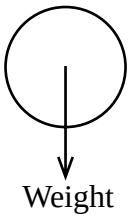
1 A science centre houses a display with tall, transparent tubes of different liquids. Visitors can pump air into the bottom of the tubes to create bubbles that rise to the top at different steady speeds.

(a) (i) Add labelled arrows to the diagram to show the other two forces acting on a bubble as it rises through a liquid.

(2)



(ii) With reference to the forces on the bubble, explain why the bubble initially accelerates and then reaches a steady upwards speed.

(4)

(iii) Write an expression which relates these forces for a bubble moving at a steady upwards speed.

(1)

(b) If the weight of the air in the bubble is ignored, the steady upwards speed is given by

$$v \quad \frac{2\rho r^2 g}{9\eta}$$

Where ρ is the density of liquid, r is the radius of the sphere and η is the coefficient of viscosity of the liquid.

(i) Explain why it is reasonable to ignore the weight of the air.

(2)

(ii) Explain what happens to the speeds of the observed bubbles if the temperature of the liquid increases.

(2)

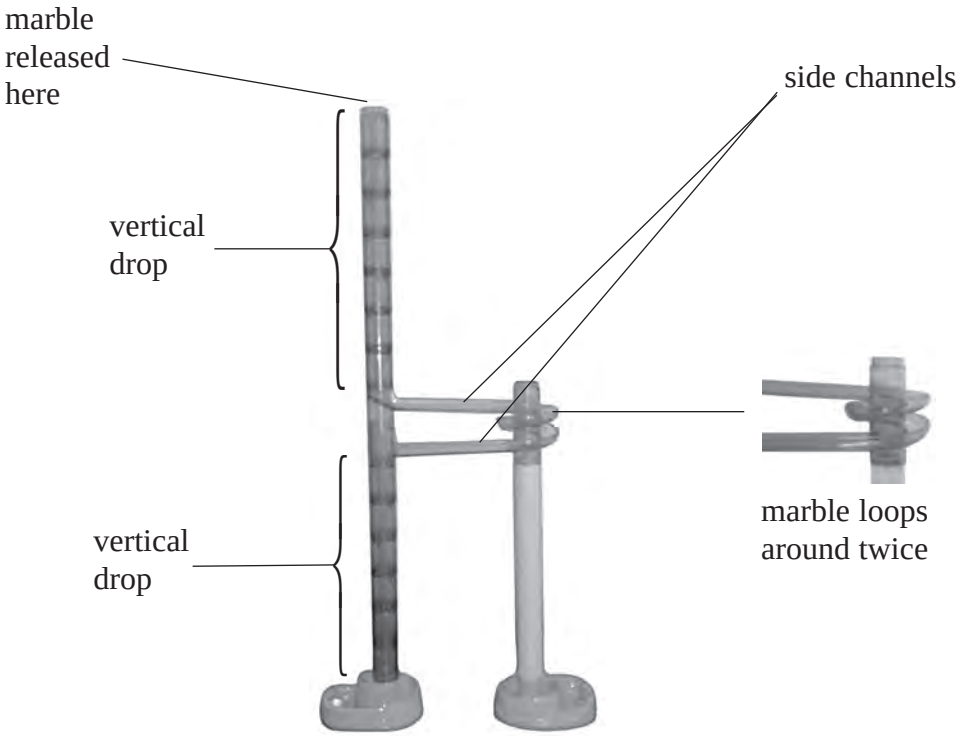
(iii) It is possible to create a small bubble followed by a larger bubble.

Use the expression to explain why the larger bubble catches up with the smaller one.

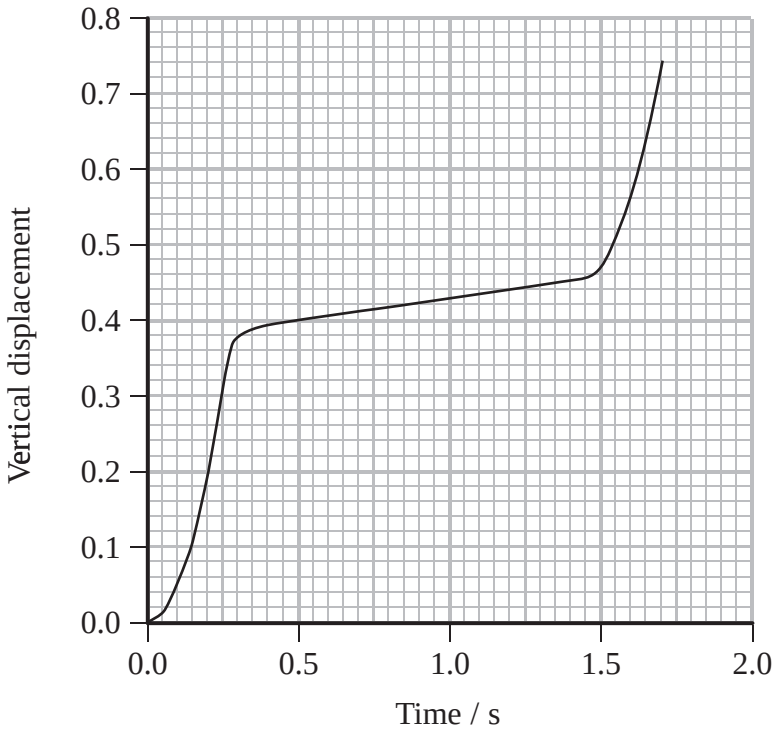
(1)

(Total for Question 17 = 12 marks)

2 The photograph shows a marble game.



A marble was released and its motion was recorded using a digital video camera. The data was uploaded to a computer and then analysed using a motion capture programme. The following vertical displacement-time graph was obtained.



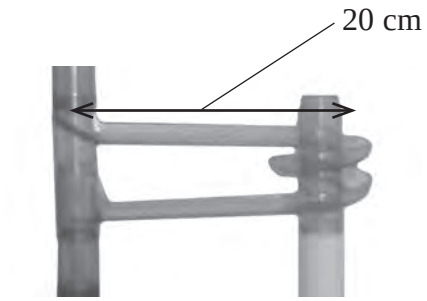
(a) (i) While the marble is in the side channels its speed remains constant.

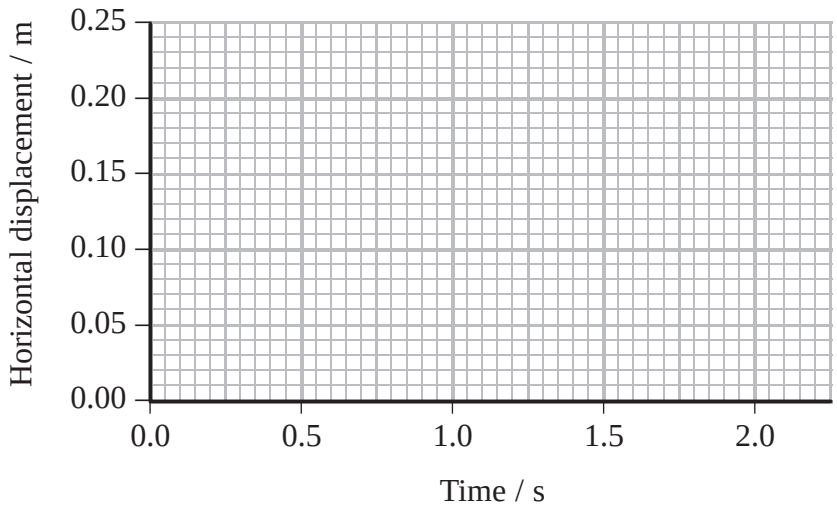
Use the graph to show that the vertical velocity is about 0.06 m s^{-1}.

(2)

(ii) On the axis below sketch the displacement-time graph for the horizontal displacement of the marble.

(4)





(iii) State the average horizontal velocity of the ma

(1)

(b) Measurements of the displacement of the marble and time taken could have been made using a rule and stopwatch.

Explain the advantages of using the digital video camera compared with a rule and stopwatch to obtain the data.

(3)

(Total for Question = 10 marks)

3 The photograph shows a wind turbine. Kinetic energy of the wind is transferred to electrical energy by the turbine as the blades rotate.

(a) Explain why we can say that the wind is doing work on the blades.

(2)

(b) The area swept out by one blade, as it turns through 360°, is 6000 m^2. Wind at a speed of 9 m s^{1} passes the turbine.

(i) Show that the volume of air passing through this area in 5 seconds is about 300 000 m^3.

(2)

(ii) Calculate the mass of this air.

density of air 1.2 kg m ^{3}

(2)

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Mass .....

(iii) Calculate the kinetic energy of this mass of air.

(2)

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Kinetic energy .....

(iv) Betz's law states that a turbine cannot usefully transfer more than 59% of the kinetic energy of the wind.

Use this law to find the maximum power output of the wind turbine.

(2)

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Maximum power .....

(c) Suggest a reason why it is not possible to usefully transfer 100% of the kinetic energy of the wind.

(1)

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(d) Suggest the limitations of using wind turbines to provide power.

(2)

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(Total for Question 13 marks)

4 One account of the origin of the term *horsepower* is as follows.

In the eighteenth century, James Watt manufactured steam engines. He needed a way to demonstrate the benefits of these compared to the horses they replaced. He did some calculations based on horses walking in circles to turn a mill wheel.

Watt observed that a horse could turn the wheel 144 times in one hour. The horse travelled in a circle of radius 3.7 m and exerted a force of 800 N.

(a) Show that the work done by the horse in turning the wheel through one revolution was about 20 000 J.

(3)

(b) Calculate the average power of the horse in SI units.

(3)

Average power =

(Total for Question = 6 marks)

5 You are asked to determine the acceleration of free fall at the surface of the Earth, g, using a free fall method in the laboratory.

(a) Describe the apparatus you would use, the measurements you would take and explain how you would use them to determine g.

(6)

(b) Give **one** precaution you would take to ensure the accuracy of your measurements.

(1)

(Total for Question = 7 marks)