1. (a) correctly deduces extension is 2.6 or 2.7 mm ✓

Should see $AC^2 = 1.50^2 + (6.34 \times 10^{-2})^2$;

(new) AC = 1.50134;

Extension of AC = (1.50134 − 1.50 =) 0.00134 m or 1.34 mm; and then doubles this

Final value must be to at least 2 sf

1

(b) evidence of correct working: ✓

$\sin\theta = \dfrac{6.34 \times 10^{-2}}{\text{their new AC}}$ or $\theta = 2.42°$ seen

OR

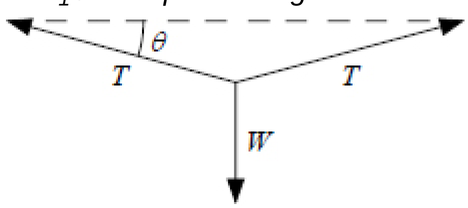
$W = 2T \sin\theta$ seen

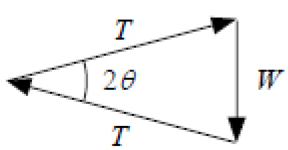
OR

suitable vector diagram with θ labelled

tension correctly calculated from

For $_1$✓ acceptable diagrams are shown below





Correct final answer of 11.8 N or 12 N earns both marks

2

(c) ruled best-fit line between first and sixth points;

line must pass above 2nd point

and

must pass below 4th point $_1$✓

for $_1$✓ withhold mark if line is thick, faint or discontinuous

gradient calculated from $\frac{\Delta(W/y)}{\Delta y^2}$ with $\Delta y^2 \geq 0.004$ $_2$✓

(gradient ~ 3850)

for $_2$✓ condone read off errors of ± 1 division

for $_3$✓ note that $1.50^3 = 3.375$ so allow sub of 3.38

for $_4$✓ reject 2 sf 1.2×10^{11}

evidence of using E = $\frac{\text{their gradient} \times 1.50^3}{1.11 \times 10^{-7}}$ $_3$✓

for $_3$✓ note that $1.50^3 = 3.375$ so allow sub of 3.38

E in range 1.10×10^{11} to 1.24×10^{11} (Pa) $_4$✓

for $_4$✓ reject 2 sf 1.2×10^{11}

4

(d) kg s^{-2} ✓

no credit for N m^{-1}

correct answer only

1

[8]

2. (a) 28 (°C) ✓

1

(b) The energy transferred reduces the number of nearest atomic neighbours

First alternative must not imply total loss of intermolecular forces or neighbours.

A reference to 'breaking <u>the</u> bonds' implies all the bonds and does not gain the mark.

No mark for saying bonds weaken.

However these errors in discussing the bonds does not prevent a mark coming from another point

OR
allows atoms to move their centre of vibration

Last alternative might be expressed as 'atoms change from fixed positions to them being able to slide around each other'.

Ignore any references to changes in separation.

OR
breaks some of the (atomic) bonds

OR
crystalline to amorphous ✓ (owtte)

An explanation that involves increasing the kinetic energy will lose the mark.

So will any description that implies it becomes a gas.

1

(c) The (total or mean) kinetic energy remains constant. ✓
The (total or mean) potential energy increases. ✓

2

(d) The <u>mean</u> speed/<u>mean</u> kinetic energy increases ✓

Ignore references to larger separation (because it's not always true): collisions (as it is not a gas) or measures of randomness (which are usually too vague).

Condone use of average for mean.

Don't allow velocity instead of speed.

During this time interval the atoms are all in the liquid form so no credit for references that indicate a change of state.

1

(e) Using both $\Delta Q = mc\Delta\theta$ **and** $\Delta Q = P\Delta t$ ✓

$$\left(c = \frac{P\Delta t}{m\Delta\theta} = \frac{35 \times (14.8 - 11.2) \times 60}{0.25 \times (110 - 28)} = 369\right)$$

c = 370 ✓ (allow 365–375)

J kg^{-1} K^{-1} ✓ (or J kg^{-1} C^{-1})

First mark can be given by seeing the substitution which may have some errors for example not using exactly 28. These will be penalised in the second mark.

Correct answer gains first two marks NB 400 J kg^{-1} K^{-1} shows candidate has wrongly made calculations for the solid. No mark for the unit if a solidus is used because of the uncertainty of whether the K is on the top or bottom line. (which is correct J / kg / K or J / kg K ?)
However allow a prefix if kilojoules are used for example.

3

(f) (Using both $\Delta Q = ml$ and $\Delta Q = P\Delta t$)

$$l\left(=\frac{P\Delta t}{m}\right) = \frac{35 \times ((11.2-1.8) \times 60)}{0.25} = 79 \text{ kJ kg}^{-1}$$ ✓

hence M = gallium ✓ (condone an ecf consistent with the calculation provided a comment is made if the value falls outside the range of the table)

The calculation yields1.3 kJ kg^{-1} if the 60 seconds is omitted.

Interim stage heat supplied = 19.7 kJ

A valid calculation must be shown to gain this second mark.

2

[10]

3. (a) general procedure

- collect water for a measured time;
- **divide** measured / calculated volume by time to determine rate $_1$✓

__static__ volume should be measured __after timing__, eg

reject 'measure time to fill cylinder' ***or $_1$✓ = 0***

accept 'find V for different t, plot V against t,

gradient = Q' but not if by continuous flow method

1

names 2 suitable instruments $_2$✓

for time use stopwatch or stopclock;

treat as neutral: 'timer' or 'light gate / data logger'

for volume use measuring cylinder / graduated beaker;

treat as neutral: 'measuring beaker' / 'burette'

OR

for mass use balance; use of $V = \frac{m}{\rho}$ *(any subject)*

condone 'volume of 1 g is 1 cm ^{3}*';*

reject 'weigh'/'weighed'

1

method to reduce uncertainty in volume $_3$✓

read water level at bottom of the meniscus (or wtte or allow sketch); don't penalise further use of 'beaker' treat as neutral: 'dry cylinder before use'

OR

procedure to avoid systematic error in determining mass, eg tare / reset / zero the balance with empty beaker on pan / find mass of beaker empty and subtract from mass of beaker plus water;

don't penalise further use of 'weigh'/ 'scales' allow 'use balance on a horizontal surface'

method to reduce uncertainty in time $_4$✓

✓*ensure stopwatch is zeroed / reset before use*

added detail $_5$✓ $_6$✓ $_7$✓

collect large(r) volume / for long(er) time / ≥ 60 s $_5$✓

this reduces percentage / fractional uncertainty $_6$✓

read at eye level or wtte, to reduce parallax $_7$✓

MAX 2

(b) sensible mark identifying second box indicating (N m^{-2} s) only

auto marked question

1

(c) 19.8% (from 4 × 2.9% + 1.8% + 6.4%) earns both marks ✓✓

don't insist on seeing '%' unless 0.198 etc

allow final answer rounded to 20%

allow 1 mark for 0.198 or 0.20 but reject 1 sf 0.2

for incorrect answer the following can earn one mark:

(percentage uncertainty in d =) 4 × 2.9% / 11.6% / 12% seen in working but wrong final answer

OR missing × 4 eg 2.9% + 1.8% + 6.4% = 11(.1)%

OR incorrect multiplier applied to 2.9 eg 2 × 2.9%

OR with × 4 applied wrongly eg

2.9 + (1.8 × 4) + 6.4 = 16.5 % or 17 % /

2.9 + 1.8 + (6.4 × 4) = 30(.3) %

2

(d) appropriate use (ie close to and parallel with the vertical side of the tube, but not necessarily in contact with the tube) of:

a metre ruler made vertical using a set-square in <u>contact with the bench</u> / <u>floor</u> / (flat) <u>surface</u>

OR

a plumb line / weight on vertical string (reject 'pendulum')

OR

a spirit level ✓

the mark can be awarded for a convincing sketch, eg use of a very large set square without ruler

accept 'tri-square' for set square

the only acceptable horizontal reference is the bench: don't allow use of horizontal T, eg set square placed on T even if sketch looks convincing

no credit for attempt to show graduations on tube are horizontal / use of 'protractor' for set-square / 'each side of meniscus at same level' / use of clamp stand rod or wall as vertical reference

1

(e) attempted use of $y = y_0 e^{-\lambda\Delta t}$ with substitution of values of y, y_0 and Δt obtained **directly** from **Figure 4** / plausible values obtained from **Figure 7**

OR

tangent drawn on **Figure 4** to find $\frac{dy}{dt}$;

use of $\frac{dy}{dt}$ = (–) $\lambda \times y^*$ and y^* is where tangent meets the curve $_1$✓

valid calculation **seen** leading to a result for λ that rounds to 3 sf in range 4.45 to 4.55 $\times 10^{-3}$ (s^{-1});

award if seen in body of answer $_2$✓

for $_1$✓ do not penalise y / y_0 interchanged, read off errors, manipulation errors / Δt = t / t0 / $\frac{t}{t_0}$ or use of incorrect symbols eg A, N for y;

no ecf for $_2$✓

*allow use of **Figure 7***

y_0 = 60.0 cm, y = 52.2 cm; Δt = 60 – 29 = 31 s

$52.2 = 60\ e^{-31\lambda}$; $\therefore \lambda = 4.49 \times 10^{-3}\ s^{-1}$

if the intermediate step is seen, eg

$$\lambda = \frac{1}{\Delta t} \times \ln\left(\frac{y_0}{y}\right) = \frac{1}{31} \times \ln\left(\frac{60}{52.2}\right)$$

accept 'log' for 'ln'

no credit allowed for reverse-working method in a 'Show that' problem

no credit for assuming straight line and y = mx + c, measuring the gradient then by determining the equation of the line or by using $m = \frac{y_2 - y_1}{t_2 - t_1}$

determines the half life; finds λ from $\frac{\ln 2}{\text{half life}}$

no credit for common error λ = gradient × 2

for $_2$✓ look for any answer in the body that deserves credit (for a 'Show that' we can overlook truncation in the value given on the answer line) variation on use of use of $y = y_0 e^{-\lambda\Delta t}$ for $_1$✓:

λ can be found if points t_1, y_1 and t_2, y_2 are used and the values substituted into $\frac{y_1}{e^{-\lambda t_1}} = \frac{y_2}{e^{-\lambda t_2}}$;

if this approach is used substitute the data into $\lambda = \frac{1}{\Delta t} \times \ln\left(\frac{y_0}{y}\right)$ to confirm that the result for λ is correct before awarding $_2$✓

1

1

(f) use of $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ OR $\frac{\ln 0.5}{-\lambda}$ with substitution of **recognisable** λ;

evaluated to ≥ 2 sf in range 140 s to 170 s ✓

calculation can have any subject;

accept use of 2 sf λ = 4.5 × 10^{-3} usually leading to 154 but allow correctly truncated to 150 or 1.5 × 10^{2}

1

(g) (mostly) continuous line drawn on **Figure 7**;

below dashed line and with negative gradient between *t* = 0 and *t* = 120;

do not penalise linear line or shaky / thick / hairy line or slight

discontinuities; accept ≈ horizontal after 100 s $_1$✓

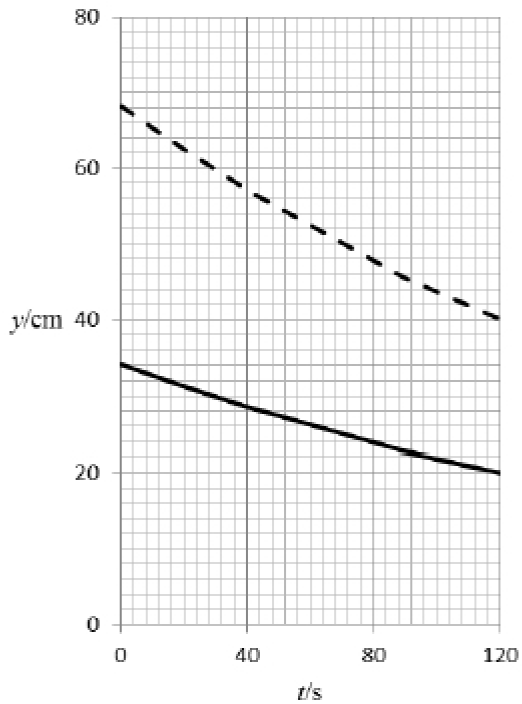
line passes through:

t/s	*y*/cm min	*y*/cm max
0	33	35

AND through EITHER of

t/s	y/cm min	y/cm max
60	24	28
120	17	23

2✓



2

[13]

4. (a) Mass of alpha particle = $\dfrac{2\times1.6\times10^{-19}}{4.81\times10^{7}}$ =6.6(53) × 10^{-27} (kg)

Allow mass = 2 × m_p + 2 × m_n = 6.696 × 10^{-27} kg

Allow mass = 4 × 1.66 × 10^{-27} kg = 6.64 × 10^{-27} kg

Allow mass = 4 × 1.67 × 10^{-27} kg = 6.68 × 10^{-27} kg

Allow slight rounding on mass (must be correct to 2 sf)

OR

Correctly re-arranged k.e. equation (with v^2 or v as subject) with 8.1×10^{-13} (J) substituted correctly$_1$✓

1.56×10^7 seen $_2$✓

Condone ***incorrect mass*** *in otherwise correct substitution* ***with v or v²* recognisable** *as subject .*

Alternative approaches are:

$$v = \sqrt{\frac{E_k \times \text{specific charge}}{e}}$$

$$v = \sqrt{\frac{2 \times E_k}{m_\alpha}}$$

Must see answer to at least 2 sf

Must see attempt to use one of the alternative approaches to support correct answer

2

(b) Use of $W = Fs$, $F = 8.1 \times 10^{-13} \div 3.5 \times 10^{-2}$ $_1$✓

(F=) 2.3×10^{-11} (N) $_2$✓

Condone POT error

Correct answers gets 2 marks

OR

Use of an appropriate equation of motion to find a **and** $F = ma$

(allow their mass and their velocity in this sub) $_1$✓

Condone POT error

(F=) 2.3×10^{-11} (N) $_2$✓

Condone POT

OR

Use of an appropriate equation of motion to find t **and** $F = \Delta mv/t$

(allow their mass and their velocity in this sub) $_1$✓

(F=) 2.3×10^{-11} (N) $_2$✓

[answer is

$$\frac{(\text{their speed})^2 \times (\text{their } m_\alpha)}{0.070}$$

Using 2×10^7 m s^{-1} yields(5.71×10^{15} × their m_∞) – allow 1 sf answer in this case

Expect to see 3.8×10^{-11} (N) or 4×10^{-11} (N)]

2

(c) (Number of ions formed over range =)

$5.1 \times 10^4 \times 3.5$ seen **or** 1.785×10^5 (ions) seen

OR

8.1×10^{-13} converted to eV seen $_1$✓

$8.1 \times 10^{-13} \div 1.785 \times 10^5$

OR

$5.06 \times 10^6 \div 1.785 \times 10^5$ seen $_2$✓

Condone POT error in first mark

Ignore units

$8.1 \times 10^{-13} \div (5.1 \times 10^4 \times 3.5)$ is worth 1st and 2nd marks

Condone POT errors in second mark

Correct answer obtains 3 marks

28 (.4) (eV) $_3$✓

99(.3) (eV) scores 1 mark

3

(d) (Q =) $0.85 \times 10^{-3} \times 1.2 \times 10^{-9} = 1.02 \times 10^{-12}$

OR

n = (their Q) $\div 1.6 \times 10^{-19}$ $_1$✓

$n = 6.4 \times 10^6$ (c.a.o.) $_2$✓

Condone one POT error for one mark

2

(e) At 3.5 cm the pd drops / the current begins

OR

When the source is 10 cm away no ionisation occurs in the air gap (because the alpha particles have insufficient range to reach the air gap)

OR

When the radioactive source is <u>close enough</u> (approx. 5 cm) ionisation occurs ✓

OR

When beyond 3.5 cm no change in pd / current equals zero

Must be sense of abrupt change

MAX 3

When ionisation occurs / charge carriers are liberated in the air gap:

Allow more ionisation for second mark

resistance has decreased

OR

current increases (from zero)

OR

the potential difference decreases (with a maximum current) (to its minimum value) (across the air gap)✓

From 10 cm separation until 5 cm (approx) separation nothing changes / appreciates that pd is 4500 V / pd across gap = 4500 V until ionisation occurs ✓

Current is produced: the pd across 5 MΩ resistor is 4250 V / most pd is across the 5 MΩ resistor / small pd across air gap ✓

Current is produced and the pd across the air gap is 250 V✓

Current is produced and the pd across the air gap is 250 V✓

3

[12]

5. (a) Length of resistance wire = $50 \times 2 \times 3.14 \times 4 \times 10^{-3} = 1.26$ m ✓

or $50 \times 3.14 \times 8 \times 10^{-3}$

1

Substitution of data in resistance formula

or $A = \rho L/R$ seen ✓

ecf for incorrect length from attempt at a calculation

1

Area of cross section = $2.1(1) \times 10^{-9}$ (m^2) ✓

1

(b) Maximum possible pd across 0.25 kΩ is 9 V ✓

1

(Max power dissipated) = $9^2/250 = 0.32$ W so resistor is suitable ✓

1

OR

When resistor dissipates maximum power

$V^2 = 0.36 \times 250$ so max $V = 9.5$ V ✓

This is higher than the supply pd so this power dissipation so will not be reached ✓

OR

Power dissipated when output is 5 $V = 4^2/250 = 0.064$ W ✓

Which is below the max power dissipation of 0.36 W ✓

$9^2/250 = 0.32$ W with incorrect conclusion scores 1

Second mark implies the first

$9^2/0.36 = 225$ Ω alone is not a useful calculation in the context. Still need to explain the effect of using the 250 Ω

First mark is for a valid useful calculation

(c) Use of potential divider formula to determine resistance of parallel combination ✓

0.313 kΩ ✓

Use of equation for resistors in parallel ✓

540 Ω ✓

Alternative to find resistance of combination

Current in circuit at room temp = 4/250 = 16 mA ✓

Resistance of combination = 5/16mA = 313 Ω ✓

OR

$$\frac{V_{combination}}{V_{250}} = \frac{R_{combination}}{250}$$

$$\frac{5}{4} = \frac{R_{combination}}{250}$$

$R_{combination} = 313$ Ω

OR

Current in circuit at room temp = 4/250 = 16 mA ✓

Current in thermistor = 5/750 = 6.7 mA ✓

Current in R = 9.3 mA ✓

R = 5/9.3 = 540 Ω ✓

2sf answer ✓

(only allowed with some relevant working leading to a resistor value)

Max 5

(d) Resistance of thermistor decreases ✓

Output pd decreases since

resistance of the parallel combination /circuit decreases

1

OR

lower proportion of pd across the parallel combination (or higher proportion across 250Ω)

OR

higher current so greater pd across the 0.25 k resistor ✓

Accept correct consequences for R increasing with temperature for 1 mark

1

[12]

6. (a) (Total) kinetic energy ✓

1

(b) Attempt to apply conservation of momentum ✓

NB This is a 'show that' so all stages must be seen

1

16 000 × 2.8 – 12 000 × 3.1 = 28 000 v ✓

Must see substitution

1

v = 0.27(1) (m s^{-1}) ✓

Correct equation (watch signs) gets first and second marks

1

(c) Impulse = 16 000(2.8 – 0.271) or 12 000(3.1 + 0.271) = 4.0(5) × 10^4 ✓

If 0.3 m s–1 used then impulse will be 4.0 × 10^4 or 4.08(4.1) × 10^4

1

N s or kg m s^{-1} ✓

1

(d) Trucks move in opposite directions/rebound ✓

1

Velocity of **B** is greater than that of **A** because total momentum is to the right OR **B** has lower mass ✓

OR

Momentum of **B** after collision is same as that of **A** before the collision (and vice versa)

1

[8]

7. (a) (The electric field strength at a point) is the force per unit charge ✓

On a (small) <u>positive</u> charge (at that point) ✓
(only given if an attempt is made at the first mark)

An equation is not sufficient unless the symbols are defined. Unit charge can be replaced by coulomb.

(Reference to a point is not needed as it is in the question but a reference to moving between points or other points can cancel a mark.)

If "mass" appears in the answer, it must be a synonym for "object".

2

(b) (At B) the (magnitude) of the electric field strength due to Q = the magnitude of the electric field strength due to the 46 μC charge ✓

$$\frac{46 \times 10^{-6}}{4\pi\varepsilon_0(0.054)^2} = \frac{Q}{4\pi\varepsilon_0(0.066)^2} \checkmark$$

$$(Q = 46 \times 10^{-6}\left(\frac{0.066}{0.054}\right)^2)$$

$Q = 6.9 \times 10^{-5}$ (C) ✓ (68.7 μC rounding must be correct)

This first mark may be inferred from the equation but must refer to an electric field.

(Note: the answer 5.6×10^{-5} shows that an inverse square has not been used).

A correct answer gains full marks.

Allow first and second marks even with arithmetic errors ie 10^{-6} missing, distances in mm and the constant $4\pi\varepsilon_0$ not present.

Award one mark if they use the inverse square coulomb law equation to correctly calculate one side of the equation ($\frac{46 \times 10^{-6}}{4\pi\varepsilon_0(0.054)^2}$ =) 1.4×10^8.

3

(c) Work must be done on the positive proton because P is at a positive potential

OR

Work must be done (on the positive proton) due to the repulsive forces / because like charges repel OWTTE ✓

The potential at infinity is zero ✓

2

(d) (As the ball falls) it experiences both vertical and horizontal <u>forces/accelerations</u> ✓

The ball is given a constant acceleration

OR

The motion is in a straight line

OR

The motion is at 30° to the vertical (away from the wall) ✓

In this 2nd mark a wrong answer will gain zero marks even if accompanied by a correct answer

'Horizontal' needs to be accompanied by some implication that it is away from the wall. This may be by some reference to repulsion from the wall.

Moves diagonally can imply straight.

"Moving away and downwards" does not imply straight.

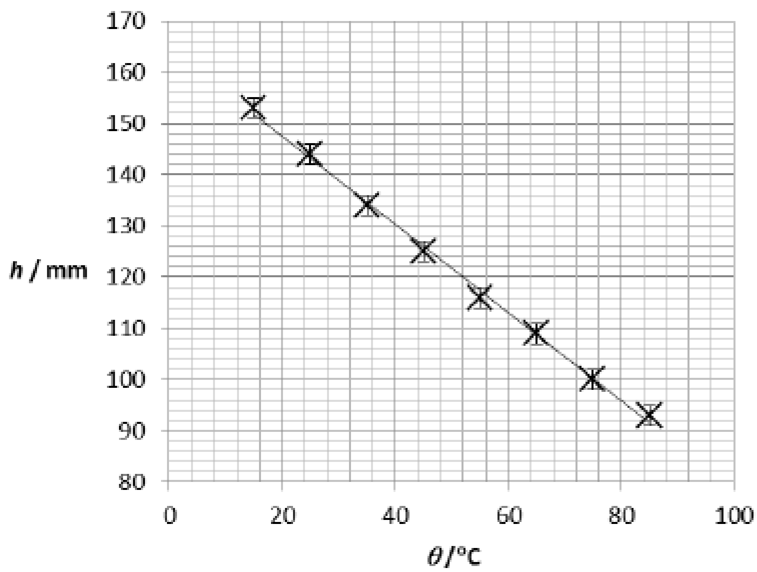
Do not credit "horizontal straight line" or "vertical straight line."

'Gravity ' on its own is not a force whereas weight is.

2

[9]

8. (a) Straight line of best fit passing through all error bars ✓



Look for reasonable distribution of points on either side

1

(b) h_0 = 165 ± 2 mm✓

1

(c) Clear attempt to determine gradient ✓

1

Correct readoffs (within ½ square) for points **on line** more than 6 cm apart and correct substitution into gradient equation ✓

1

h_0k gradient =(-) 0.862 mm K^{-1} and negative sign quoted ✓

Condone negative sign
Accept range -0.95 to -0.85

1

(d) $k = \frac{\text{candidate value for } h_0 k}{\text{candidate value for } h_0}$

$= 5.2 \times 10^{-3}$ ✓

Allow ecf from candidate values

1

K^{-1} ✓

Accept range 0.0055 to 0.0049

1

(e) for $h = 8000$ mm, $d^{-1} = \frac{8000}{14.5}$ ✓

1

$d = 1.8 \times 10^{-3}$ mm ✓

1

(f) Little confidence in this answer because

One of

It is too far to take extrapolation ✓

OR

This is a very small diameter ✓

1

[10]

9. (a) 6.5×10^{10} Pa ✓

1

(b) kg m^{-1} s^{-2} ✓

1

(c) Direction of movement of particles in transverse wave perpendicular to energy propagation direction✓

1

Parallel for longitudinal✓

1

(d) $\rho_1 c_1 = \rho_2 c_2$✓

$E = \rho c^2$ or $\rho c = \frac{E}{c}$ seen

1

$\left[\frac{E_1}{c_1} = \frac{E_2}{c_2}\right]$

1

(e) $[\frac{\rho_x}{\rho_y} = \frac{c_y}{c_x}$ and $c_x = 2c_y$]

0.5✓

1

(f) speed of the wave in seawater is less than speed of the wave in glass✓ **1**

argument to show that ${}_{water}n_{glass}$ <1✓ **1**

so tir could be observed when wave moves from water to glass ✓ **1**

[10]