Physics with Synno – Motion-2 – Lesson 21

M.7.4 Energy

When we do work, such as pushing a wheel barrow, we get tired or use up the quantity known as energy. ***ENERGY*** is the ability to do work.

Energy does not disappear, but is either

1) transferred to another object

or 2) transformed into another kind.

Thus we formulate the principle of conservation of energy which states that

Energy is neither created or destroyed

we say that

Work done by an object = transfer of energy from that object
and Work done on an object = gain in energy to that object

or **W = ΔE**

The units for energy are the same as the units for work, the Joule (J).

Example:
If a man does 200 J of work pushing a wheel barrow, he transfers 200 J of energy to the wheel barrow.

M.7.5 Types of Energy

M.6.7.1 Kinetic Energy

We define kinetic energy as the energy a body has when it is in motion. We can derive an expression for kinetic energy.

Consider an object of mass, m, originally at rest being acted upon by a force of F N for a distance of d m. No friction.

We have

Work done = energy gain = final K.E. (in this case)

$\therefore$ Final K.E. $= F \times x$
$= m\, a \times x$ (eq^n 1)

Evaluating the acc^n using constant acc^n formula

$$v^2 = u^2 + 2ax$$

$u = 0 \quad v = v \quad x = d \quad a = a$

$$v^2 = 0 + 2ad$$

$$v^2 = 2ad$$

$$\Rightarrow \quad a = \frac{v^2}{2d}$$

Now substitute into eq^n 1

$$\text{Final K.E.} = \frac{m\ v^2}{2x} \times x$$

$$= \frac{1}{2} m v^2$$

so **E_K =** $\frac{1}{2} m v^2$

In fact work done = change in kinetic energy = Final K.E. – Initial K.E.

$$W = \Delta E_k = \frac{1}{2} m v^2 - \frac{1}{2} m u^2$$

Examples:

1. A body of mass 6 Kg has a speed of 3 m s^{-1}. What is its K.E.?

   E_K = $\frac{1}{2} m v^2$
   E_K = $\frac{1}{2} \times 6 \times 3^2$
   E_K = 27 J

2. A body of mass 4 Kg with a speed of 3 m s^{-1} accelerates to a speed of 6 m s^{-1}. What is
   a) the change in K.E.

   $\Delta E_k = \frac{1}{2} m v^2 - \frac{1}{2} m u^2$
   $\Delta E_k = \frac{1}{2} \times 4 \times 6^2 - \frac{1}{2} \times 4 \times 3^2$
   $\Delta E_k = 72 - 18$
   $\Delta E_k = 54$ J

   b) the work done on the body

   $W = \Delta E$
   $W = 54$ J

Video: Physics of Car Crashes #227

M.7.5.2 Potential Energy

The potential energy is the energy stored within a body. The symbol used to represent potential energy is U. Usually followed by a subscript indicating what type.

M.7.5.2.1 Elastic Potential Energy

Springs can store energy when they are stretched or compressed. We can store the energy in the spring by applying a force to alter its length, thus we are doing work on the spring.
we have

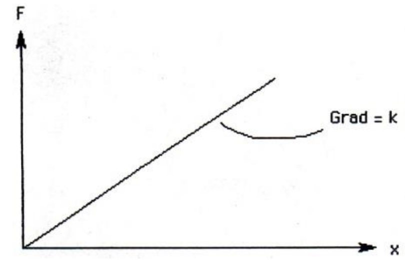
Energy stored = potential energy of spring = work done on spring

In about 1675 Robert Hooke noticed that the more you stretch a spring from it's natural length, the stronger the force needed.
i.e. $F \alpha \Delta x$

we write $\mathbf{F = k\,x}$ Hooke's law

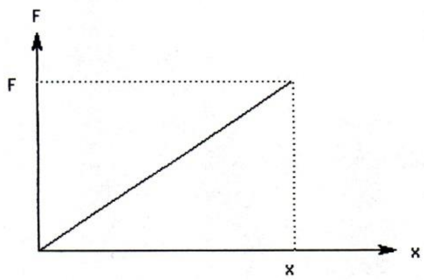
where k = spring constant (unit $N\ m^{-1}$)

we get a graph which looks like



Now P.E. of spring = Work done on it

We can calculate the work done on a spring in stretching it x metre from the force-distance graph.



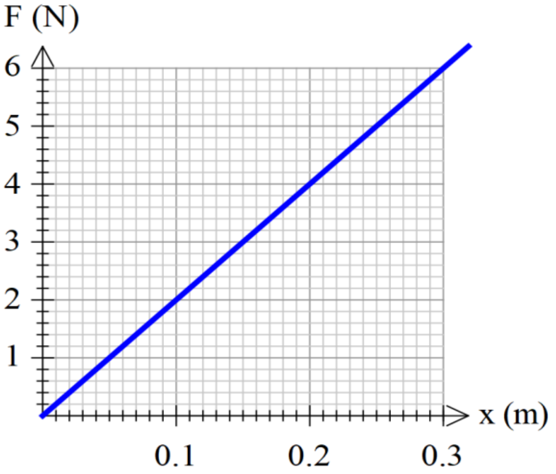
Work done = area under graph (can't use $w = f \times x$ because force not constant)
$= \frac{1}{2} F x$
But $F = k x$

So work done $= \frac{1}{2} k x x$
$= \frac{1}{2} k x^2$

$\therefore$ $\mathbf{U_s = \frac{1}{2} k x^2}$ **(Joule)**

Note: For a spring compressed and then released Δ P.E. (spring) = Δ K.E. (body).
Conservation of energy. $E_{total} = E_K + U_s$

Example 1. Find the P.E. of the spring when compressed 0.2 m.



$$U_s = area$$
$$U_s = \frac{1}{2} \times 0.2 \times 4$$
$$U_s = 0.4\,J$$

Example 2.
For a spring with k = 5 N m^{-1}. Find

a) Δ P.E. when compressed from 0→20 cm

$U_s = ½\ k\ x^2$
$U_s = ½ \times 5 \times 0.20^2$
$U_s = 0.1$ J

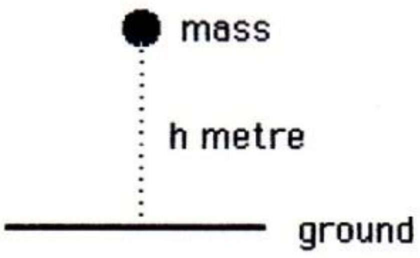
b) If compressed by 20 cm and a body is placed there and let go. What is the K.E. as it passes zero compression?

$U_s \rightarrow E_k$
$E_k = 0.1\,J$

M.7.5.2.2 Gravitational Potential Energy

When an object is raised above the surface of the Earth energy is stored.
To raise a body above the ground we must do work against the weight force.

Let us raise a mass, m, h metre above the ground



U_g = work done against weight force
= $F \times x$
= m g h (Joule)

$\therefore$ **U_g = m g h (Joule)**

Examples

1) A mass of 5 Kg is raised 6 m above the ground. What is it's P.E.?

   $U_g = m\,g\,h$
   $U_g = 5 \times 9.8 \times 6$
   $U_g = 294$ J

2) A mass of 3 Kg is 7 m above the ground. If it is released, what is it's K.E. just before it hits the ground? What is it's speed?

   $U_g = m\,g\,h$
   $U_g = 3 \times 9.8 \times 7$
   $U_g = 205.8$ J

   $U_g \rightarrow E_k$
   $E_k = 205.8\,J$

   $E_K = ½\, m\, v^2$
   $205.8 = ½ \times 3 \times v^2$
   $137.2 = v^2$
   $v = 11.7$ m/s

Problem Set#21: Text Page 432 All Questions