WORK, ENERGY AND POWER 5 MARCH 2013

Lesson Description

In this lesson we:

- Revise the definition of work as being the transfer of energy from one form to another.
- Revise the idea that power is the rate of transfer of energy.
- Learn that power can be calculated using the force and average velocity of an object.
- Use work and energy principles to work through exam-style questions.

Key Concepts

- Work is the transfer of energy from one form to another.
- Work is done by applying a force across a displacement in the same level/plane.
- Positive work is done when a force acts in the same direction as the object's motion.
- Negative work is done when a force opposes the motion of the object.
- The work-energy theorem states that the net work (total of all forces' work) on an object is equal to it's change in kinetic energy.
- Power is the rate of work.
- Power can be calculated from the applied force and the average or constant velocity.

Work

Work is done when a force moves an object over a distance.

A simple reminder that the work done can be calculated by:

$$W = F\Delta x\cos\theta$$

Note: the angle is the one between the applied force and the displacement.

If the angle is between 0° and 90°, the work will be positive and increase the energy of the object. If it is between 90° and 180° the work will be negative.

Power

Power is the rate at which work is done. Sometimes it is described as the "**rate of energy transfer**".

$$P = \frac{W}{\Delta t}$$

Another power equation:

$$W = F\Delta x$$

So,

$$P = \frac{F\Delta x}{\Delta t} \text{ and } v = \frac{\Delta x}{\Delta t}$$

$$\therefore P = Fv$$

You don't need to remember how this equation is derived but you must be able to use it!

The "F" is the force applied and the "v" is the **average** or a **constant velocity**.

Example:

A car of mass 1200 kg drives up a hill at 10 $m{\cdot}s^{-1}$ angle of 30° to the horizontal. The frictional force acting on the car is 300 N.

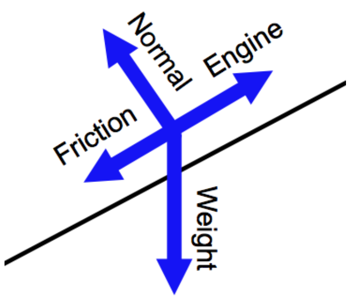
1) What is the change in kinetic energy of this object during the hill-climb?
2) What is the net work done on this car?
3) Draw a free-body diagram of the car, showing all the forces acting on it.
4) What is the force applied by the engine on the car to keep it going up the hill?
5) Now, calculate the power of the engine.

Solution:

1) Since there is no change in the car's kinetic energy, the change in kinetic energy is 0 J
2) Now for the Work-Energy theorem:

$$W_{net} = \Delta K$$
$$W_{net} = 0 \text{ J}$$

3)



4) There is no resultant force parallel to the slope because there is no net work done.
So,

$$F_{friction} + F_{\parallel weight} + F_{engine} = 0$$

$$F_{\parallel weight} = mg\sin\theta = (1200)(9{,}8)\sin 30° = 5880\ \text{N}$$

$$(-300) + (-5880) + F_{engine} = 0$$
$$F_{engine} = 6180\ \text{N up slope}$$

5)

$$P = Fv$$
$$P = (6180)(10)$$
$$P = 61800\ \text{W}$$

Terminology

Force: a push or a pull on an object.

Work: transfer of energy.

Power: rate of work OR rate of transfer of energy.

Work-energy theorem: the work doen by a net force on an object is equal to the change in its kinetic energy.

Demonstration

Top cyclists can maintain a velocity of close to 17 $m{\cdot}s^{-1}$ for long periods. The force required to maintain this is equal the the frictional force experienced by them.

If we factor in that the human body can produce 300 W of mechanical power we can find out the average frictional force that the cyclist experience.

$$P = Fv$$
$$300 = F(17)$$
$$F = 17{,}65\ \text{N}$$

So, this explains why cyclist have such specialised clothes, helmets and even shave their legs! This tiny force increases the amount of power needed to maintain a high velocity.

Questions

Question 1

(Adapted from DOE Mar 2010, Question 1, Paper 1)

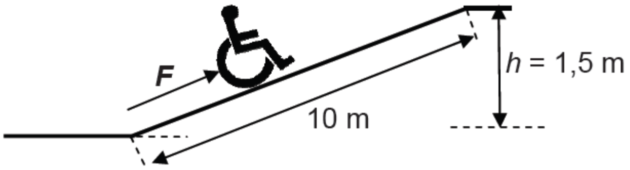
Give ONE word/term for each of the following descriptions.
The rate at which energy is transferred. (1)

Question 2

(Adapted from DOE Nov 2009, Question 5, Paper 1)

John applies a force F to help his friend in a wheelchair to move up a ramp of length 10 m and a vertical height of 1,5 m, as shown in the diagram below. The combined mass of his friend and the wheelchair is 120 kg. The frictional force between the wheels of the wheelchair and the surface of the ramp is 50 N. The rotational effects of the wheels of the wheelchair may be ignored.

The wheelchair moves up the ramp at constant velocity



a.) What is the magnitude of the net force acting on the wheelchair as it moves up the ramp? Give a reason for your answer. (2)

b.) What is the magnitude of the net work done on the wheelchair on reaching the top of the ramp? (1)

c.) Calculate the following:

i. Work done on the wheelchair by force F (5)

ii. The magnitude of force F exerted on the wheelchair by John (4)

[12]

Links

- http://www.mindset.co.za/learn/xtra
- http://www.education.gov.za/Examinations/PastExamPapers/tabid/351/Default.aspx
- http://phet.colorado.edu/en/simulation/energy-skate-park
- http://www.sportsscientists.com/2010/07/power-outputs-from-tour-de-france.html