Work and Energy

Name _____ Date _____

By the end of this topic I can…

- calculate work done by a force, including at an angle, by a gas, and from a force–displacement graph
- use kinetic and gravitational potential energy
- apply $W = \Delta E$ and conservation of energy
- define power and efficiency and use $P = Fv$

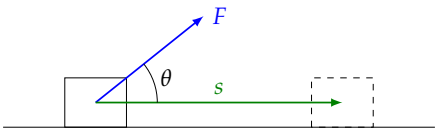
Work

_____ by a force is the product of the force and the _____:

$[W] =$ _____ $=$ ____

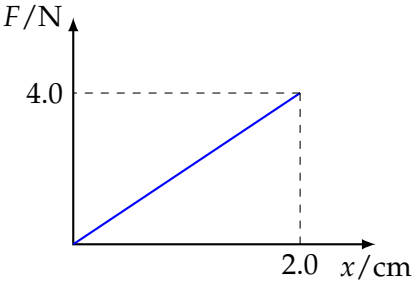
If the force acts at angle θ to the displacement, only the _____ counts:

- work is a _____: it has no direction, but can be positive or negative
- work done _____ resistive forces (friction, drag) is _____: $\theta = 180°$ and $\cos\theta = -1$
- for a gas at _____: $W = pA\Delta s$, so
- the _____ is the work done (for a varying force)



Example 6.1 A 20 N force is applied at 60° to the horizontal to move a 1.0 kg object at a constant speed of 2.0 m s^{-1} for 30 s. How much work is done by the force?

Example 6.2 A piston in a gas pump has an area of 600 cm^2. During one stroke, the pump moves a distance of 30 cm against a constant pressure of 8000 Pa. How much work is done?



Example 6.3 When a spring is compressed by 2.0 cm, the force applied increases uniformly from zero to 4.0 N. How much work is done by this force?

Energy

Kinetic energy

For a constant force: $W = Fs = mas = m\dfrac{v^2 - u^2}{2}$, so work done = _____.

_____ is the energy an object has because of its _____:

Gravitational potential energy

_____ is the energy a body has because of its _____. Near the Earth's surface the change in G.P.E. is

$$\Delta E_p = \quad$$

• only the _____ in G.P.E. matters; the zero level is chosen for convenience

Other forms

• _____: stored in a deformed spring or other elastic body

• others: _____, _____, _____ (thermal), _____, electromagnetic

Work–energy and conservation of energy

The change in the total energy of an object equals the net work done on it by external forces:

$$W_{net} = \Delta E$$

The **principle of conservation of energy**: energy cannot be _____, only _____ from one form to another; the total stays _____.

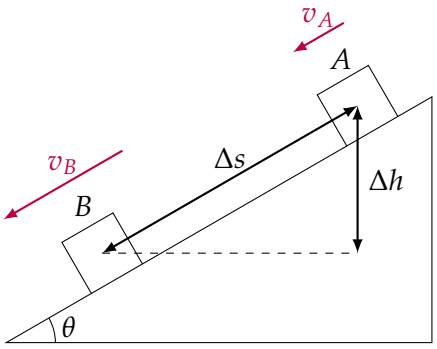
Example 6.4 A racing car of 800 kg starts off from rest. If the driving force is 5000 N, and the car experiences a constant resistive force of 1500 N, what is its speed after it has travelled 50 m?

Example 6.5 A concrete cube of side 0.50 m and density 2400 kg m^{-3} is lifted 4.0 m by a crane. How much work is done?

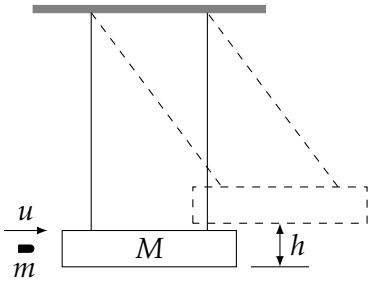
Example 6.6 For an object falling from rest due to gravity, if air resistance is negligible, what is its speed when it has fallen through a distance of h?

Example 6.7 A marble is projected vertically upwards with an initial velocity u. The average resistive force acting is f. How do you determine the maximum height reached by the marble?

Example 6.8 A box of mass m slides down along a slope that is inclined at an angle θ to the horizontal. There is a constant friction f acting on the box. When the box has moved through a distance of Δs down the slope from A to B, write down an equation relating its velocities v_A and v_B by applying the law of conservation of energy.



Example 6.9 A *ballistic pendulum*: a bullet of mass m is fired into a block of mass M hanging from light strings. The block and bullet swing up so that their centre of mass rises a height h. Find the bullet's initial speed u.



Power and efficiency

_____ is the _____:

$[P] =$ _____ $=$ _____

For a force moving at speed v in its own direction:

Example 6.10 There are 150 steps to the top of a tower, and the average height of each step is 25 cm. It takes a man of 72 kg two minutes to run up all the steps. What is his average power?

Example 6.11 A turbine is used to generate electrical power from the wind. Given that the blades of the turbine sweep an area of 500 m^2, the density of air is 1.3 kg m^{-3}, and the wind speed is 10 m s^{-1}. Assume no energy loss, find the power available from the wind.

Example 6.12 A ship is cruising a a constant speed of 15 m s^{-1}. The total resistive force acting is 9000 N. What is the output power of this ship?

Example 6.13 A car of mass $800kg$ accelerates from rest on a horizontal road. Suppose the engine provides a constant power of 24000 W, and the resistive force can be given by $f = 16v$, where v is the speed of the car in m s^{-1}. (a) What is the acceleration of the car when it is travelling at 15 m s^{-1}? (b) What happens to the car if it maintains this driving power?

_____ is the ratio of _____ to _____:

Example 6.14 A water pumping system uses 3.0 kW of electrical power to raise water from a well. The pump lifts 1500 kg of water per minute through a vertical height of 8.0 m. What is the efficiency of the sysem?

Example 6.15 Water flows into a turbine from a reservoir at a vertical distance of 70 m above. The water flows through the turbine at a rate of 2500 kg per minute. What is the output power of the turbine if it is 85% efficient?

Practice questions

Question 6.1 A trolley is pushed 2.0 m along a track by a force of 5.0 N. It experiences a constant frictional force of 3.0 N. Find the work done by (a) the 5.0 N force, (b) friction.

Question 6.2 A child of mass 40 kg slides down a slope from a height of 2.0 m above the ground. The slide is 6.0 m long. How much work is done by gravity?

Question 6.3 A fixed mass of gas at 1.50×10^5 Pa expands at constant pressure from 2.80×10^{-4} m^3 to 8.40×10^{-4} m^3. Find the work done by the gas.

Question 6.4 A stone is projected vertically upwards at 16 m s^{-1} from the ground. Air resistance is negligible. (a) Find the greatest height. (b) Find its speed at a height of 5.0 m. (c) If it is instead projected at an angle with the same speed, what is its speed at 5.0 m?

Question 6.5 A hammer of mass 600 g hits a nail at 10 m s^{-1} and pushes it 3.0 mm into a plank. Find the average resistive force on the nail.

Question 6.6 A 3.0 kg block is released from rest on a slope at $\theta = \sin^{-1}(1/5)$ to the horizontal. It travels 6.0 m down the slope against a frictional force of 5.0 N. Find its final speed.

Question 6.7 A car engine exerts an average force of 400 N in moving the car 900 m in 200 s. What is the average power of the engine?