. Why?

(4)✏<u>Estimate</u> the increase in gravitational potential energy for an apple lifted (from the Earth's surface) to a height of 10m.

Elastic potential energy

When a spring is stretched below its 'limit of proportionality' (see materials section), the energy stored in the spring is given by the expression:

$$E_{ep} = \frac{1}{2}k\Delta x^2$$

Where k is the spring constant and Δx is the extension of the spring.

(5)✏What happens to energy stored in the spring when the extension is doubled?

(6)✏What happens to the energy stored when the stiffness of the spring is increased?

Conservation of energy

The law of conservation of energy states that energy is not created or destroyed, only transferred. The total energy we have before an event is equal to the total energy we have afterwards. This is particularly useful in solving problems involving energy transfers from $potential \rightarrow kinetic$ and from $kinetic \rightarrow potential.$

Let us look at one example:

A 0.5kg ball is dropped from a height of 10m. What speed does it have when it hits the ground? Note: we will neglect the effects of air resistance. (g=9.8Nkg^{-1})

(7)✏ Use the suvat equation $v^2 = u^2 + 2as$ to solve this problem.

From an energy point of view, the ball loses gravitational potential energy as it falls and gains an equal amount of kinetic energy. This means after falling 10m the ball will have lost $\Delta E_{gp} = m(9.8)10$. It will have gained $E_k = \frac{1}{2}mv^2$=m(9.8)10.

$$\frac{1}{2}mv^2 = m(9.8)10$$

(8)✏ Cancel mass from both sides, rearrange and solve to find the speed when it hits the ground. You should find that you get the same answer you got previously using the suvat equation.

Another problem:

(9)✏ A spring is used to fire a ball bearing with mass 0.01kg into the air. The spring constant is 10000 Nm^{-1}, and it is initially stretched by 0.1m. What initial speed will the ball bearing have? What maximum height will the ball bearing reach? (Hint: assume the elastic potential energy lost is transferred to kinetic energy and then to gravitational potential energy.)