1 The picture shows a track for racing toy electric cars. A guide pin fits in a groove in the track to keep the car on the track. A small electric motor in the car is controlled, with a hand-controller, via contacts in the track.

A child places a car of mass 95 g on the track. She adjusts the controller to a power of 4.2 W so the car accelerates from rest for 0.40 s.

(a) (i) Show that the energy transferred by the motor in 0.40 s is about 2 J.

(2)

(ii) Calculate the speed of the car at 0.40 s.

(2)

Speed =

(iii) Suggest why the actual speed of the car is less than the calculated speed.

(1)

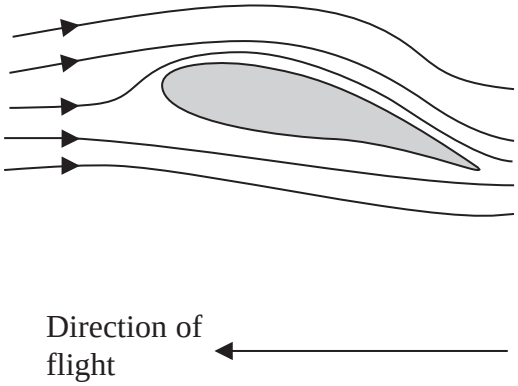
(b) At high speed the guide pin may become disengaged from the groove.

Use Newton's first law to explain why the car would then leave the track at a corner.

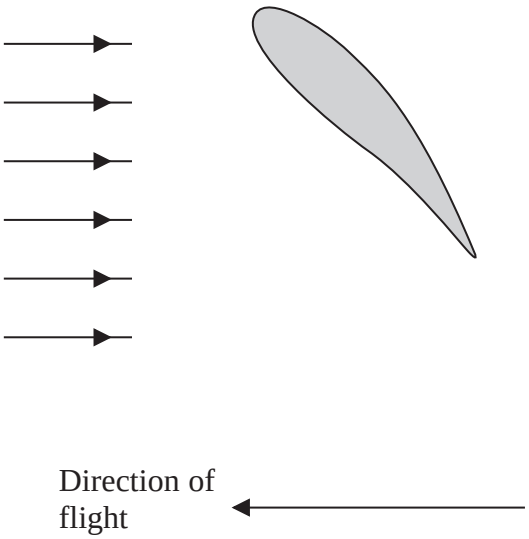
(2)

(Total for Question = 7 marks)

2 The cross section of the wing of a bird is an aerofoil shape.



In order to fly higher, a bird can tilt its wings more. If it tilts them too much, as shown in the diagram below, the air flow above the wing becomes turbulent.



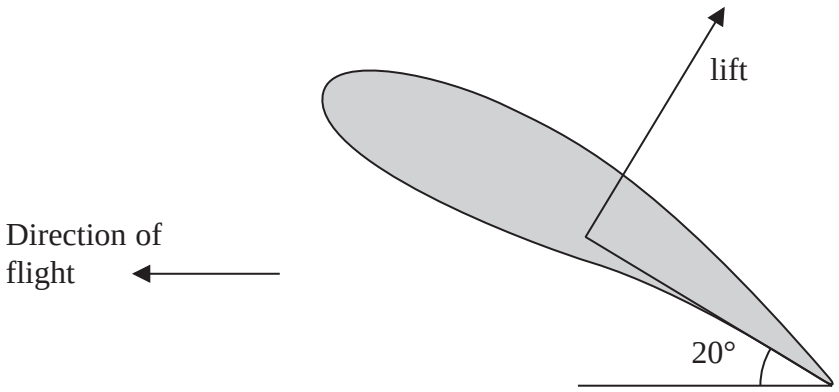
(a) Complete the diagram above to show the airflow around the wing.

(2)

(b) The tilting of the wing results in the air exerting a force on the wing which is called lift. The lift force acts perpendicular to the wing.

The total vertical component of the lift produced by both wings when tilted at an angle of 20° to the horizontal is enough to keep the bird flying at a constant height.

mass of bird = 0.063 kg



(i) Show that the total lift acting on the bird is about 1 N.

(3)

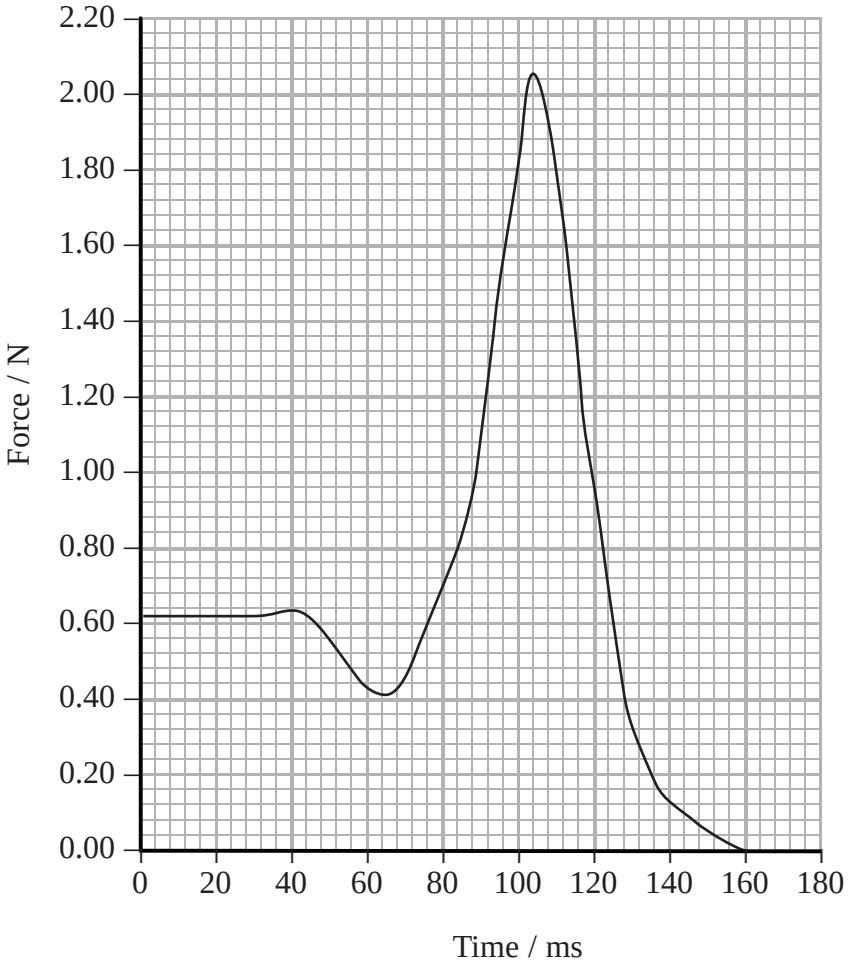
(ii) Assuming that the only forces acting on the bird are the weight and lift, calculate its acceleration at this instant.

(3)

Acceleration =

(c) When some birds take off from the ground there is no lift initially. These birds push off from the ground with their legs.

The following graph shows the downward force exerted by the leg on the ground during take off.



(i) With reference to Newton's laws explain how the downward force from the leg enables the bird to take off.

(4)

(ii) Use the graph to calculate the maximum acceleration of the bird during take off.

mass of bird = 0.063 kg

(3)

Maximum acceleration =

(Total for Question = 15 marks)

3 One method used to find the viscosity of a liquid is to measure the terminal velocity of a solid spherical object falling through it.

In such an experiment the following data are provided:

weight of sphere = 4.8×10^{-3} N
radius of sphere = 2.5×10^{-3} m
volume of sphere = 6.5×10^{-8} m^3
density of liquid = 1300 kg m^{-3}

(a) Show that the upthrust is about 8×10^{-4} N.

(2)

(b) The terminal velocity is found to be 4.6×10^{-2} m s^{-1}. Use this value to show that the viscosity of the liquid is about 2 kg m^{-1} s^{-1}.

(3)

(c) The students carrying out this experiment wish to repeat it on another day using the same equipment. State another relevant variable that needs to be controlled to make this a fair test.

(1)

(Total for Question = 6 marks)

4 The photograph shows the top of an inspection cover for a drain.

(a) The cover is marked ‘ductile’. It is made from ductile iron, which was invented in 1943. It replaced the previous form of cast iron, which was more brittle.

Explain the meaning of the following terms:

(2)

Ductile

Brittle

(b) The cover is also marked ‘35 kN’. This refers to the load it must be able to support.

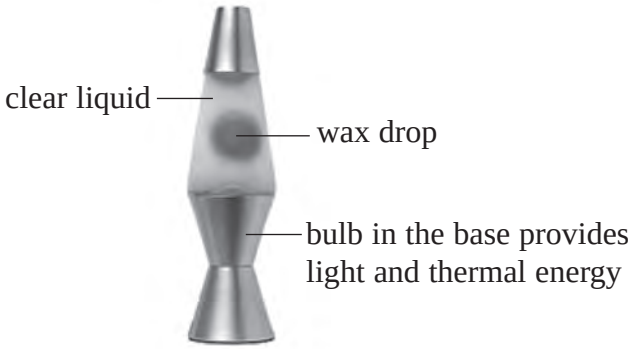
Calculate the mass that would produce this load.

(2)

Mass =

(Total for Question = 4 marks)

5 The photograph shows a ‘lava lamp’.



When the lamp is switched on, large drops of liquid wax are seen to rise and then fall within the clear liquid.

(a) As a wax drop is heated it expands, its density decreases and it rises through the clear liquid.

(i) Explain why the wax drop begins to move upwards as it is heated.

(3)

(ii) The wax drop accelerates initially and then reaches a terminal velocity.

Write a word equation for the forces acting on the wax drop when it is moving upwards at its terminal velocity.

(2)

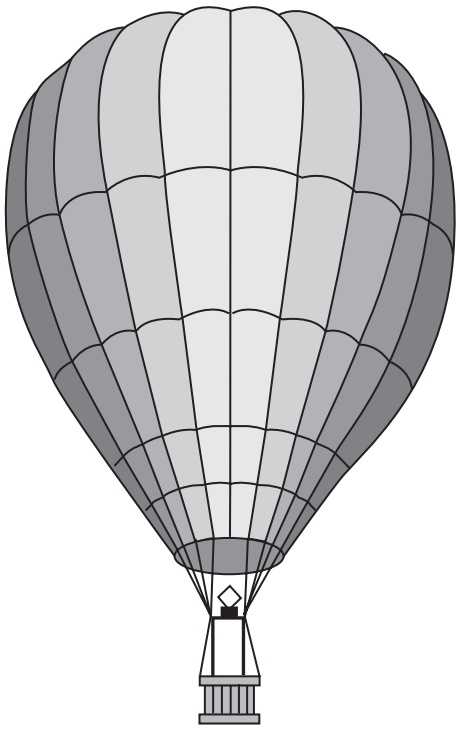
(b) The wax drop is seen to slow down as it reaches the top of the lamp.

Explain this observation.

(3)

(Total for Question = 8 marks)

6 A hot air balloon consists of an 'envelope' containing hot air, with a wicker basket suspended from it. The balloon flies because the heated air in the envelope is less dense than the surrounding air.



(a) The total volume of the hot air balloon is 2830 m^3. The total weight of the balloon, including the hot air in the envelope, is 33 100 N. The density of the surrounding air is 1.20 kg m^{-3}.

(i) Show that the resultant upward force on the balloon at the moment it is released is about 200 N.

(3)

(ii) Calculate the initial upward acceleration of the balloon. The mass of the balloon is 3370 kg.

(2)

Acceleration =

(iii) The balloon is rising through air of viscosity 1.8×10^{-5} kg m^{-1} s^{-1}, at a speed of 2.0 m s^{-1}.

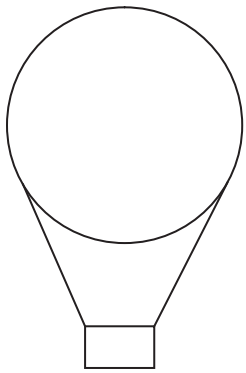
The effect of viscous drag on the balloon is negligible provided the air flow around the balloon is laminar.

Justify the statement in bold with the aid of a calculation. You may treat the whole balloon as a single sphere of radius 8.8 m.

(3)

(b) Add labelled arrows to the diagram below to show the forces acting on a vertically ascending balloon.

(2)

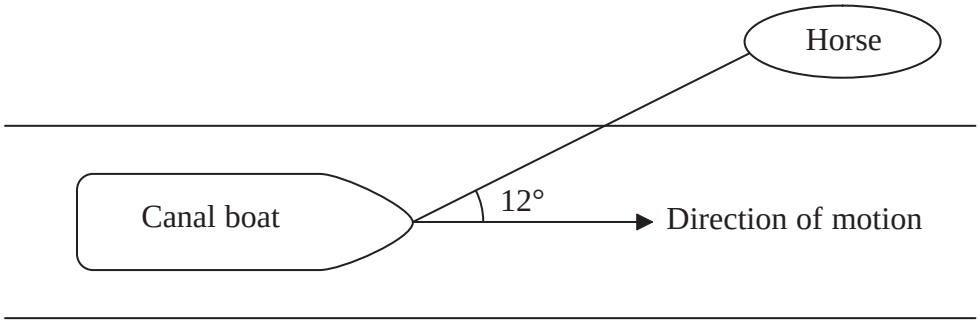


(c) As the balloon rises the density of the surrounding air decreases. Explain why this density change limits the height to which the balloon will rise.

(2)

(Total for Question = 12 marks)

7



A horse is pulling a canal boat using a rope at 12° to the direction of motion of the boat. The tension in the rope is 1150 N.

(a) The canal boat is moving at a steady speed. Calculate the resistive force opposing the boat's forward motion.

(2)

.....

.....

Force = ...

(b) Calculate the work done on the boat by the horse when the canal boat is towed 500 m along the canal.

(2)

.....

.....

Work = ...

(c) Explain why using a longer rope could allow the horse to do the same work while producing a lower tension in the rope.

(2)

.....

.....

.....

(Total for Question = 6 marks)