WJEC (Eduqas) Physics A-level

Topic 1.4: Energy Concepts

Notes

Work

Work is a concept used to calculate the effect of forces acting on a body in terms of **energy**.

The work done on a body by a force F, along a distance x in the direction of the force is given by the equation:

$$W = Fx$$

This is a very important equation in physics.

This is valid for a constant force when the body moves a distance x in the direction of that force.

Angled Forces

When the force does not act along the line of motion we have to alter the equation slightly. If the force acts at an angle of θ to the line of motion the work done is given by,

$$W = Fx\cos(\theta)$$

This is because **only the component of F in the direction of the line of motion does any work**.

Conservation of Energy

The conservation of energy states that energy can be **transferred** between multiple forms but is never created nor destroyed.

There are three types of energy you should know about mathematically.

Gravitational Potential Energy (GPE)

$$\Delta E_p = mg\Delta h$$

- m is the mass of the body
- g is the gravitational field strength
- Δh is the change in height of the body

Elastic Potential Energy (EPE)

$$E_p = \frac{1}{2}kx^2$$

- k is the spring constant / stiffness (force per unit extension)
- x is the extension of the spring or string

Kinetic Energy (KE)

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

- m is the mass of the body
- v is the speed of the body

For example, a body falling towards the Earth will be losing gravitational potential energy and it will be **transferred** to kinetic energy as the body speeds up.

Also, when a spring is fully extended it is stationary but as the spring is released and it returns to its natural length it will **lose elastic potential energy** and the end of the spring will speed up.

Work-Energy Relationship

The work energy relationship relates the **work done** by a constant force on a body to the **kinetic energy** of the body.

Mathematically it takes the form:

$$Fx = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mu^2$$

This says that the **work done on a body is equal to the change in kinetic energy of that body**.

An example is provided below.

A block of mass 5kg is initially moving with a speed of 3 m/s. A force of magnitude 12N acts along the direction of motion of the block over 10m. Find the final **velocity** of the block.

Applying the work energy principle, we have,

$$(12)(10) = \tfrac{1}{2}(5)(v)^2 - \tfrac{1}{2}(5)(3)^2$$

$$240 = 5v^2 - 45$$

$$v = \sqrt{57} = 7.5\ m/s\ (2sf)$$

Velocity is 7.5 m/s (2sf) in original direction of motion.

Power

Power is the **rate of transfer of energy**. This definition can be extended to include work. **Power is the rate of doing work**.

The equation for power is given by:

$$Power = \frac{energy\ transferred\ or\ work\ done}{time}$$

Dissipative Forces

These are forces which **reduce the efficiency** of a system. They reduce the amount of useful types of energy (e.g. kinetic) and produce un-useful forms such as heat. Examples of these forces include friction and drag.

Friction on a car's tyres reduces the amount of kinetic produced from the engine and heats up the tyres (which, in most cases, does not aid performance).

Drag on aeroplanes means a larger energy output is required from the engines to maintain the same speed (useful energy output) in the air.

Often, vehicles are adapted to reduce friction and drag. For example, sports cars will have a pointier front so that the air can flow over more easily.

Sometimes, athletes (professional cyclists especially) may wear tightly fitting clothing and special headgear such that they reduce the amount of air resistance affecting them.

Energy Efficiency

$$efficiency = \frac{useful\ energy\ transfer}{total\ energy\ input} \times 100$$

The multiplication by 100 is to convert it into a **percentage** – how it is normally provided. However, sometimes it is given as a fraction or decimal.

We can see that if you must provide a larger input energy (due to dissipative forces) for the same useful energy transfer the efficiency reduces. The maximum theoretical efficiency of a system is 100% because you cannot transfer more than you put in (**conservation of energy**).