

Name of the Student: \_\_\_\_\_

Max. Marks : 17 Marks

Time : 17 Minutes

Mark Schemes

**Q1.**

- (a) (A frame of reference ) that has a constant velocity ✓  
*Accept no acceleration*

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- (b) (i) Distance = 4.3 c light years ( or  $4.1 \times 10^{16}$  m)  
*Correct answer only gets the mark*

$$\text{Speed} = \frac{4.3c}{5.0} = 2.6 \times 10^8 \text{ m s}^{-1} \text{ (or } 0.86c \text{)}$$

*Accept 2.58*

1

- (ii)  $t = \frac{t_0}{(1 - v^2/c^2)^{1/2}}$  where  $t = 5.0$  years (or  $1.58 \times 10^8$  s)

$$\text{and } v = 0.86c \text{ (or } 2.58 \times 10^8 \text{ m s}^{-1} \text{)}$$

*CF from bi to bii provided answer to bi*

1<sup>st</sup> mark for correct substitution of either  $t$  or  $v$  into the above eqn ✓

$$t_0 = 5.0 \times (1 - (0.86c)^2 / c^2)^{1/2} \checkmark = 2.6 \text{ years } \checkmark$$

*Accept  $t$  or  $v$  in alternative units*

*Accept  $1.58$  (or  $1.6$ )  $\times 10^8$  s in place of 5.0 yr in 3<sup>rd</sup> mark point*

**Alt scheme**

$$l = l_0 (1 - v^2 / c^2)^{1/2} \text{ where } t = 5.0 \text{ years (or } 1.58 \times 10^8 \text{ s) and } v = 0.86c \text{ (or } 2.58 \times 10^8 \text{ m s}^{-1} \text{)}$$

*Accept 2.5 to 2.6 to any number of sfs*

1<sup>st</sup> mark for correct substitution of either  $t$  or  $v$  into the above eqn ✓

$$l_0 = 4.3 \times 365 \times 24 \times 3600 \times 3.0 \times 10^8 = 4.07 \times 10^{16} \text{ m}$$

$$l = 4.07 \times 10^{16} (1 - (0.86c)^2 / c^2)^{1/2} \text{ or } 2.08 \times 10^{16} \text{ m } \checkmark$$

$$t_0 = \frac{l}{v} = \frac{2.08 \times 10^{16} \text{ m}}{2.6 \times 10^8 \text{ m/s}} = 8.05 \times 10^7 \text{ s} = 2.6 \text{ years } \checkmark$$

*Alternative for last 2 marks in Alt scheme ( $l_0 = 4.3$  l yr)*

$$l = 4.3 (1 - (0.86c)^2 / c^2)^{1/2} = 2.2 \text{ l yr } \checkmark$$

$$t_0 = \frac{l}{v} \quad (= \frac{2.2}{0.86}) = 2.6 \text{ years } \checkmark$$

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## Q2.

- (a) (i) (at terminal velocity  $v$ ), weight of droplet ( or  $mg$ ) = viscous drag (or  $6 \pi \eta r v$ )  $\checkmark$

*Backward working 3 marks max;*

$$\text{viscous force } (= 6 \pi \eta r v) = 6 \pi \times 1.8 \times 10^{-5} \times 1.0 \times 10^{-6} \times 1.1 \times 10^{-4} = 3.7 \times 10^{-14} \text{ N } \checkmark$$

mass ( $m$ ) of droplet =  $(\frac{4}{3} \pi r^3) \times \rho$ , (where  $r$  is the droplet radius)  $\checkmark$

weight =  $mg$  =

$$\frac{4}{3} \pi (1.0 \times 10^{-6})^3 \times 880 \times 9.8 = 3.6 \times 10^{-14} \text{ N } \checkmark$$

(allow 3.7)

(therefore)  $(\frac{4}{3} \pi r^3) \times \rho g = 6 \pi \eta r v$  ( or rearranged)  $\checkmark$

(hence)  $r = (9 \eta v / 2 \rho g)^{1/2}$

$$= \frac{9 \times 1.8 \times 10^{-5} \times 1.1 \times 10^{-4}}{2 \times 880 \times 9.8} \text{ gives } r = 1.0(3) \times 10^{-6} \text{ m } \checkmark$$

(therefore) viscous force = weight as required for constant velocity  $\checkmark$

note; some evidence of calculation needed to give final mark

*Allow final answer for  $r$  in the range  $1$  to  $1.05 \times 10^{-6}$  to any number of sig figs*

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(ii)  $m = ((\frac{4}{3} \pi r^3) \times \rho) = \frac{4}{3} \pi (1.0 \times 10^{-6})^3 \times 880 = 3.7 \times 10^{-15} \text{ kg } \checkmark$

*Allow ecf for  $r$  from a(i) in a correct calculation that gives  $m$  in the range  $3.6$  to  $4.0 \times 10^{-15} \text{ kg}$*

( or correct calculation of  $6 \pi \eta r v / g$ )

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- (iii) electric force ( or  $QV / d$ ) = droplet weight ( or  $mg$ )  $\checkmark$

*Allow ecf  $m$  (or  $r$ ) from a(ii) (or a(i)).*

$$Q = \left( \frac{mgd}{V} \right) = \frac{3.7 \times 10^{-15} \times 9.8 \times 6.0 \times 10^{-3}}{680} \checkmark$$

*Accept values in 1<sup>st</sup> mark line*

[or  $Q$  (= viscous force  $\times d / V$ )

*Use of  $e$  instead of  $Q$  or  $q$  = 2 marks max*

$$= 6 \pi \times 1.8 \times 10^{-5} \times 1.0 \times 10^{-6} \times 1.1 \times 10^{-4} \times 6.0 \times 10^{-4} / 680 \checkmark]$$

*For the 2nd mark, allow use of viscous force calculation. Use of viscous force method does not get 1st mark.*

$$Q = 3.2 \times 10^{-19} \text{ C } \checkmark$$

If both methods are given and only one method gives  $Q = ne$  (where  $n = \text{integer} > 1$ ), ignore other method for 2<sup>nd</sup> mark and 3<sup>rd</sup> mark.

For the final mark,  $Q$  must be within  $n e \pm 0.2 \times 10^{-19}$  from a correct calculation.

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- (b) The weight of the second droplet is greater than the maximum electric force on it ✓

Alternative for 1st mark;

weight = drag force + elec force ( owtte)

**Scheme using V for next 5 marks;**

If  $n = 1$  for the second droplet, pd to hold it = 1580 V (=  $mgd / e$ ) ✓

which is not possible as  $V_{\text{max}} = 1000$  V ✓

If  $n = 2$ , it would be held at rest by a pd of 790 V (=  $1580 / 2$  or  $680 \times 4.3 / 3.7$  V) ✓

if  $n > 2$ , it would be held at rest by a pd of less than 790 V ( or  $790 / n$  V) ✓

So  $n = 1(e)$  must be the droplet charge ✓

**Alternative schemes for last 5 marks**

**Q scheme** Using  $QV/d = mg$  for a stationary droplet gives  $Q = mgd / V$   
=  $2.53 \times 10^{-19}$  C ✓

which is not possible as  $Q = \text{integer} \times e$  ✓

(so)  $Q (=ne) < 2.53 \times 10^{-19}$  C ✓ owtte)

Calculation to show

$Q = 1e$  fits above condition ✓

$Q = 2e$  does not fit above condition ✓

**F scheme**;- Calc of  $mg$  to give  $4.2 (\pm 0.2) \times 10^{-14}$  N ✓

Calc for  $Q = 1e$  of  $QV/d$  to give  $2.6(\pm 0.2) \times 10^{-14}$  N ✓

Calc for  $Q = 2e$  of  $QV/d$  to give  $5.3 (\pm 0.2) \times 10^{-14}$  N ✓

$mg >$  elec force for  $Q = 1e$  or  $< 2e$  for  $Q = 2e$  ✓

So  $n = 1(e)$  must be the droplet charge ✓

Max 4

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