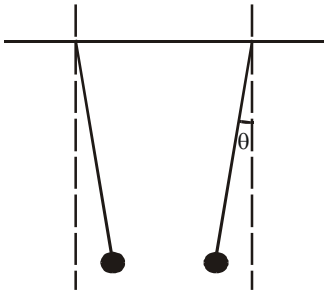
Gravity, gravitational potential energy, and kinetic energy

Gravity

The gravitational force is produced by the attraction of two masses towards one another.

It is a universal force that exists between all objects by virtue of their mass. For example, if two massive balls are suspended next to one another by inextensible string they will be attracted to one another, so they will not hang exactly vertically.



At this level we are concerned with the effect of gravity on objects on or near the surface of the earth.

Gravity is a force that is mutual, equal and opposite – that is, if two objects are opposite – that is, if two objects are attracted towards one another then the magnitude of the force on one object is equal to the magnitude of the force on the other.

However, when one of the objects is very much more massive than the other, the equal force acting on it will produce hardly any motion. For instance, if I drop a coin towards the surface of the earth then the earth will hardly move towards the coin; it is the coin that is most noticeably affected. Thus, in such cases it is simplest to assume that the more massive body does not move at all.

Another simplifying assumption is to assume that the strength of the force remains constant.

In fact, as an object is moved away from the source of the gravitational field the strength of the gravitational force diminishes. But for objects on or near the surface of the earth the distances travelled are so minute in comparison with the radius of the earth that the gravitational force can be treated as constant.

We denote this constant acceleration produced by a gravitational field by g. It is the density of the gravitational force at the surface of the Earth. That is, it is a force produced per unit mass. So it is also called the gravitational field strength. Hence the weight is the force acting on an object and is given by

$$\text{weight} = \text{mass} \times \text{gravitational field strength}$$
$$W = mg$$

Kinetic and Gravitational Potential Energy

Kinetic energy is the energy objects have because they are moving. We intuitively know that objects have kinetic energy because when we are struck by a moving object it hurts.

When an object is dropped it speeds up – it acquires kinetic energy. This makes us believe that the objects have energy before they are dropped. The energy derives from their position in a gravitational field. Hence it is called gravitational potential energy. When an object falls, ignoring air-resistance, gravitational potential energy is converted to kinetic energy.

Kinetic energy is defined to be

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

Gravitational potential energy is given by

$$\text{Gravitational potential energy} = \text{mass} \times \text{gravitational field strength} \times \text{height}$$
$$U = mgh$$

This is an instance of the general rule regarding work (or energy)

$$\text{Energy} = \text{force} \times \text{distance}$$
$$W = fd$$

Example:

An object falls 100m. Ignoring air-resistance, calculate its terminal velocity.

Answer

Loss of gravitational potential energy = gain of kinetic energy

$$\Delta U = \Delta K_E$$
$$mgh = \frac{1}{2}mv^2$$
$$v = \sqrt{2gh}$$
$$= \sqrt{2 \times 9.81 \times 100}$$
$$= 44.294 = 44 ms^{-1} \ (2.S.F.)$$