WEBSITE PROBLEMS: **DYNAMICS**

5 Level 6

Exercise 1: A car driving along the motorway accelerates and doubles its speed. The momentum and kinetic energy of the car respectively increase by a factor of

a) Momentum $\times$ 4 : Kinetic Energy $\times$ 4

b) Momentum $\times$ 4 : Kinetic Energy $\times$ 4

c) Momentum $\times$ 2 : Kinetic Energy $\times$ 2

d) Momentum $\times$ 2 : Kinetic Energy $\times$ 4

e) Momentum $\times$ 1 : Kinetic Energy $\times$ 1

[*Question by RWH*]

Exercise 2: Two ice skaters on an ice rink skate towards each other. They collide and stay together. It is useful to know what quantity is the same before and after the collision (conserved). In the collision

a) The kinetic energy is conserved but the momentum is not conserved.

b) The momentum is conserved but the kinetic energy is not conserved.

c) The momentum is conserved only if the skaters have the same mass.

d) Neither the kinetic energy nor the momentum is conserved.

e) Both the kinetic energy and momentum are conserved.

[*Question by RWH*]

Exercise 3: Two different masses are released and fall to the floor. If the air resistance can be neglected,

a) the smaller mass falls faster than the larger mass.

b) the larger mass falls faster than the smaller mass.

c) they fall at the same rate.

d) the speed depends on the shape of the mass.

e) the denser mass falls faster.

[*Question by RWH*]

Exercise 4: Using a value of $g = 10$ m s^{-2}, a heavy ball is dropped from rest. Ignoring air resistance, its speed after one, two and three seconds is

a) 1 m s^{-1}, 2 m s^{-1}, 3 m s^{-1}

b) 0 m s^{-1}, 20 m s^{-1}, 40 m s^{-1}

c) 1 m s^{-1}, 4 m s^{-1}, 9 m s^{-1}

d) 10 m s^{-1}, 20 m s^{-1}, 30 m s^{-1}

e) 1 m s^{-1}, 4 m s^{-1}, 8 m s^{-1}

[*Question by RWH*]

Exercise 5: An 80 kg sprinter runs a 100 m race in 10.4 s. He accelerates to 9 m s^{-1} in the first 1.2 s with constant acceleration (this is a simplified model). Use $g = 10$ m s^{-2}.

a) What average force does he push with to get up to speed?

b) What is the ratio of the accelerating force produced by his legs to the weight of his whole body supported by his legs?

c) What distance does he travel in the first 1.2 s?

d) How much energy does he convert in 1.2 s?

e) What average power do his legs produce to accelerate him to his racing speed?

f) Since his legs can easily hold up more than twice his weight (he could easily lift a fellow athlete on to his shoulders) why is it that he cannot accelerate much faster at the start of the race?

[*Question by RWH*]

Exercise 6: A child of mass 25 kg sits at one end of a see-saw, 2 m away from the pivot.

a) Where should her 60 kg parent sit in order to balance the see-saw?

b) If the child tips the see-saw very gently by pushing on the ground with her legs so that she rises by 0.4 m, how far will her parent fall on the other side?

c) How does the potential energy gained by the child compare with the potential energy lost by the parent?

[*Question by RWH*]

Exercise 7: A rocket similar to that which launches NASAs space shuttle into a low earth orbit has a take-off mass of 2000 tonnes (1 tonne= 1×10^3 kg) and provides a thrust at take-off of 24 MN (1 MN= 1×10^6 N). The thrust remains constant and $g = 10$ m s^{-2}. Air resistance can be neglected at take-off.

a) Sketch a diagram of the rocket and mark on the forces acting during take-off.

b) Calculate the acceleration of the rocket at take-off.

c) What fraction of the acceleration due to gravity (g) is this?

d) To reach orbit, the shuttle has to achieve a speed of 8 km s^{-1}. How long would this take with this acceleration?

e) The fuel is burnt off at the rate of 4.0 tonnes each second. For how long can the engines provide the thrust?

f) What simple explanation is there for the large difference in the two times that you have calculated in (d) and (e) for the shuttle to reach orbit?

[*Question by RWH*]

Exercise 8: An airzooka can fire a pocket of air across a room by quickly firing a squirt of air out of an elasticated polythene bag.

a) If the volume of the air pocket is 2 litres, what is the mass if the density of air is 1.2 kg m^{-3} (there are 1000 litres in 1 m^3)?

b) What is its kinetic energy if it crosses a 6 m wide room in 0.4 s?

c) What is the momentum of the air pocket?

d) Before the air pocket is fired, it is stationary. It consists of air molecules moving around randomly at about 500 m s^{-1} (a little faster than the speed of sound). If the average mass of one molecule is 5×10^{-26} kg, how many molecules are there in the 2 litres pocket of air?

e) What is the total kinetic energy of all of the molecules?

f) What is the total momentum of all of the molecules?

g) If the kinetic energy is calculated using the answer to part (a) for the mass of the pocket, and the speed of the molecules is 500 m s^{-1}, do you obtain the same as the answer to part (e), the total kinetic energy of the molecules?

h) Why can the answer to part (f), the total momentum, not be calculated using the mass of the pocket in part (a) and the 500 m s^{-1} average speed of the molecules?

[*Question by RWH*]

Exercise 9: A Big Mac has 2.2 MJ of chemical potential energy which can be released by eating it.

a) How much energy is needed to lift a 50 kg student upwards through a height of 0.4 m?

b) How many step-ups of 0.4 m would the student need to make in order to burn off the energy of a Big Mac?

c) How many Big Macs would he need to consume in order to reach the top of Mount Everest, a height of 8 km?

d) If the energy of a Big Mac could be used by itself to propel itself upwards, how high could it rise? (The mass of a Big Mac is 0.22 kg.)

[*Question by RWH*]