SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which of the following is equivalent to the joule in terms of SI base units?

☐ **A** kg m^2 s^{-3}

☐ **B** kg m^2 s^{-2}

☐ **C** kg m s^{-2}

☐ **D** kg m s^{-1}

$W = Fd$

$J \equiv Nm \quad (F = ma)$

$\equiv kg\,m\,s^{-2}\,m$

$\equiv kg\,m^2\,s^{-2}$

(Total for Question 1 = 1 mark)

2 A wind turbine generates 550 W of electrical power for an average of 7 hours each day.

What is the total energy, in MJ, generated each day?

☐ **A** 0.23

☐ **B** 14

☐ **C** 230

☐ **D** 14000

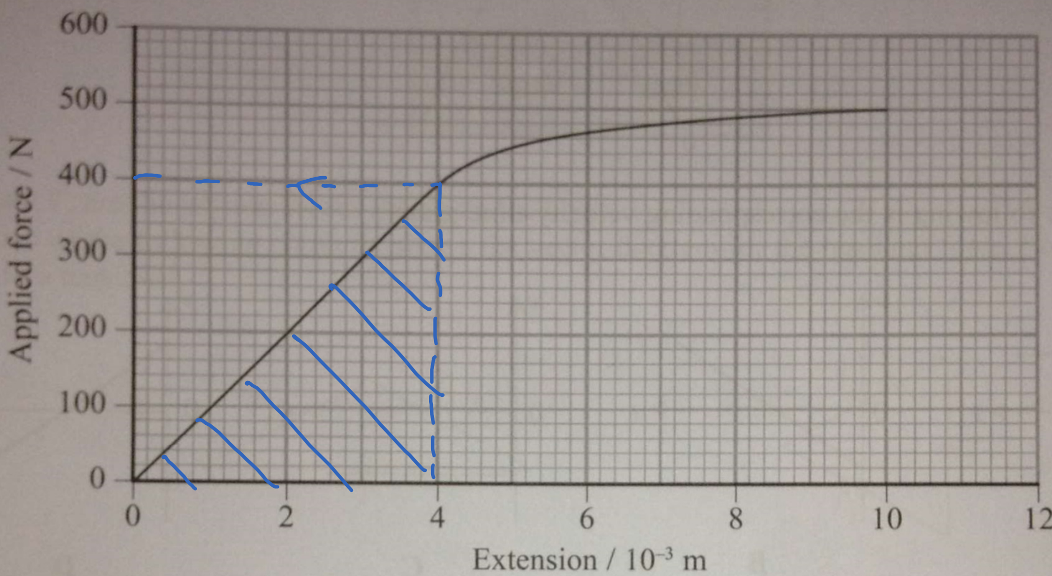
$7 \times 60 \times 60 \times 550 = 14 \times 10^6\,J$

(Total for Question 2 = 1 mark)

Questions 3 and 4 refer to the information below.

A student applied a range of forces to the ends of a copper wire and measured the corresponding new length of the wire.

The force-extension graph for the wire is shown.



3 What is the maximum force that could be applied and then removed such that the wire would go back to its original length?

- ☒ **A** 200 N
- ☒ **B** 300 N
- ☒ **C** 400 N
- ☒ **D** 500 N

(Total for Question 3 = 1 mark)

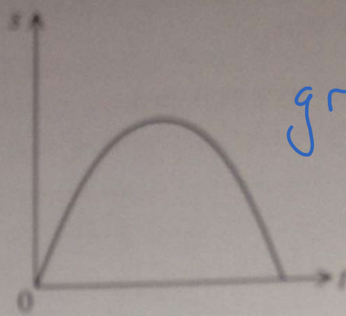
4 What is the elastic strain energy stored in the wire when it is extended by 4 mm?

- ☒ **A** 0.8 J
- ☒ **B** 1.6 J
- ☒ **C** 800 J
- ☒ **D** 1600 J

$E = \frac{1}{2} \times 4 \times 10^{-3} \times 400$

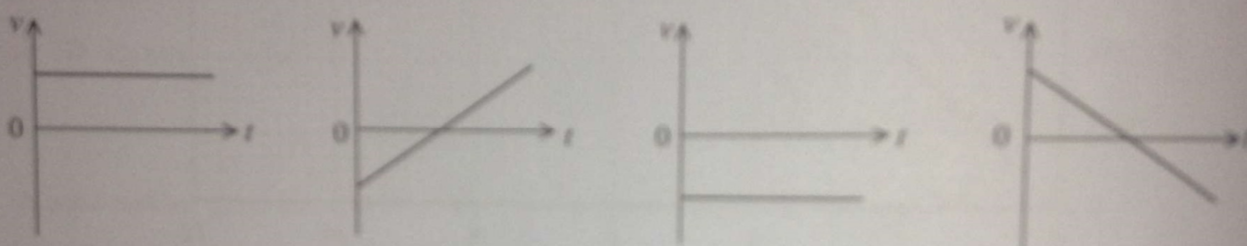
(Total for Question 4 = 1 mark)

5 The displacement-time graph for an object is shown.



gradient = velocity

Which of the following is the corresponding velocity-time graph?

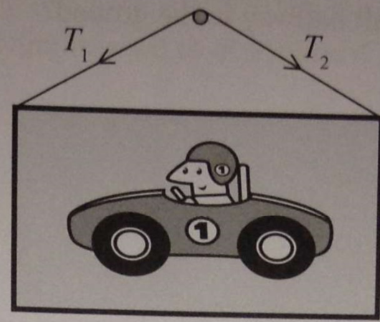


A B C D

- ☐ A
- ☐ B
- ☐ C
- ☐ D

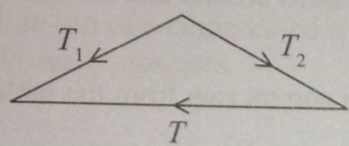
(Total for Question 5 = 1 mark)

6 A picture is hung using a wire placed over a small hook as shown.

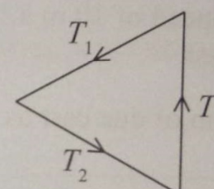


hook is pulled down

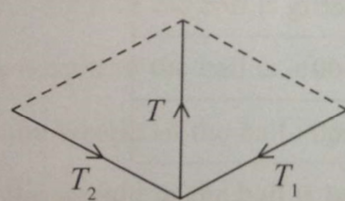
T_1 and T_2 are the tension forces acting on the hook.
Which of the following correctly shows the vector diagram for the resultant force T of the two tensions?



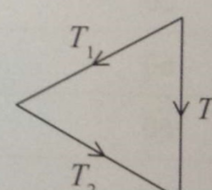
A



B



C



D

☒ A

☒ B

☒ C

☒ D

(Total for Question 6 = 1 mark)

7 A ball of mass m falls through a height h to the ground.

What is the kinetic energy of the ball halfway to the ground?

$\Delta GPE = \Delta KE$

☒ A mgh

☒ B $\frac{mgh}{2}$

☒ C $\sqrt{mgh}$

☒ D $\sqrt{\frac{mgh}{2}}$

(Total for Question 7 = 1 mark)

8 A car travels at a speed of 20 m s^{-1} due east and then turns around and travels at a speed of 40 m s^{-1} due west.

Taking the direction of due east as positive, select the correct row from the table.

$40 - 20 = 20$ $-40 - 20 = -60$

	Change in speed / m s^{-1}	Change in velocity / m s^{-1}
☒ A	20	−60
☒ B	20	60
☒ C	60	−60
☒ D	60	60

(Total for Question 8 = 1 mark)

9 A football is kicked across a football pitch with an initial vertical component of velocity u. The ball lands back on the pitch after a time of flight t.

Which of the following equations can be used to determine t?

☒ **A** $\frac{u}{2g}$

☒ **B** $\frac{u}{g}$

☒ **C** $\frac{g}{u}$

☒ **D** $\frac{2u}{g}$

(Total for Question 9 = 1 mark)

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10 A ball was placed on top of a compressed spring. When the spring was released the ball was accelerated vertically upwards.

If this were to be repeated on the Moon, the acceleration of the ball would be

☒ **A** less as the weight of the ball is greater.

☒ **B** less as the weight of the ball is less.

☒ **C** greater as the weight of the ball is greater.

☒ **D** greater as the weight of the ball is less.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A crane supports a load of 950 N with a steel cable. If the breaking stress of steel is 500 MPa, calculate the smallest diameter cable that can be used.

(3)

$\text{stress} = \frac{\text{force}}{\text{area}}$

$500 \times 10^6 = \frac{950}{\pi d^2/4}$

$d = 1.56 \times 10^{-3}$

Smallest diameter of cable = ...

(Total for Question 11 = 3 marks)

12 A student was asked to define the yield point of a material. The student said 'the stress at which there is a large extension.'

Explain why the student's definition is incorrect.

(2)

It is the point at which a small increase in stress causes a large increase in strain

(Total for Question 12 = 2 marks)

13 The Olympic flame for the 2012 Games held in London consisted of 204 separate copper petals supported by steel stems.

Each petal was made using a thin copper sheet wrapped around a shaped piece of wood.

wood

copper sheet

(a) Explain why copper was a suitable material from which to make the petals.

(2)

It is malleable so it can be shaped into thin sheets

(b) Explain why steel was a suitable material from which to make the stems.

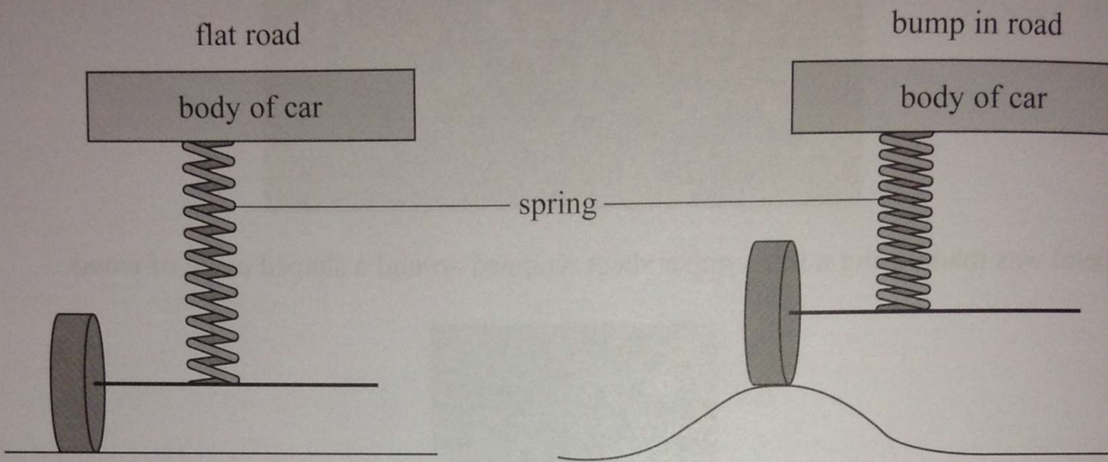
(2)

It is stiff so doesn't deform under the weight of petals

(Total for Question 13 = 4 marks)

14 Cars have a suspension system which includes springs that are compressed by the weight of the car. This is necessary to keep the body of the car at approximately the same level, when the surface of a road is uneven.

The diagrams show a simplified suspension system for one wheel when on a flat road and when on a bump in the road.



(a) The surface of a racing track is much smoother than the surface of a road. Racing cars are therefore able to use springs with a greater stiffness constant k.

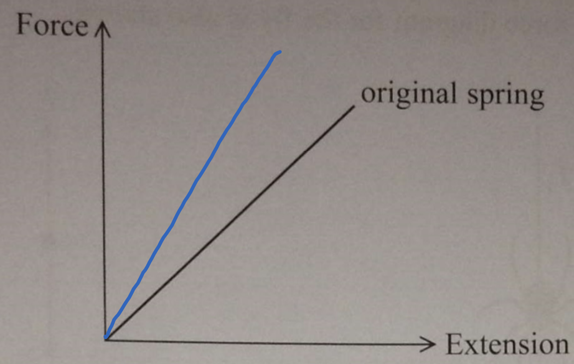
(i) Suggest what the effect would be of using springs with a greater value k when driving on a bumpy road.

(2)

The springs would not deform as much so the body of the car would move more, resulting in an uncomfortable ride

(ii) Add an appropriate line to the force-extension graph for the new spring with a higher value of k.

(1)



(b) A spring used in the front suspension of a car has an initial length of 0.316 m and a new length of 0.205 m when under a load of 4.07 kN.

Calculate the spring constant of the spring.

(3)

$F = kx$

$k = \frac{4.07 \times 10^3}{0.316 - 0.205}$

$= 3.67 \times 10^4 \ Nm^{-1}$

Spring constant = ...

(Total for Question 14 = 6 marks)

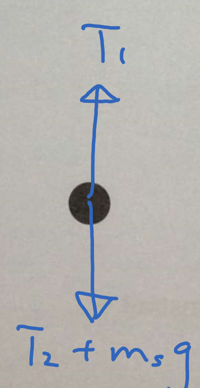
15 A spider of mass m_s is hanging from a thread of spider silk. A fly of mass m_f is hanging from another thread of silk below the stationary spider.

The magnitudes of the tensions in each thread of silk are T_1 and T_2 as shown in the diagram. The free-body force diagram for the fly is also shown.

Free-body force diagram for the fly

(a) (i) Complete the free-body force diagram below for the spider.

(3)



(ii) Write equations for the forces acting on the spider and for the forces acting on the fly.

(2)

S: $T_1 = T_2 + m_s g$ F: $T_2 = m_f g$

....

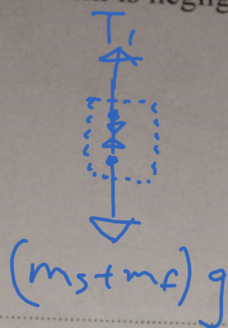
(b) The spider produces more silk, so the length of the thread of silk above the spider increases. The spider and the fly both accelerate towards the ground.

Assuming that the mass of the silk is negligible, calculate their acceleration.

$m_s = 6.5 \times 10^{-4}$ kg

$m_f = 8.0 \times 10^{-5}$ kg

$T_1 = 1.9 \times 10^{-3}$ N



(3)

[F = ma]

$(m_s + m_f)g - T_1 = (m_s + m_f)a$

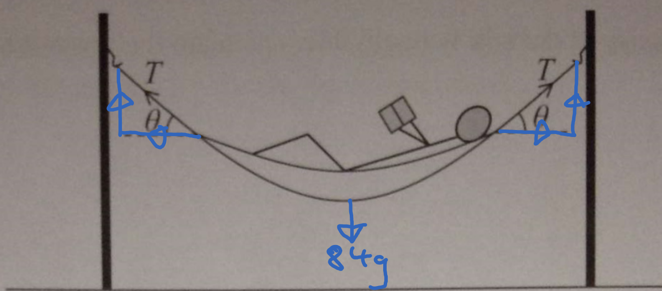
$a = \dfrac{(6.5\times10^{-4} + 8.0\times10^{-5})\,9.81 - 1.9\times10^{-3}}{6.5\times10^{-4} + 8.0\times10^{-5}}$

$= 7.2\ \text{ms}^{-2}$

Acceleration = ...

(Total for Question 15 = 8 marks)

16 A hammock is suspended between two rigid poles. Both ropes supporting the hammock are at an angle of θ to the horizontal as shown.



(a) When a man of mass 80 kg lies in the hammock, θ is 40°.

Show that the tension T in each of the hammock's supporting ropes is about 650 N.

mass of hammock and ropes = 4 kg

(3)

$2 \times T \sin 40 = 84 \times 9.81$

$T = 6.4 \times 10^2$ N

*(b) The force of the supporting ropes could cause the poles to fall inwards.

By considering the vertical and horizontal components of the tension in one of the supporting ropes, explain why a larger value of θ creates a smaller force on the poles supporting the hammock.

(5)

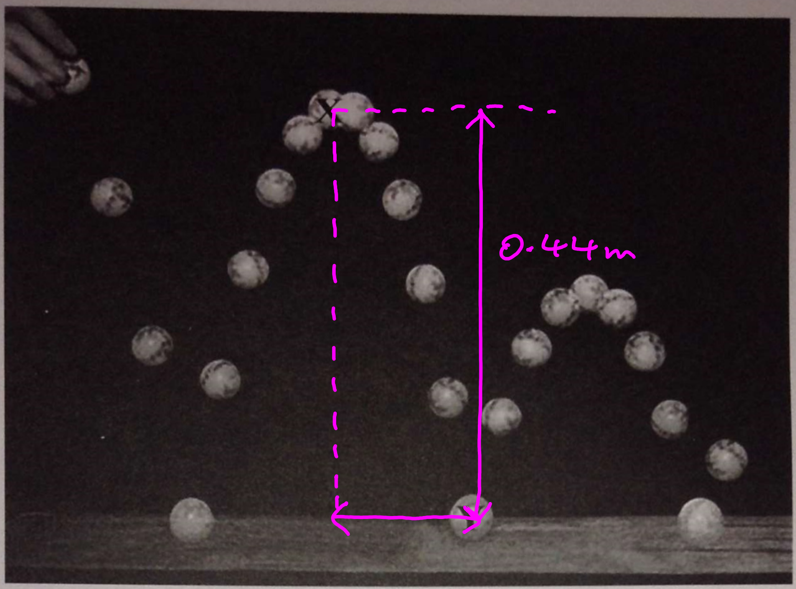
Vertical component must equal half the weight whatever the value of θ. $T\sin\theta = mg/2$

As θ increases, so does $\sin\theta$ and the tension in the rope decreases

The horizontal component is $T\cos\theta$, which would also be lower.

Since the force on poles is by the tension there's less force for greater θ.

17 The photograph shows a sequence of images of a bouncing ball. 20 images were taken per second.



(a) (i) Show that the distance the ball fell between point X and point Y is about 0.4 m.

(3)

6 images ⇒ $6 \times 1/20 = 0.3\,s$

$s = ut + \frac{1}{2}at^2$

$s = 0 + \frac{9.81}{2} \times 0.3^2 = 0.44\,m$

(ii) Use measurements from the photograph to calculate the horizontal velocity of the ball.

(4)

0.44m : 5.5 units on photograph

Horizontal dist is 2 units:

$v = \left[\frac{0.44}{5.5} \times 2\right] \frac{1}{0.3} = 0.54\,ms^{-1}$

(b) The vertical position of the ball a short time before a bounce was always higher than the vertical position the same time after a bounce.

Explain the difference in height of the ball before and after each bounce.

(2)

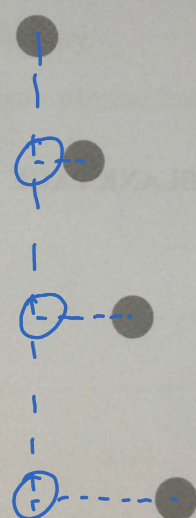
There's an inelastic collision between the ball and the surface. The ball loses some of its energy with each bounce

(c) The ball was released with a small horizontal velocity.

(i) The position of the ball in the first 4 images is shown below.

Draw in the first 4 positions of the ball had it been released with no horizontal velocity.

(2)



(ii) Explain why you have drawn the ball in these positions.

(2)

Horizontal and vertical motions are independent. The ball would still have the same acceleration downwards

(Total for Question 17 = 13 marks)

18 The photograph shows a rower during a race. During each stroke the rower applies a force to the end of each oar. The other end of each oar exerts a force on the water.

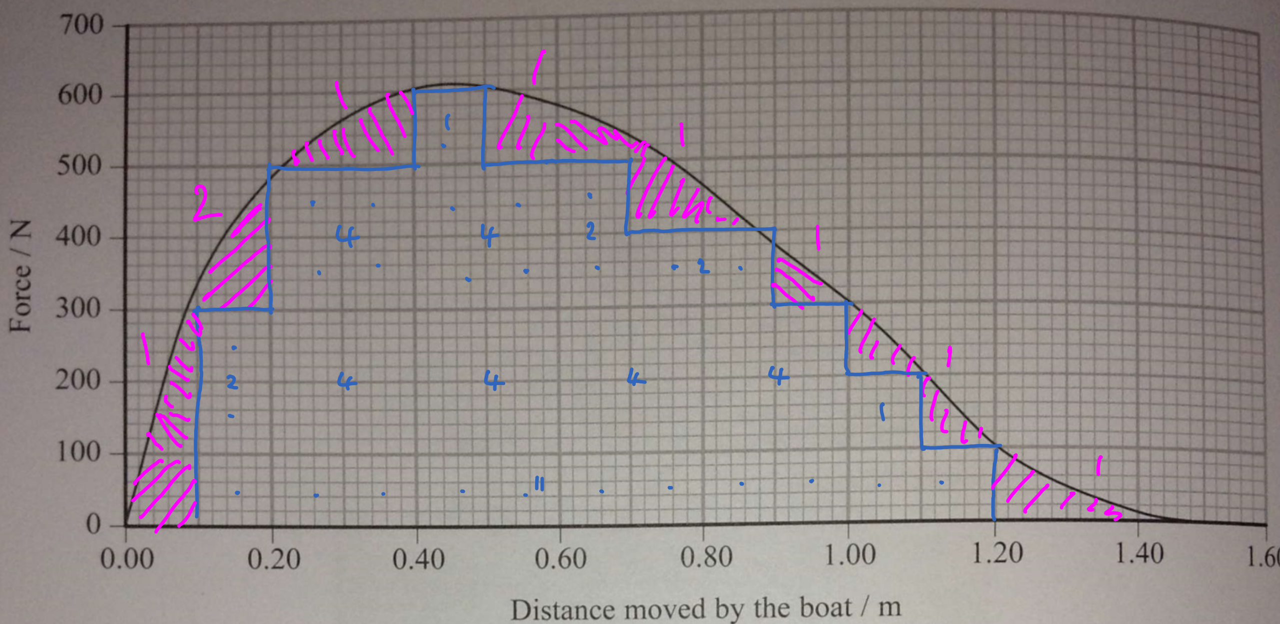
*(a) At the start of the race the boat is stationary.

Using Newton's laws of motion, explain why the boat begins to move through the water as the rower applies a force.

(4)

When the oars exert a force on water, there's an equal force in the opposite direction on the oars by water (N3). This creates a resultant force on the boat, which makes it accelerate (N2, F=ma)

(b) The graph shows how the force applied to the boat varies with the distance moved by the boat during one complete stroke.



(i) Use the graph to show that the work done on the boat during one stroke is about 500 J.

(3)

WD = area under F-d graph

$(43 + 9) \times 0.1 \times 100 = 520$ J

(ii) Hence calculate the average power developed.

average stroke rate = 24 strokes per minute

(3)

$P = \frac{E}{t} = \frac{520 \times 24}{60} = 200$ W

(c) The work done by the rower is greater than the kinetic energy gained by the rower and the boat.

Suggest **two** reasons why.

(2)

There's friction between the boat and water

Water pushed gains kinetic energy as well

(d) Suggest why the rower and the boat gain different amounts of kinetic energy during each stroke.

(1)

They have different masses

(Total for Question 18 = 13 marks)

19 Stokes' law can be used to calculate the resistive force F acting on an object as it moves through a fluid.

The equation for Stokes' law is

$$F = 6\pi\eta rv$$

(a) Stokes' law is only valid if the flow around the object is laminar.

(i) State what is meant by laminar flow.

(1)

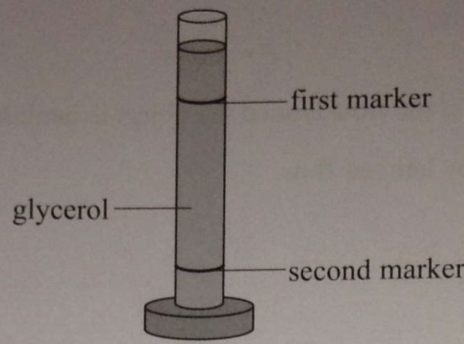
Flow is in layers, streamlines do not mix

(ii) State the conditions required for the flow around the object to be laminar.

(2)

Small object
curved /smooth surface of object
high viscosity of fluid
low flow speed

(b) A student carried out an experiment to determine the viscosity of glycerol using the apparatus shown.



A ball bearing was released at the top of a measuring cylinder containing glycerol. A stopwatch was used to measure the time taken to fall between the markers. This was repeated for ball bearings of different sizes.

The following equation was used to calculate the viscosity η.

$$\frac{4\pi r^3}{3}\rho_b g - \frac{4\pi r^3}{3}\rho_g g = 6\pi r\eta v$$

r = radius of ball bearing
ρ_b = density of ball bearing
ρ_g = density of glycerol
v = terminal velocity

(i) The density of the glycerol and the ball bearing are known.

State **two** other quantities the student would have to measure directly to calculate the viscosity.

(2)

Diameter of ball bearing

Distace between markers to calculate terminal velocity

(ii) State the quantity that is represented by the term $\frac{4\pi r^3}{3}\rho_b g$.

(1)

weight of ball

(iii) State the quantity that is represented by the term $\frac{4\pi r^3}{3}\rho_g g$.

(1)

upthrust on ball

(iv) Describe how the results obtained and a graphical method can be used to determine a value for the viscosity of the glycerol.

(4)

$$\frac{4\pi r^3}{3}\rho_b g - \frac{4\pi r^3}{3}\rho_g g = 6\pi r \eta v$$

$$2gr^2(\rho_b - \rho_g) = 9\eta v$$

$$v = \frac{2g(\rho_b - \rho_g)}{9\eta} r^2$$

Calculate radius (r) = $\frac{\text{diameter}}{2}$ and terminal velocity (v) = $\frac{\text{distance between markers}}{\text{time}}$.

Plot a graph of v against r^2. A straight line through the origin should be obtained. The gradient is $\frac{2g(\rho_b - \rho_g)}{9\eta}$, which can be rearranged for η.

(c) Glycerol can be pumped into waste systems to remove nitrogen during the treatment of waste water.

Explain the effect that low temperatures could have on the supply of glycerol to a waste system.

(2)

Low temperatures would increase the viscosity of glycerol, which makes pumping more difficult

(Total for Question 19 = 13 marks)