34 Kinetic Energy

The kinetic energy associated with a moving object depends upon its mass and speed.

Kinetic energy is a scalar quantity, which means that it has a magnitude but no direction.

Kinetic energy is measured in joules (J).

Numerically, if an object has 400 J of kinetic energy it will require a 400 N force to stop it in 1 m, as work done = force × distance ($W = Fd$).

Formula:

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$
$$E = \frac{1}{2} mv^2$$

(you can see where this formula comes from if you do Q34.9)

Suppose an object has 400 J of kinetic energy.

- The energy of an object with twice the mass, but the same speed, would be 800 J (double) because kinetic energy is proportional to mass.
- The energy of an object with twice the speed, but the same mass, would be 1600 J (quadruple) because kinetic energy is proportional to the square of the speed.

Example 1 – A 2.00 kg carton of milk is falling at 2.50 m/s. Calculate its kinetic energy.

E = $\frac{1}{2} mv^2 = \frac{1}{2} \times 2.00$ kg $\times$ (2.50 m/s)^2 = 6.25 J

Example 2 – A 4.50 kg rolling skateboard has a kinetic energy of 32.0 J. How fast is it going?

E = $\frac{1}{2} mv^2$, so 32.0 J = $\frac{1}{2} \times 4.50$ kg $\times v^2$

Therefore $32.0 = 2.25v^2$
$32/2.25 = v^2 = 14.2$, so $v = 3.77$ m/s

Example 3 – How much force will it take if you wish to stop a 930 kg car going at 14.5 m/s in a distance of 23.0 m?

E = $\frac{1}{2}mv^2 = \frac{1}{2} \times 930\text{ kg} \times (14.5\text{ m/s})^2 = 97\,800$ J
Energy transferred = force × distance, so $97\,800\text{ J} = F \times 23.0$ m,
$F = 97\,800\text{ J}/23.0\text{ m} = 4\,250$ N

34.1 Calculate the kinetic energy of a 2.0 kg motion trolley going at 3.0 m/s.

34.2 Calculate the kinetic energy of an 800 kg car when it is going at

(a) 30 mph (which is 13.4 m/s);

(b) 40 mph (which is 17.9 m/s).

(c) Road safety campaigners are continually reminding motorists that 40 mph is much more dangerous than 30 mph even though it only seems a little bit faster. What does this question suggest about the issue?

34.3 (a) Calculate the kinetic energy of a 20 tonne bus travelling at 40 mph. (1 tonne = 1 000 kg)

(b) Calculate the kinetic energy of a 600 kg Formula 1 race car going at 83 m/s (about 190 mph), and compare it to that of the bus.

34.4 A 500 kg pumpkin is dropped 15 m on top of a school bus.

(a) How much gravitational potential energy was gained when it was winched up 15 m?

(b) Assuming all of this GPE is turned into kinetic energy as the pumpkin drops, work out its speed as it hits the school bus.

(c) Would the speed be any different for a 5.0 kg pumpkin?

34.5 At what speed is a 250 g stone moving if its kinetic energy is 3.5 joules?

34.6 What is the mass of an object travelling at 8.0 m/s which has 96 J of kinetic energy?

34.7 A car of mass 1200 kg slows down from a speed of 20 m/s to 10 m/s. How much kinetic energy does the car lose? [Hint: first work out the kinetic energy before and after the deceleration.]

34.8 How fast was a 1400 kg car travelling if it lost 280 kJ of kinetic energy in coming to a stop?

34.9 This question allows you to derive the equation for kinetic energy using a numeric example. We assume constant acceleration and no resistive forces.
You can use these equations:
distance $=$ average speed $\times$ time
acceleration $=$ change in speed / time taken
force $=$ mass $\times$ acceleration
work done $=$ force $\times$ distance

(a) A 700 kg car accelerates uniformly from rest to 30 m/s in 10 s. Calculate its acceleration.

(b) Calculate the force needed to give the car this acceleration.

(c) The average speed of the car is midway between the starting speed (0.0 m/s) and the final speed. Use this information to work out how far the car will go while accelerating.

(d) The kinetic energy equals the work done in accelerating it. Calculate the kinetic energy.

(e) Now repeat this question for a car of mass m going from rest to speed v in time t.

34.10 A $300\,000$ kg airliner is flying at 250 m/s at an altitude of $11\,000$ m. How large is its kinetic energy when expressed as a percentage of the total of the kinetic and gravitational potential energy?