4.7.2 Work and energy

When a force is used to move an object, work is done. Work is measured in joules and represents the energy transferred in doing the moving.

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work done (W) = force x distance moved in the direction of the force

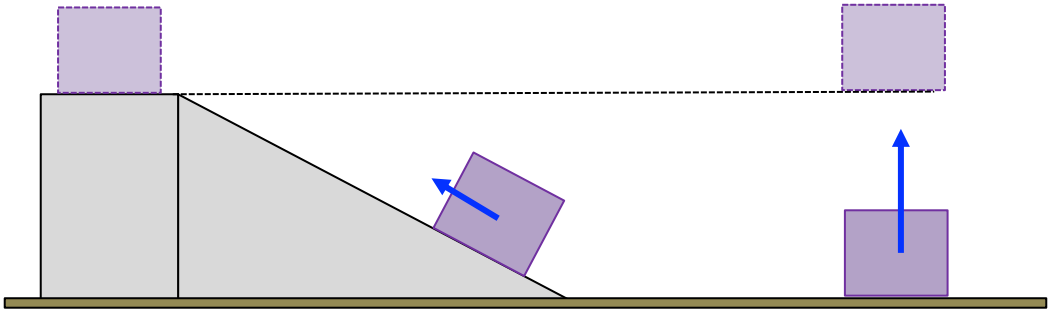
In the case of something being lifted up, the work done (W) to lift the object is equal to the gravitational potential energy gained by the object:

$$W = mg\Delta h$$

where m=mass, g=gravitational constant (=9.8N/kg), Δh=change in height

(1) What work would be required to lift a 1000kg car by 10m?

Work is only done against a resisting force. In the case of raising objects, work is done against gravity. In the absence of friction work can only be done in the vertical plane. Consider the following:



A block is pushed up a frictionless ramp and raised to the height shown. Another identical block is lifted up directly to this height.

(2) In which situation is the most work done? Why?

For an object being pushed horizontally, in the absence of friction, the force will cause the object to accelerate. According to the simplified version of Newtons 2nd law (F=ma), because the force is constant, acceleration will be constant (uniform). The work done is given by:

$$W = force\ x\ distance\ moved$$
$$W = F \times s$$

The *suvat* equations apply to motion involving uniform acceleration. The distance moved (s) can be obtained from the *suvat* equation ($v^2 = u^2 + 2as$).

(3) Taking the initial speed u to be zero, rearrange to make s the subject.

(4)✐ Substitute for s in the equation for work done, above.

(5)✐ Using the simplified version of Newton's second law (F=ma), substitute for F in the equation for work done. Then, simplify.

(6)✐ Does the formula you get for work done look familiar? What is the work done equal to?

Work done by brakes

When a car slows down under braking, work is done by the brakes.

(7)✐ What energy transfer occurs during braking.

A car of mass 1000kg slows down under braking from $10ms^{-1}$ to zero in a time of 5s.

(8)✐ What is the braking force? (Hint: use Newton's 2nd law)

(9)✐ What is the braking distance? (Hint: distance travelled is area under the velocity-time graph – it's a triangle)

(10)✐ Use your values of force and distance to calculate the work done by the brakes.

(11)✐ Calculate the initial kinetic energy of the car. (Hint: $E_k=½mv^2$)

(12)✐ How does the initial kinetic energy of the car compare to the work done by the brakes in slowing the car to a stop?

Work done in stretching springs

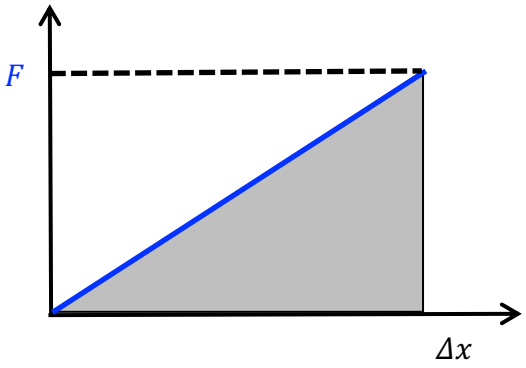
When a spring is stretched (below its limit of proportionality) we find the extension (Δx) is proportional to the applied force (F):

$$F = k\Delta x$$

where k is the spring constant.

This is called Hooke's Law – after the English scientist Robert Hooke.

Consider the graph of force against extension for the spring:



We can see that the force increases as the spring extends.

The work done in stretching the spring is given by:

$$W = force \times distance\ moved$$
$$\therefore W = F \times \Delta x$$

However, force is not a constant. The work done is the area under the graph above:

$$W = area = \frac{1}{2}F \times \Delta x$$

(13)✎ Use Hooke's law to substitute for F in the equation for work, above.

(14)✎ Does this formula look familiar? What is the work equal to?