Revision Topic 1 *[141 marks]*

1. A student measures the radius *r* of a sphere with an absolute uncertainty Δ *r*. What is the fractional uncertainty in the volume of the sphere? *[1 mark]*

   A. $\left(\frac{\Delta r}{r}\right)^3$

   B. $3\frac{\Delta r}{r}$

   C. $4\pi\frac{\Delta r}{r}$

   D. $4\pi\left(\frac{\Delta r}{r}\right)^3$

Markscheme

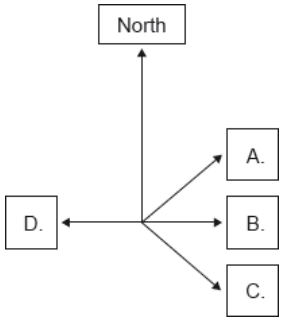
B

Examiners report

[N/A]

2. A river flows north. A boat crosses the river so that it only moves in the direction east of its starting point. *[1 mark]*

   What is the direction in which the boat must be steered?



Markscheme

C

Examiners report

[N/A]

3. What is the best estimate for the diameter of a helium nucleus? *[1 mark]*

   A. 10^{-21} m

   B. 10^{-18} m

   C. 10^{-15} m

   D. 10^{-10} m

Markscheme

C

Examiners report

[N/A]

4. Which is a unit of force? *[1 mark]*

A. J m

B. J m^{-1}

C. J m s^{-1}

D. J m^{-1} s

Markscheme

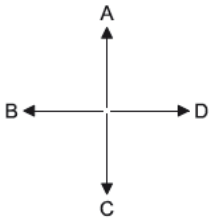
B

Examiners report

[N/A]

5. The velocities $\boldsymbol{v}_X$ and $\boldsymbol{v}_Y$ of two boats, X and Y, are shown. *[1 mark]*

Which arrow represents the direction of the vector $\boldsymbol{v}_X - \boldsymbol{v}_Y$?



Markscheme

D

Examiners report

[N/A]

6. How many significant figures are there in the number 0.0450? *[1 mark]*

A. 2

B. 3

C. 4

D. 5

Markscheme

B

Examiners report

[N/A]

7. An object is positioned in a gravitational field. The measurement of gravitational force acting on the object has an uncertainty of 3 % and the uncertainty in the mass of the object is 9 %. What is the uncertainty in the gravitational field strength of the field? *[1 mark]*

A. 3 %

B. 6 %

C. 12 %

D. 27 %

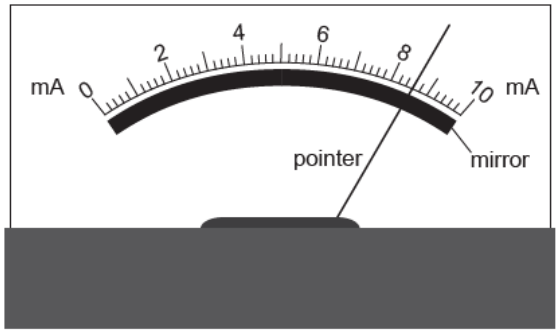
Markscheme

C

Examiners report

[N/A]

8. The diagram shows an analogue meter with a mirror behind the pointer. *[1 mark]*



What is the main purpose of the mirror?

A. To provide extra light when reading the scale

B. To reduce the risk of parallax error when reading the scale

C. To enable the pointer to be seen from different angles

D. To magnify the image of the pointer

Markscheme

B

Examiners report

[N/A]

9. What is a correct value for the charge on an electron? *[1 mark]*

A. 1.60×10^{-12} μC

B. 1.60×10^{-15} mC

C. 1.60×10^{-22} kC

D. 1.60×10^{-24} MC

Markscheme

C

Examiners report

[N/A]

10. What is the unit of electrical energy in fundamental SI units? *[1 mark]*

A. kg m^2 C^{-1} s

B. kg m s^{-2}

C. kg m^2 s^{-2}

D. kg m^2 s^{-1} A

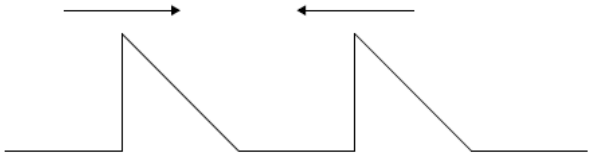
Markscheme

C

Examiners report

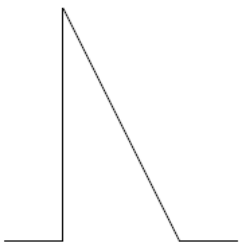
[N/A]

11. Two pulses are travelling towards each other. *[1 mark]*

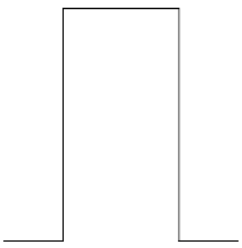


What is a possible pulse shape when the pulses overlap?

A.

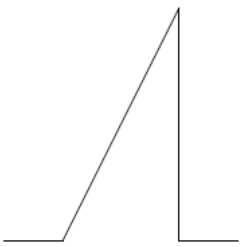


B.



C.

D.



Markscheme

A

Examiners report

[N/A]

12. Which of the following is a scalar quantity? *[1 mark]*

A. Velocity
B. Momentum
C. Kinetic energy
D. Acceleration

Markscheme

C

Examiners report

[N/A]

13. A stone falls from rest to the bottom of a water well of depth *d*. The time t taken to fall is 2.0 ±0.2 s. The depth of the well is calculated to be 20 m using $d = \frac{1}{2}at^2$. The uncertainty in a is negligible. *[1 mark]*

What is the absolute uncertainty in *d*?

A. ± 0.2 m

B. ± 1 m

C. ± 2 m

D. ± 4 m

Markscheme

D

Examiners report

[N/A]

14. Which is a vector quantity? *[1 mark]*

A. Pressure

B. Electric current

C. Temperature

D. Magnetic field

Markscheme

D

Examiners report

[N/A]

15. A boy jumps from a wall 3m high. What is an estimate of the change in momentum of the boy when he lands without rebounding? *[1 mark]*

A. 5×10^{0} kg m s^{-1}

B. 5×10^{1} kg m s^{-1}

C. 5×10^{2} kg m s^{-1}

D. 5×10^{3} kg m s^{-1}

Markscheme

C

Examiners report

[N/A]

16. Light of wavelength 400nm is incident on two slits separated by 1000µm. The interference pattern from the slits is observed from a satellite orbiting 0.4Mm above the Earth. The distance between interference maxima as detected at the satellite is *[1 mark]*

A. 0.16Mm.
B. 0.16km.
C. 0.16m.
D. 0.16mm.

Markscheme

B

Examiners report

[N/A]

17. A car moves north at a constant speed of 3m s^{-1} for 20s and then east at a constant speed of 4m s^{-1} for 20s. What is the average speed of the car during this motion? *[1 mark]*

A. 7.0m s^{-1}
B. 5.0m s^{-1}
C. 3.5m s^{-1}
D. 2.5m s^{-1}

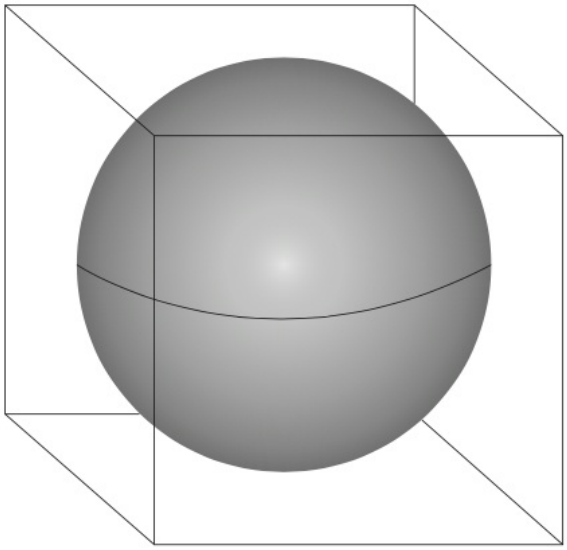
Markscheme

C

Examiners report

[N/A]

18. A sphere fits inside a cube. *[1 mark]*



The length of the cube and the diameter of the sphere are 10.0±0.2cm.

What is the ratio $\frac{\text{percentageuncertaintyofthevolumeofthesphere}}{\text{percentageuncertaintyofthevolumeofthecube}}$?

A. $\frac{3}{4\pi}$

B. 1

C. 2

D. 8

Markscheme

B

Examiners report

[N/A]

19. A swimming pool contains 18×10^6 kg of pure water. The molar mass of water is 18gmol^{-1}. What is the correct estimate of the number of water molecules in the swimming pool? *[1 mark]*

A. 10^4
B. 10^{24}
C. 10^{25}
D. 10^{33}

Markscheme

D

Examiners report

[N/A]

20. Which of the following is a derived unit? *[1 mark]*

A. Mole

B. Kelvin

C. Coulomb

D. Ampere

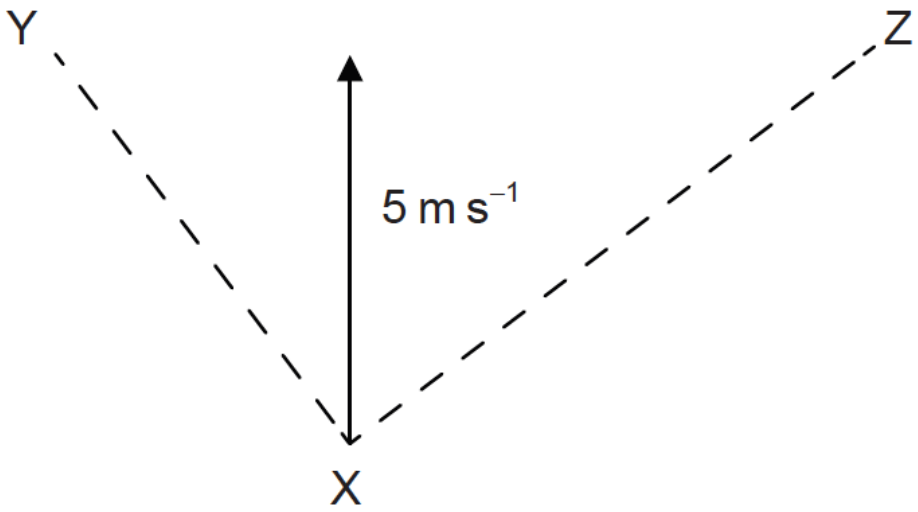
Markscheme

C

Examiners report

[N/A]

21. A velocity of 5 m s^{-1} can be resolved along perpendicular directions XY and XZ. *[1 mark]*



The component of the velocity in the direction XY is of magnitude 4 m s^{-1}. What is the magnitude of the component in the direction XZ?

A. 4 m s^{-1}

B. 3 m s^{-1}

C. 2 m s^{-1}

D. 1 m s^{-1}

Markscheme

B

Examiners report

[N/A]

22. What is the unit of energy density? *[1 mark]*

A. J kg^{-1}

B. J kg^{-1} m^3

C. J mol^{-1}

D. J K^{-1}

Markscheme

A

Examiners report

[N/A]

23. Which of the following expresses the watt in terms of fundamental units? *[1 mark]*

A. kg m^2 s

B. kg m^2 s^{-1}

C. kg m^2 s^{-2}

D. kg m^2 s^{-3}

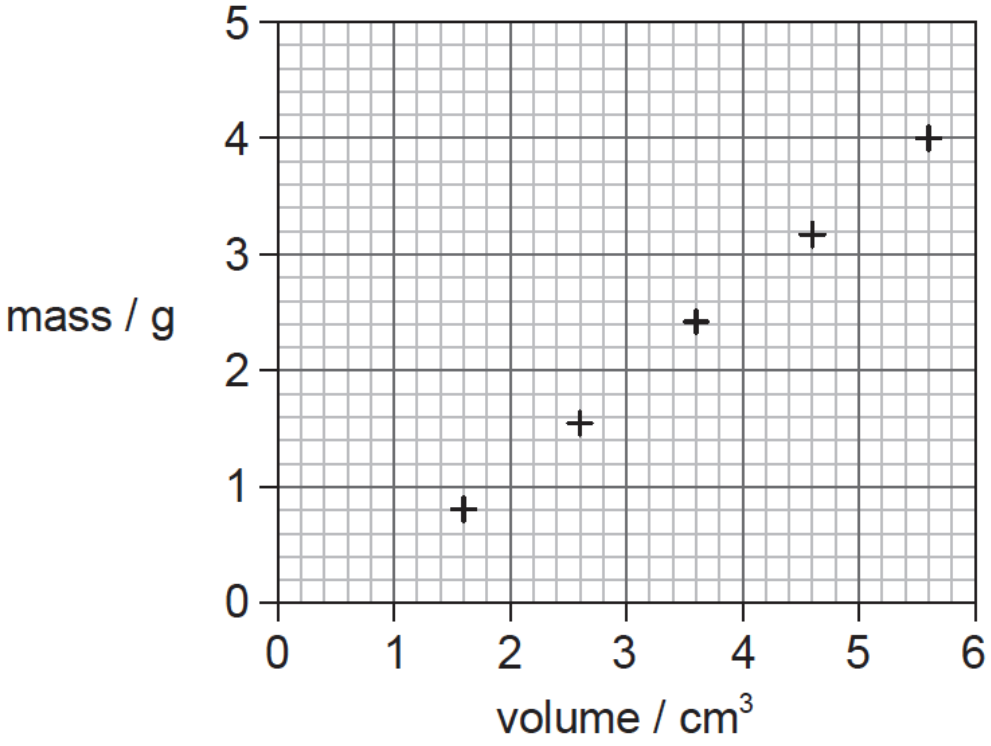
Markscheme

D

Examiners report

[N/A]

24. The graph shows a set of experimental results to determine the density of oil. The results have systematic errors and random errors. *[1 mark]*



Using the information on the graph, what can be said about the measurements used to find the density of oil?

	Systematic errors	Random errors
A.	small	small
B.	small	large
C.	large	small
D.	large	large

Markscheme

C

Examiners report

[N/A]

25. Which of the following expresses the units of capacitance in terms of fundamental units? *[1 mark]*

A. $s^4A^2m^{-2}kg^{-1}$

B. $s^2Am^{-2}kg^{-1}$

C. $s^4A^2m^{-2}$

D. s^2Am^{-2}

Markscheme

A

Examiners report

[N/A]

26. Which of the following is a fundamental unit? *[1 mark]*

A. Ampere

B. Coulomb

C. Ohm

D. Volt

Markscheme

A

Examiners report

[N/A]

27. The maximum acceleration a_{max} of an oscillator undergoing simple harmonic motion (SHM) has a percentage uncertainty of 12%. The amplitude x_0 of the oscillation has a percentage uncertainty of 20%. If $k = \sqrt{\frac{a_{max}}{x_0}}$ what is the percentage uncertainty in the constant k? *[1 mark]*

A. 4%

B. 8%

C. 16%

D. 32%

Markscheme

C

Examiners report

It was surprising to see the number of candidates who clearly did not realise that the square root involves halving the percentage uncertainty.

28. The radius of a sphere is measured with an uncertainty of 2%. What is the uncertainty in the volume of the sphere? *[1 mark]*

A. 2%

B. 4%

C. 6%

D. 8%

Markscheme

C

Examiners report

Consideration of units leads to C. It is not necessary to know the formula for the volume of a sphere.

29. The force of air resistance F that acts on a car moving at speed v is given by $F=kv^2$ where k is a constant. What is the unit of k? *[1 mark]*

A. kg m^{-1}
B. kg $m^{-2}s^2$
C. kg m^{-2}
D. kg $m^{-2}s^{-2}$

Markscheme

A

Examiners report

30. Which of the following is a unit of energy? *[1 mark]*

A. kg m^{-1} s^{-1}
B. kg m^2 s^{-2}
C. kg m s^{-2}
D. kg m^2 s^{-1}

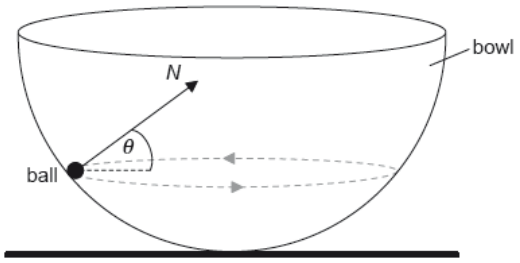
Markscheme

B

Examiners report

[N/A]

A small ball of mass m is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.



The normal reaction force N makes an angle θ to the horizontal.

31a. State the direction of the resultant force on the ball. *[1 mark]*

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Markscheme

towards the centre «of the circle» / horizontally to the right

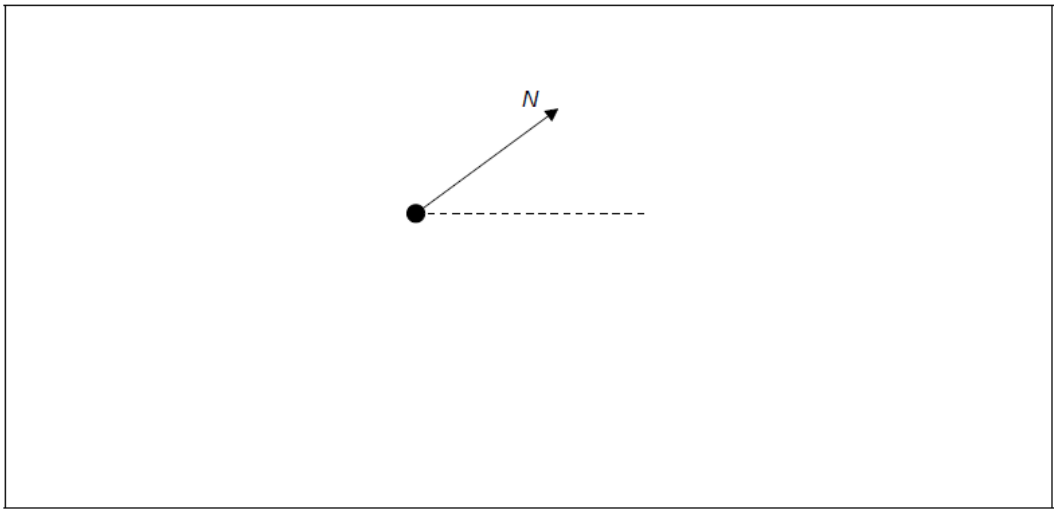
Do not accept towards the centre of the bowl

[1 mark]

Examiners report

[N/A]

31b. On the diagram, construct an arrow of the correct length to represent the weight of the ball. *[2 marks]*



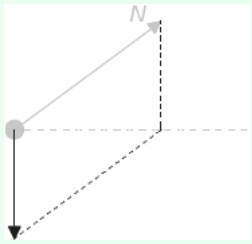
Markscheme

downward vertical arrow of any length

arrow of correct length

Judge the length of the vertical arrow by eye. The construction lines are not required. A label is not required

eg:



[2 marks]

Examiners report

[N/A]

31c. Show that the magnitude of the net force *F* on the ball is given by the following equation. *[3 marks]*

$$F = \frac{mg}{\tan\theta}$$

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Markscheme

ALTERNATIVE 1

$F = N \cos \theta$

$mg = N \sin \theta$

dividing/substituting to get result

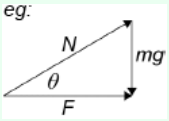
ALTERNATIVE 2

right angle triangle drawn with F, N and W/mg labelled

angle correctly labelled and arrows on forces in correct directions

correct use of trigonometry leading to the required relationship

eg:



$\tan \theta = \frac{O}{A} = \frac{mg}{F}$

[3 marks]

Examiners report

[N/A]

31d. The radius of the bowl is 8.0 m and $\theta = 22°$. Determine the speed of the ball. *[4 marks]*

Markscheme

$\frac{mg}{\tan\theta} = m\frac{v^2}{r}$

$r = R\cos\theta$

$v = \sqrt{\frac{gR\cos^2\theta}{\sin\theta}} / \sqrt{\frac{gR\cos\theta}{\tan\theta}} / \sqrt{\frac{9.81\times 8.0\cos 22}{\tan 22}}$

v = 13.4/13 «ms^{-1}»

*Award **[4]** for a bald correct answer*

*Award **[3]** for an answer of 13.9/14 «ms^{-1}». MP2 omitted*

[4 marks]

Examiners report

[N/A]

31e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. *[2 marks]*

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Markscheme

there is no force to balance the weight/N is horizontal

so no / it is not possible

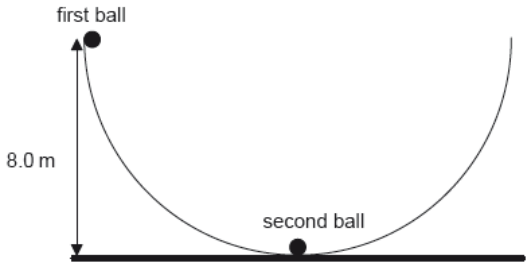
Must see correct justification to award MP2

[2 marks]

Examiners report

[N/A]

31f. A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m. *[3 marks]*



The first ball is released and eventually strikes the second ball. The two balls remain in contact. Determine, in m, the maximum height reached by the two balls.

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Markscheme

speed before collision v = «$\sqrt{2gR}$ =» 12.5 «ms^{-1}»

«from conservation of momentum» common speed after collision is $\frac{1}{2}$ initial speed «$v_C = \frac{12.5}{2}$ = 6.25 ms^{-1}»

h = «$\frac{v_c^2}{2g} = \frac{6.25^2}{2\times 9.81}$» 2.0 «m»

Allow 12.5 from incorrect use of kinematics equations

*Award **[3]** for a bald correct answer*

*Award **[0]** for mg(8) = 2mgh leading to h = 4 m if done in one step.*

Allow ECF from MP1

Allow ECF from MP2

[3 marks]

Examiners report

[N/A]

32a. State the direction of the resultant force on the ball. *[1 mark]*

. . . . . .

. . . . . .

. . . . . .

Markscheme

towards the centre «of the circle» / horizontally to the right

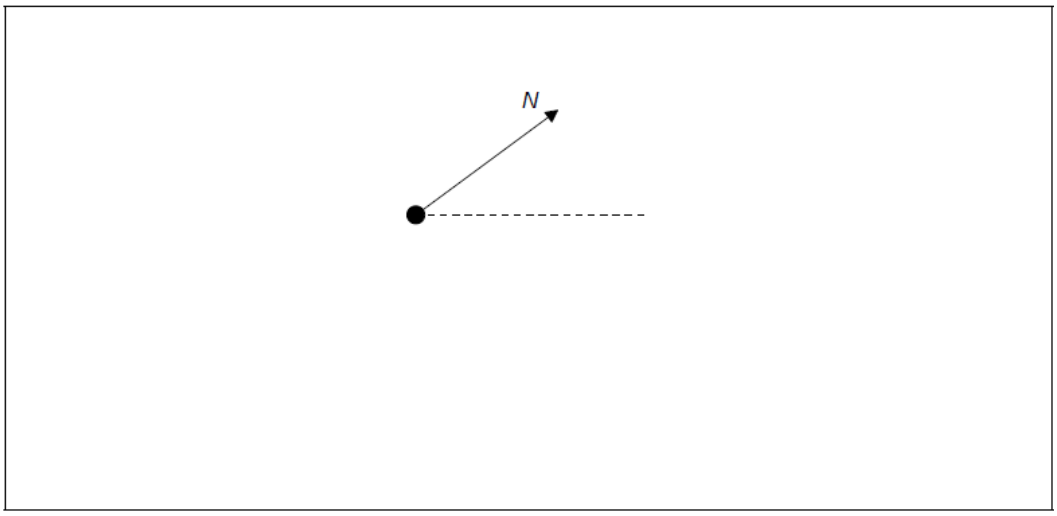
Do not accept towards the centre of the bowl

[1 mark]

Examiners report

[N/A]

32b. On the diagram, construct an arrow of the correct length to represent the weight of the ball. *[2 marks]*



Markscheme

downward vertical arrow of any length

arrow of correct length

Judge the length of the vertical arrow by eye. The construction lines are not required. A label is not required

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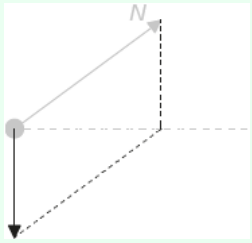

[2 marks]

Examiners report

[N/A]

32c. Show that the magnitude of the net force *F* on the ball is given by the following equation. *[3 marks]*

$$F = \frac{mg}{\tan\theta}$$

. . . . . .

. . . . . .

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Markscheme

ALTERNATIVE 1

$F = N\cos\theta$

$mg = N\sin\theta$

dividing/substituting to get result

ALTERNATIVE 2

right angle triangle drawn with *F*, *N* and *W/mg* labelled

angle correctly labelled and arrows on forces in correct directions

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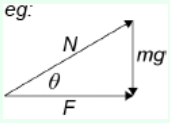

$\tan\theta = \frac{O}{A} = \frac{mg}{F}$

[3 marks]

Examiners report

[N/A]

32d. The radius of the bowl is 8.0 m and $\theta = 22°$. Determine the speed of the ball. *[4 marks]*

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Markscheme

$\frac{mg}{\tan\theta} = m\frac{v^2}{r}$

$r = R\cos\theta$

$v = \sqrt{\frac{gR\cos^2\theta}{\sin\theta}} / \sqrt{\frac{gR\cos\theta}{\tan\theta}} / \sqrt{\frac{9.81\times 8.0\cos 22}{\tan 22}}$

v = 13.4/13 «ms^{-1}»

*Award **[4]** for a bald correct answer*

*Award **[3]** for an answer of 13.9/14 «ms^{-1}». MP2 omitted*

[4 marks]

Examiners report

[N/A]

32e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. *[2 marks]*

. . . . . .

. . . . . .

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Markscheme

there is no force to balance the weight/N is horizontal

so no / it is not possible

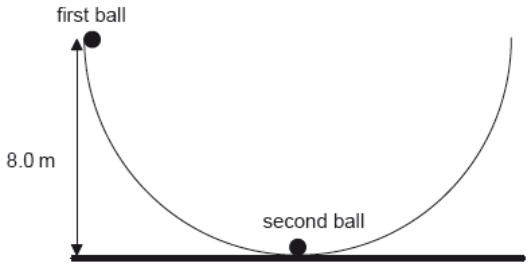
Must see correct justification to award MP2

[2 marks]

Examiners report

[N/A]

32f. A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m. *[3 marks]*



The first ball is released and eventually strikes the second ball. The two balls remain in contact. Determine, in m, the maximum height reached by the two balls.

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Markscheme

speed before collision v = «$\sqrt{2gR}$ =» 12.5 «ms^{-1}»

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Allow 12.5 from incorrect use of kinematics equations

*Award **[3]** for a bald correct answer*

*Award **[0]** for mg(8) = 2mgh leading to h = 4 m if done in one step.*

Allow ECF from MP1

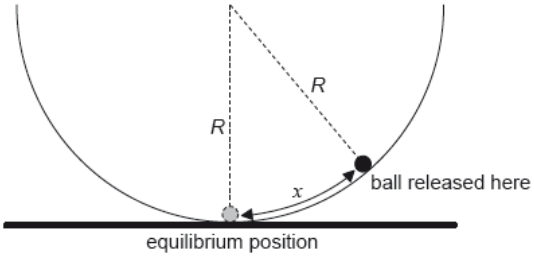
Allow ECF from MP2

[3 marks]

Examiners report

[N/A]

The ball is now displaced through a small distance x from the bottom of the bowl and is then released from rest.



The magnitude of the force on the ball towards the equilibrium position is given by

$$\frac{mgx}{R}$$

where R is the radius of the bowl.

32g. Outline why the ball will perform simple harmonic oscillations about the equilibrium position. *[1 mark]*

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Markscheme

the «restoring» force/acceleration is proportional to displacement

Direction is not required

[1 mark]

Examiners report

[N/A]

32h. Show that the period of oscillation of the ball is about 6 s. *[2 marks]*

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Markscheme

ω = «$\sqrt{\frac{g}{R}}$» = $\sqrt{\frac{9.81}{8.0}}$ «= 1.107 s^{-1}»

T = «$\frac{2\pi}{\omega}$ = $\frac{2\pi}{1.107}$ =» 5.7 «s»

Allow use of or *g = 9.8 or 10*

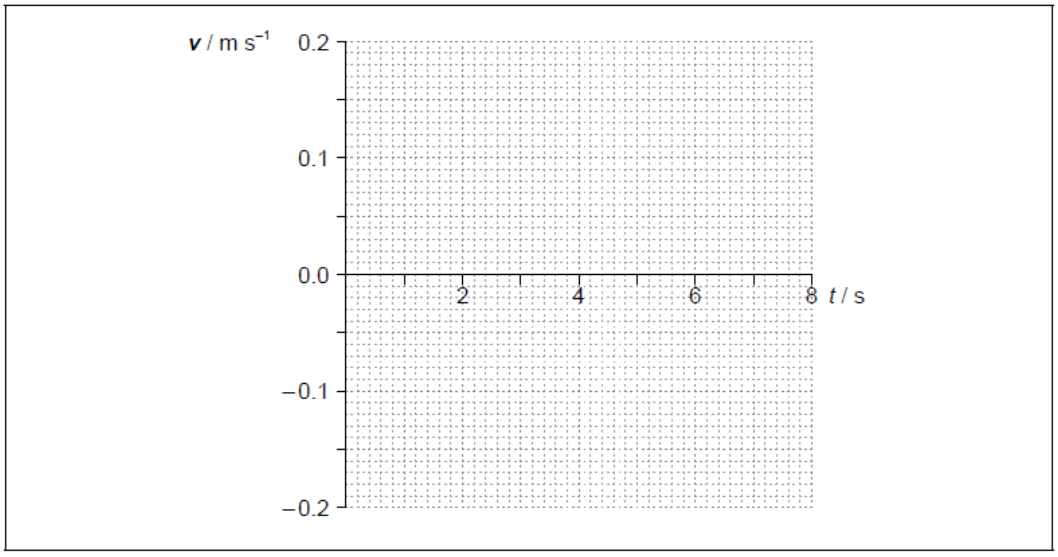
Award ***[0]*** *for a substitution into* $T = 2\pi\sqrt{\frac{I}{g}}$

[2 marks]

Examiners report

[N/A]

32i. The amplitude of oscillation is 0.12 m. On the axes, draw a graph to show the variation with time *t* of the velocity ***v*** of the ball during one period. *[3 marks]*



Markscheme

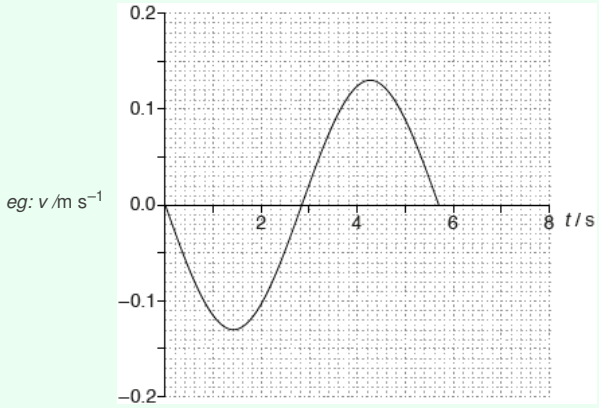
sine graph

correct amplitude «0.13 m s^{-1}»

correct period and only 1 period shown

Accept ± sine for shape of the graph. Accept 5.7 s or 6.0 s for the correct period.

Amplitude should be correct to $\pm\frac{1}{2}$ square for MP2

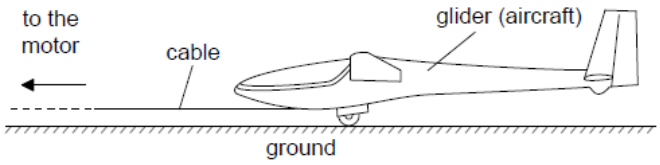


[3 marks]

Examiners report

[N/A]

A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.



33a. The glider reaches its launch speed of 27.0 m s^{-1} after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

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Markscheme

correct use of kinematic equation/equations

148.5 ***or*** 149 ***or*** 150 «m»

Substitution(s) must be correct.

Examiners report

[N/A]

33b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. *[3 marks]*

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Markscheme

$a = \frac{27}{11}$ ***or*** 2.45 «m s^{-2}»

$F - 160 = 492 \times 2.45$

1370 «N»

Could be seen in part (a).
*Award **[0]** for solution that uses a = 9.81 m s^{-2}*

Examiners report

[N/A]

33c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. *[3 marks]*

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Markscheme

ALTERNATIVE 1

«work done to launch glider» = 1370 x 149 «= 204 kJ»

«work done by motor» $= \frac{204 \times 100}{23}$

«power input to motor» $= \frac{204 \times 100}{23} \times \frac{1}{11} = 80$ ***or*** 80.4 ***or*** 81 k«W»

ALTERNATIVE 2

use of average speed 13.5 m s^{-1}

«useful power output» = force x average speed «= 1370 x 13.5»

power input = «$1370 \times 13.5 \times \frac{100}{23} =$» 80 ***or*** 80.4 ***or*** 81 k«W»

ALTERNATIVE 3

work required from motor = KE + work done against friction «$= 0.5 \times 492 \times 27^2 + (160 \times 148.5)$» = 204 «kJ»

«energy input» $= \frac{\text{work required from motor} \times 100}{23}$

power input $= \frac{883000}{11} = 80.3$ k«W»

*Award **[2 max]** for an answer of 160 k«W».*

Examiners report

[N/A]

33d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s^{-1}. Include an appropriate unit for your answer. *[2 marks]*

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Markscheme

$\omega = «\frac{v}{r} =» \frac{27}{0.6} = 45$

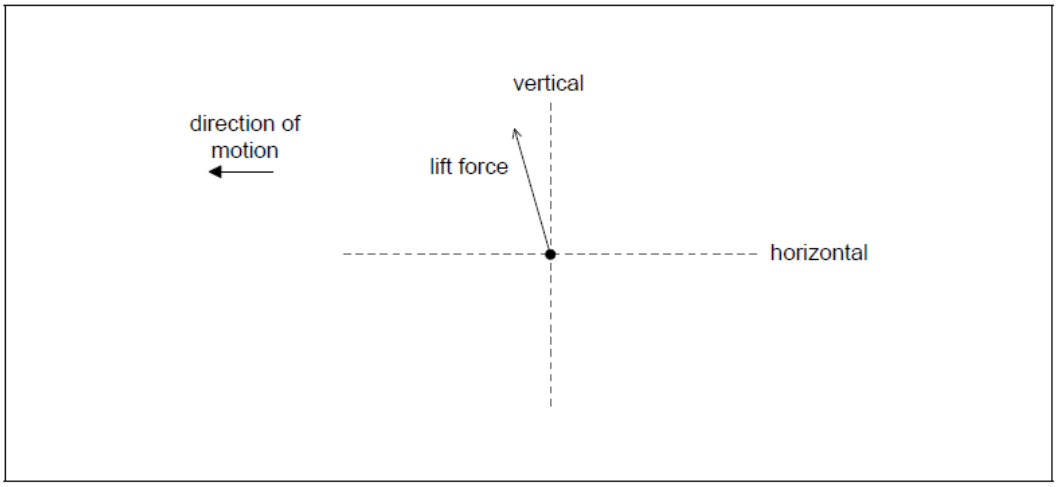
rad s^{-1}

Do not accept Hz.
*Award **[1 max]** if unit is missing.*

Examiners report

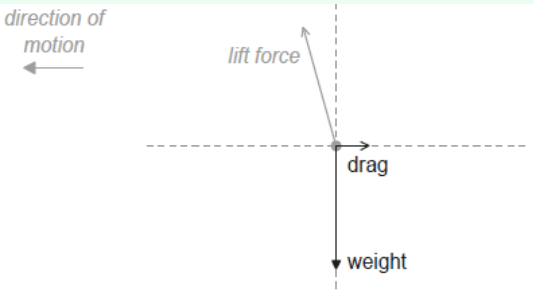
[N/A]

33e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider. *[2 marks]*



Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

Markscheme



drag correctly labelled and in correct direction

weight correctly labelled and in correct direction ***AND*** no other incorrect force shown

*Award **[1 max]** if forces do not touch the dot, but are otherwise OK.*

Examiners report

[N/A]

33f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

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Markscheme

name Newton's first law

vertical/all forces are in equilibrium/balanced/add to zero
OR
vertical component of lift mentioned

as equal to weight

Examiners report

[N/A]

33g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

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Markscheme

any speed and any direction quoted together as the answer

quotes their answer(s) to 3 significant figures

speed = 12.7 m s^{-1} ***or*** direction = 9.46° ***or*** 0.165 rad «below the horizontal» ***or*** gradient of $-\frac{1}{6}$

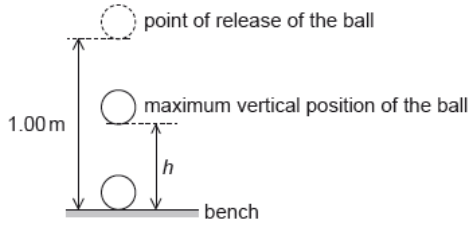
Examiners report

[N/A]

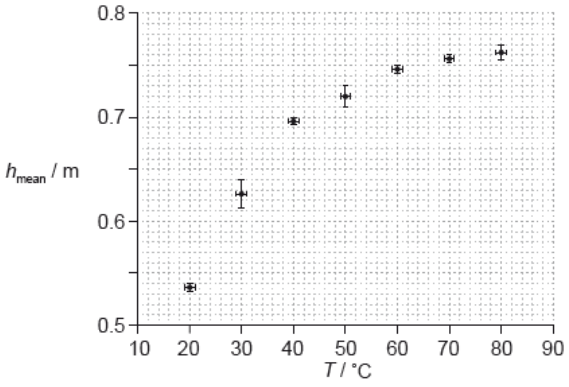
Data analysis question.

An experiment is undertaken to investigate the relationship between the temperature of a ball and the height of its first bounce.

A ball is placed in a beaker of water until the ball and the water are at the same temperature. The ball is released from a height of 1.00 m above a bench. The maximum vertical height h from the bottom of the ball above the bench is measured for the first bounce. This procedure is repeated twice and an average h_{mean} is calculated from the three measurements.



The procedure is repeated for a range of temperatures. The graph shows the variation of h_{mean} with temperature T.



34a. Draw the line of best-fit for the data. *[1 mark]*

Markscheme

smooth curve line through all error bars;

Do not allow kinked or thick lines or double/multiple lines.

Ignore any line beyond the range of plotted points.

Assume a broken line is due to scan and allow BOD.

Line must go through vertical part of error bar. Do not allow line to clip horizontal endcaps.

Examiners report

Many candidates were able to draw acceptably smooth curves but sometimes these failed to stay within the region of the error bar "box". Only a handful attempted to draw a straight line through the points. On the whole, the technical drawing of the lines was better than in previous years but there are still too many thick, doubled or kinked lines.

34b. State why the line of best-fit suggests that h_{mean} is not proportional to T. *[1 mark]*

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Markscheme

line (of best-fit) not straight/curved/changing gradient;

ratio of h to $T \times 10^{-4}$ is not constant;

Allow "does not pass through origin" ***only*** *if a straight line drawn in (a).*

Otherwise treat as neutral.

Examiners report

Many candidates stated that the line did not go through the origin. Although this answer was counted as neutral it showed that candidates were repeating by rote rather than applying their knowledge to the graph in question.

34c. State the uncertainty in each value of T. *[1 mark]*

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Markscheme

(±)1° C/K/deg; *(do not allow 2 or more sig figs in the answer)*

Examiners report

This was usually correct. The main error was to quote the answer to 2 or more significant figures.

34d. The temperature is measured using a liquid in glass thermometer. State what physical characteristic of the thermometer suggests that the change in the liquid's length is proportional to the change in temperature. *[1 mark]*

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Markscheme

equal graduations / constant cross-section/capillary diameter / (volume of) liquid expands linearly/proportionally to T / *OWTTE*;

Accept synonym for "capillary", eg: "tube".

Examiners report

This was poorly done. The question asks about a physical characteristic of the thermometer and proportionality. Answers often just repeated the question in other words.

34e. Another hypothesis is that $h_{\text{mean}} = KT^3$ where K is a constant. Using the graph on page 2, calculate the absolute uncertainty in K corresponding to $T = 50^{\circ}\text{C}$. *[4 marks]*

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Markscheme

$\frac{\Delta h}{h} = \frac{0.01}{0.72}$ ***or*** 0.014 ***or*** 1.4% and $\frac{\Delta T}{T} = \frac{1}{50}$ ***or*** 0.02 ***or*** 2%; *(allow ECF from (c)(i))*

$\frac{\Delta K}{K} = 3 \times \frac{1}{50} + \frac{0.01}{0.72}$ ***or*** $= 7.4 \times 10^{-2}$ ***or*** 7.4%;

$K = 5.8/5.76/6 \times 10^{-6}$;

$\Delta K = 4 \times 10^{-7}\,\text{m}\,\text{K}^{-3}$ ***or*** $\text{m}^{\circ}\text{C}^{-3}$; *(1 sig fig **and** correct unit required)*

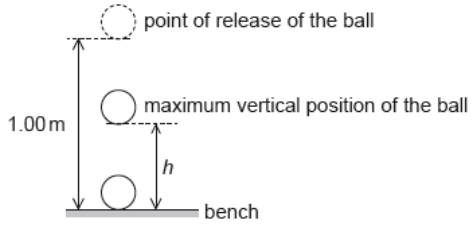
Examiners report

There were many correct and well explained evaluations of the uncertainty in K. However many candidates failed to link the magnitude of the percentage uncertainty with a sensible significant figure for the final answer. Only 1 significant figure was accepted by examiners following the large final percentage error in the answer. A unit for the answer was also required and this too was frequently omitted.

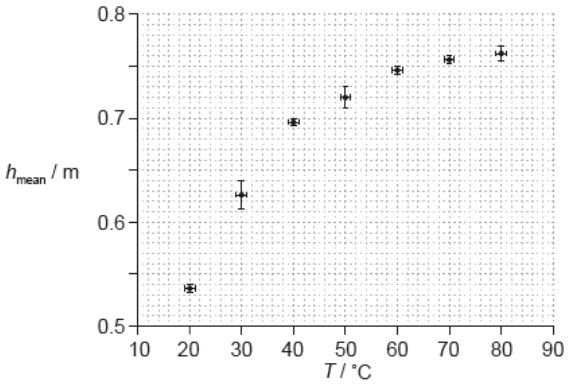
Data analysis question.

An experiment is undertaken to investigate the relationship between the temperature of a ball and the height of its first bounce.

A ball is placed in a beaker of water until the ball and the water are at the same temperature. The ball is released from a height of 1.00 m above a bench. The maximum vertical height h from the bottom of the ball above the bench is measured for the first bounce. This procedure is repeated twice and an average h_{mean} is calculated from the three measurements.



The procedure is repeated for a range of temperatures. The graph shows the variation of h_{mean} with temperature T.



A student hypothesizes that h_{mean} is proportional to T^2.

35a. Comment, using **two** points on your line of best-fit, whether or not this is a valid hypothesis. *[3 marks]*

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Markscheme

coordinates of two points on the line correctly read from the graph; } *(check points read to within half a square and ignore omission of powers of ten in reading)*

$\frac{T^2}{h}$ or $\frac{h}{T^2}$ calculated for both values;

consistent conclusion that values similar within the (typical) experimental error so sensible / differ outside (typical) experimental error so not sensible;} *(must see reference to experimental error not just bald statement)*

*Award **[2 max]** for a graph of h_{mean} versus T^2 and a conclusion that hypothesis is not valid.*

Do not award credit for "does not go through origin".

Examiners report

Many read two points correctly from the line, but too often examiners saw lines that missed a data point with the printed point still being used for the read-off. These derived data then generally led to a correct evaluation of $\frac{h}{T^2}$ (or it's reciprocal). However, for full marks, the examiners needed to see some consideration of the (sometimes considerable) error represented by the error bars and this was only rarely present.

35b. Suggest why using two points cannot confirm that h_{mean} is proportional to T^2. *[2 marks]*

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Markscheme

two points define a straight line / any arbitrary curve can pass through two points; to confirm hypothesis third point (or more) must lie on the straight line;

or

refers to experimental error in data (and therefore error in ratio) / depending on the two points chosen the hypothesis may be confirmed;

increasing the number of data points increases the strength of conclusion;

or

one of the two points chosen may be anomalous/erroneous/outlier;

third point needed to confirm hypothesis;

Examiners report

There were a number of alternative statements that could gain credit here. The most frequently seen suggestion was that, because two points can define a line of any curvature, therefore a third (or more) data point is required to establish the proportionality.

35c. The temperature is measured using a liquid in glass thermometer. Explain why it is likely that the uncertainty in T is constant. *[2 marks]*

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Markscheme

same thermometer used;

same eyes used;

same reading method used;

this type of thermometer has (typically) equal graduations;

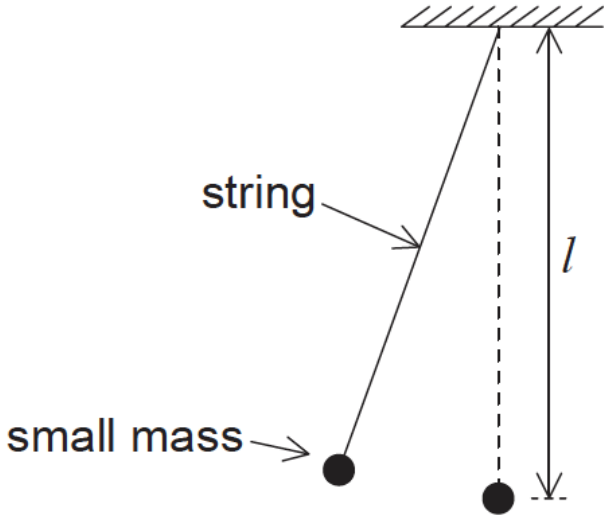
liquid in thermometer expands linearly;

Examiners report

[N/A]

Data analysis question.

A simple pendulum of length *l* consists of a small mass attached to the end of a light string.



The time *T* taken for the mass to swing through one cycle is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where *g* is the acceleration due to gravity.

36. A student measures *T* for one length *l* to determine the value of *g*. Time $T = 1.9s \pm 0.1s$ and length $l = 0.880m \pm 0.001m$. Calculate the fractional uncertainty in *g*. *[2 marks]*

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Markscheme

fractional uncertainty in $l = \frac{1}{880}$ ***or*** 0.00114

<u>and</u> fractional uncertainty in $T = \frac{1}{19}$ ***or*** 0.0526; } *(both needed) (accept percentage, or fraction here – allow candidate to quote* $\frac{2}{19}$ *directly if added correctly later)*

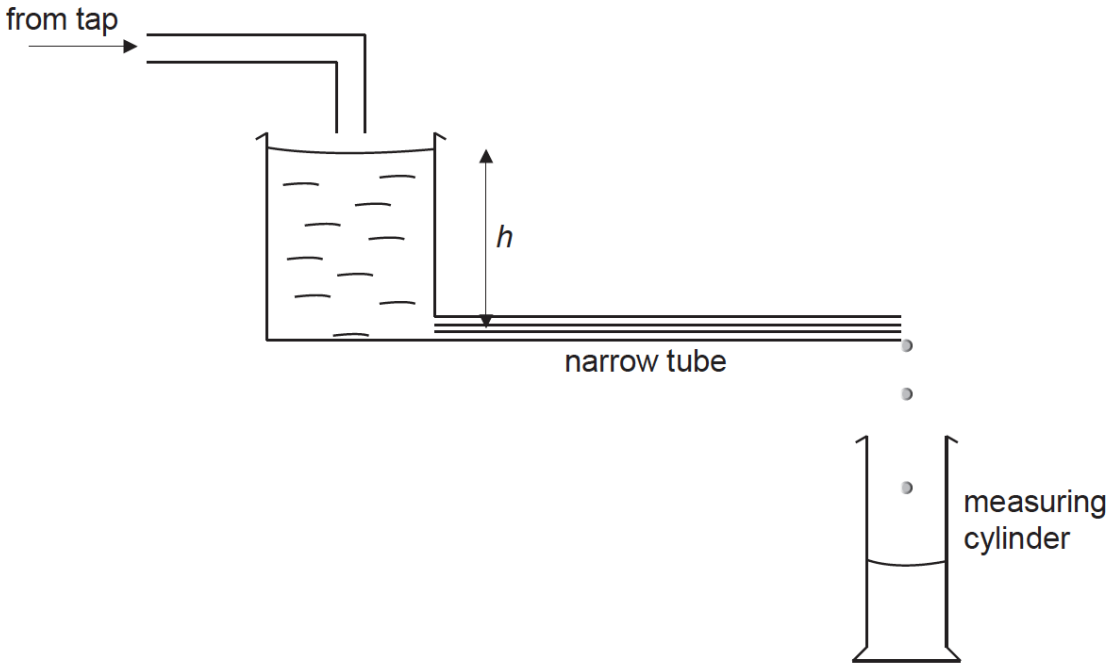
fractional uncertainty in $g = (2 \times 0.0526 + 0.00114 =) 0.106$; } *(accept percentage, do not accept fraction)*

Examiners report

[N/A]

This question is about the flow of liquids.

A student carries out an experiment to investigate how the rate of flow *R* of water through a narrow tube varies with the pressure difference across the tube. The pressure difference is proportional to the height *h* shown in the diagram. The student measures *h* in cm with a metre ruler. *R* is obtained by measuring the volume of water collected in a measuring cylinder in a time of 100s.



37a. The equation of the trend line shown in (b) is given by *[4 marks]*

$R = -0.0005h^2 + 0.0843h - 1.5632$.

(i) Calculate the value of *R* for $h = 0$.

(ii) State why this value of *R* is not physically possible.

(iii) State the number of significant figures that you have used for your value in (c)(i).

(iv) Comment, with reference to the experimental data, on the number of significant figures that you have used for your value in (c)(i).

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Markscheme

(i) R0 = –1.6(–1.5632)cm3 s–1 ;

(ii) it is negative / this would mean water running uphill / gaining potential energy / OWTTE;

(iii) an answer consistent with candidate's value;

(iv) should be 2 significant figures (in line with data values);

Examiners report

[N/A]

37b. The student estimates that the uncertainty in timing 100s is ±1s. Using the data on the graph, deduce the absolute uncertainty in the volume of water collected when R = 2.1 units. *[4 marks]*

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Markscheme

% uncertainty in t = 1%;
% uncertainty in V (= 5 + 1)=6% or % uncertainty in V (= 5 – 1) = 4%;
V (= 2.1 100) = 210 (units);

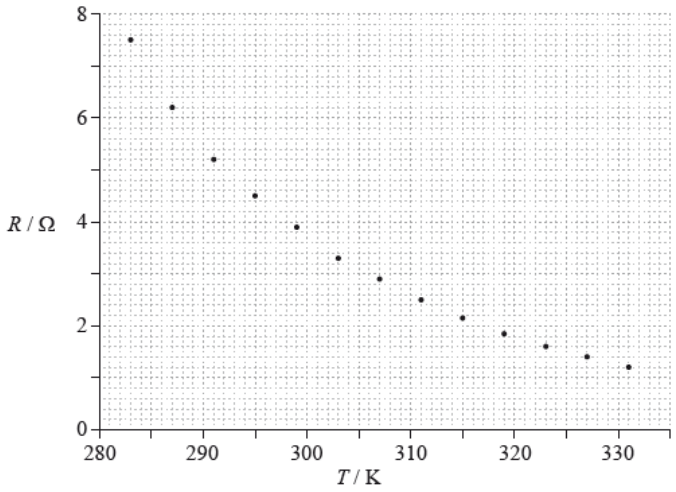
absolute uncertainty (= 210 × 6%) = 12.6 / 13 / 10 (units) or absolute uncertainty (= 210 × 4%) = 8.4 / 8 (units);

Examiners report

[N/A]

Data analysis question.

A student sets up a circuit to study the variation of resistance R of a negative temperature coefficient (NTC) thermistor with temperature T. The data are shown plotted on the graph.



38a. Draw the best-fit line for the data points. *[1 mark]*

Markscheme

smooth curve that passes within ± 0.5 squares of all data points;

Examiners report

[N/A]

38b. Calculate the gradient of the graph when $T = 291\ \text{K}$. *[3 marks]*

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Markscheme

a tangent drawn at $[291,\ 5.2]$ and selection of two extreme points on the tangent that use $\Delta R > 3.5\ \Omega;\}$ *(judge by eye)*

gradient magnitude determined as 0.20 ± 0.02;

negative value given;

Examiners report

Very poorly executed. Few SL candidates knew how to draw an acceptable tangent.

38c. State the unit for your answer to (b)(i). *[1 mark]*

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Markscheme

$\Omega\ \text{K}^{-1}$;

Examiners report

[N/A]

38d. The uncertainty in the resistance value is 5%. The uncertainty in the temperature is negligible. On the graph, draw error bars for the data point at $T = 283\ \text{K}$ and for the data point at $T = 319\ \text{K}$. *[2 marks]*

Markscheme

correct error bar for 283 K (total length of bar 3–5 squares, centred on point);

correct error bar for 319 K (total length of bar 0.5–2 squares, centred on point);

Examiners report

[N/A]

The electric current through the thermistor for $T = 283\ \text{K}$ is 0.78 mA. The uncertainty in the electric current is 0.01 mA.

38e. Calculate the power dissipated by the thermistor at $T = 283\ \text{K}$. *[1 mark]*

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Markscheme

substituting $I^2R = \left([0.78 \times 10^{-3}]^2 \times 7.5\right) = 4.5 \times 10^{-6}\ \text{W}$ ***or*** $4.6 \times 10^{-6}\ \text{W}$;

Examiners report

[N/A]

38f. Determine the uncertainty in the power dissipated by the thermistor at $T = 283\ \text{K}$. *[3 marks]*

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Markscheme

fractional uncertainty in $I^2 = 2 \times \frac{0.01}{0.78}$ (= 0.026 ***or*** 2.6%);

uncertainty in power $\left(= [0.026 + 0.05] \times 4.6 \times 10^{-6}\right) = 0.34 \times 10^{-6}\ \text{W}$ to $0.35 \times 10^{-6}\ \text{W}$;

answer rounded to 1 significant figure;

or

uncertainty in $I^2 = 2 \times 1.3\%/0.026$;

total uncertainty in $\text{P} = 7.6\%/0.076$;

answer rounded to 1 significant figure;

Examiners report

[N/A]

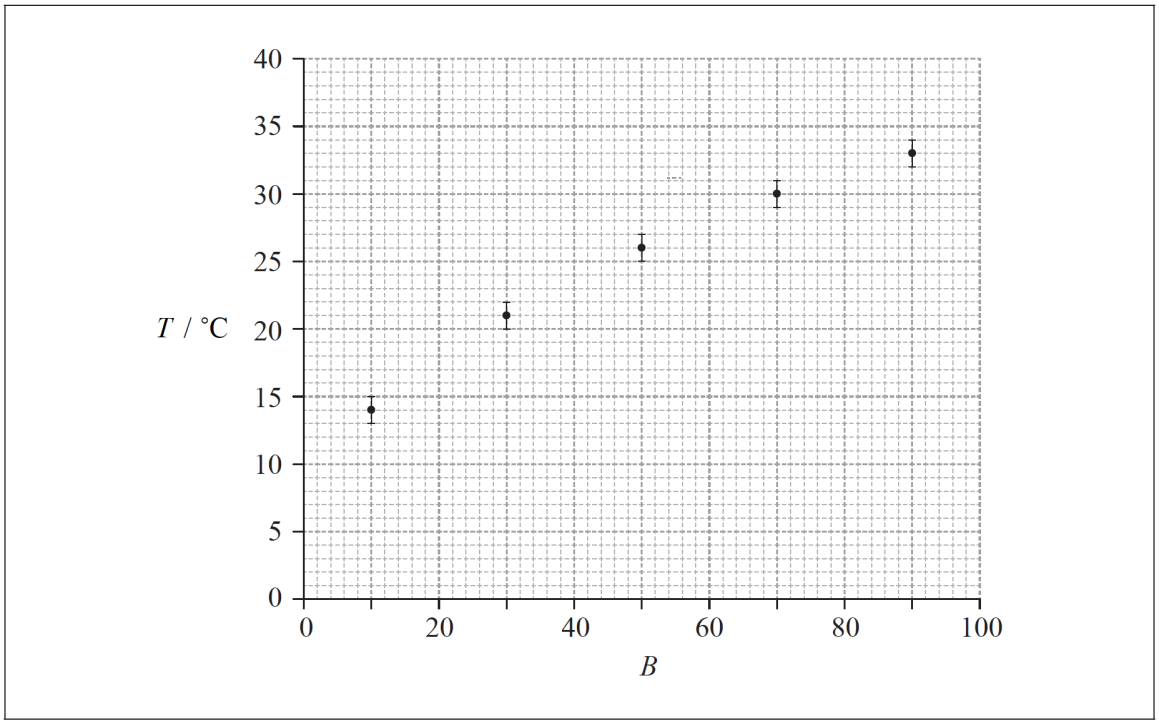
Data analysis question.

Connie and Sophie investigate the effect of colour on heat absorption. They make grey paint by mixing black and white paint in different ratios. Five identical tin cans are painted in five different shades of grey.

10 % black paint | 30 % black paint | 50 % black paint | 70 % black paint | 90 % black paint

Connie and Sophie put an equal amount of water at the same initial temperature into each can. They leave the cans under a heat lamp at equal distances from the lamp. They measure the temperature increase of the water, *T*, in each can after one hour.

39a. Connie suggests that *T* is proportional to *B*, where *B* is the percentage of black in the paint. To test this hypothesis, she plots a graph of *T* against *B*, as shown on the axes below. The uncertainty in *T* is shown and the uncertainty in *B* is negligible. *[6 marks]*



(i) State the value of the absolute uncertainty in *T*.

(ii) Comment on the fractional uncertainty for the measurement of *T* for *B*=10 and the measurement of *T* for *B*=90.

(iii) On the graph opposite, draw a best-fit line for the data.

(iv) Outline why the data do not support the hypothesis that *T* is proportional to *B*.

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Markscheme

(i) (±) 1 (°C);

(ii) absolute uncertainty is the same for the two points;
since T is higher at B = 90 (stated or shown), relative uncertainty is smaller;

or

fractional uncertainties are 0.07/
$\frac{1}{14}$ /7% for B=10 and 0.03/
$\frac{1}{33}$/3% for B=90;
fractional uncertainty is smaller for B=90;

(iii) smooth curve passing through all error bars;
Do not allow thick or hairy or doubled lines, or lines where the curvature changes abruptly.

(iv) the line is not straight/is a curve/does not have a constant gradient/is not linear;
it does not pass through the origin/(0, 0)/zero;

Examiners report

ai) Most candidates could accurately read the absolute uncertainty from an error bar. The only mistake made was by those who wrote ± 2.

aii) Most were able to calculate the fractional uncertainties, but too often the figures were not compared.

aiii) This was mainly answered well, with few straight lines.

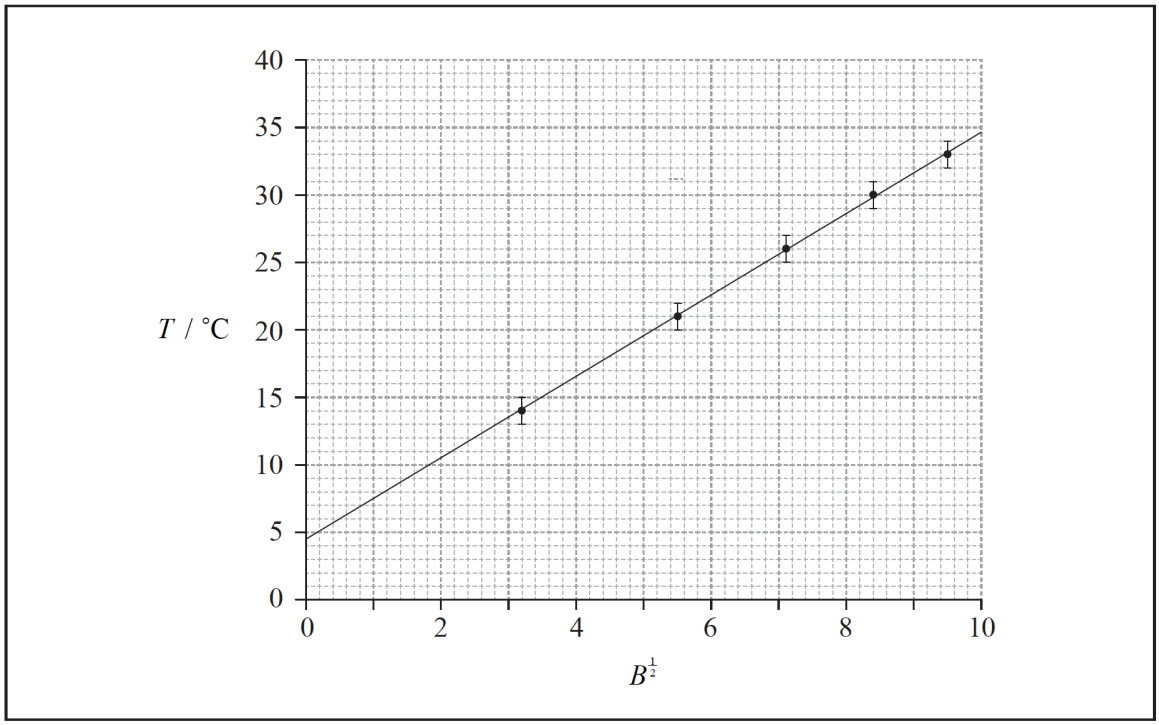
aiv) Most recognized the shape of the line required for proportionality.

39b. Sophie suggests that the relationship between T and B is of the form *[5 marks]*

$$T = kB^{\frac{1}{2}} + c$$

where k and c are constants.

To test whether or not the data support this relationship, a graph of T against $B^{\frac{1}{2}}$ is plotted as shown below. The uncertainty in T is shown and the uncertainty in $B^{\frac{1}{2}}$ is negligible.



(i) Use the graph to determine the value of c with its uncertainty.

(ii) State the unit of k.

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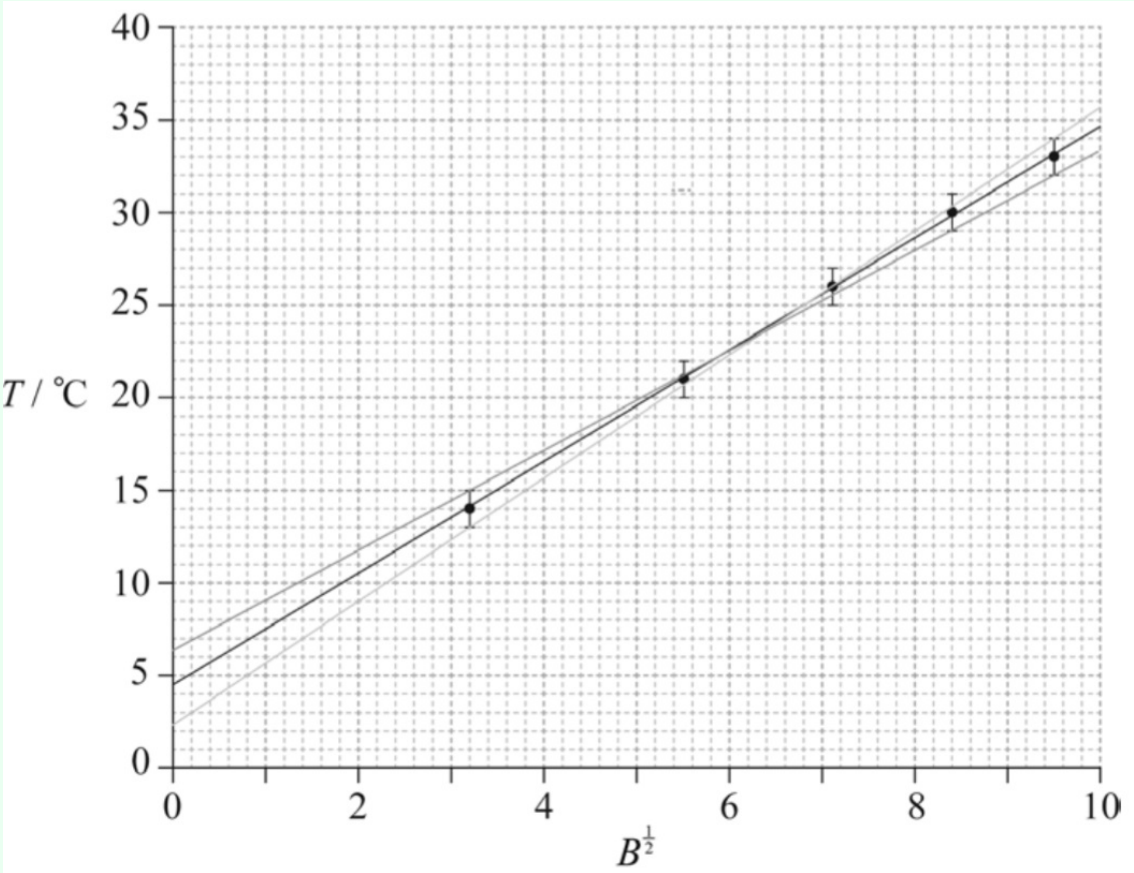
Markscheme

(i)



intercept read as 4.7; (ignore significant figures, allow range of 4.5 to 4.9)
two worst fit lines drawn through extremes of error bars;
uncertainty found from worst fit lines;
uncertainty rounded to 1 significant digit expressed in the form as ± (value)
and intercept rounded to same precision;
Award [4] for a statement of 5±2 and lines drawn.

(ii) °C ;

Examiners report

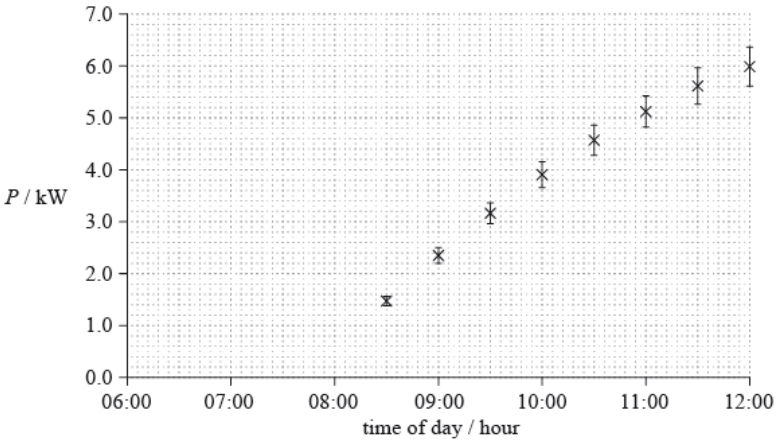
bi) Few candidates appreciated the importance of using the best and worst fit lines in finding an uncertainty from the line of best-fit. Many candidates could not state the uncertainty and value to an appropriate precision.

bii) Most candidates successfully identified the unit.

Data analysis question.

An array of photovoltaic cells is used to provide electrical energy for a house. When the array produces more power than is consumed in the house, the excess power is fed back into the mains electrical supply for use by other consumers.

The graph shows how the power *P* produced by the array varies with the time of day. The error bars show the uncertainty in the power supplied. The uncertainty in the time is too small to be shown.



40a. Using the graph, estimate the time of day at which the array begins to generate energy. *[2 marks]*

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Markscheme

smooth curve drawn through all error bars and curve extrapolated appropriately to *x*-axis;

their own intercept correctly read to within ±6 minutes (1 small square) / 7:50 hour to 8:00 hour if no line drawn;

Examiners report

Most candidates understood the requirements of the question. They were able to draw an acceptably smooth curve extrapolated to the time axis. There were fewer poor quality lines than in previous examinations. Nevertheless, a substantial minority ended the curve at a time of 08:30 and then quoted this time as that at which the solar panels began to generate energy. Some drew a straight line (that could not possibly touch all the error bars) and extrapolated this line to a time of about 07:30. Some credit was available for this.

40b. The average power consumed in the house between 08:00 and 12:00 is 2.0 kW. Determine the energy supplied by the array to the mains electrical supply between 08:00 and 12:00. *[3 marks]*

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Markscheme

calculates total energy used by house = 8 (kWh) ***or*** 28.8 (MJ);

estimate of total area = 14 ± 1 (kWh) ***or*** 50.4 ± 3.6 (MJ);

6 ± 1 (kWh) ***or*** 21.6 ± 3.6 (MJ); (*allow ECF from first two marking points)*

or

clear attempt to estimate any area of graph;

correct calculation of area above 2 kW line on graph;

6 ± 1 (kWh) ***or*** 21.6 ± 3.6 (MJ); (*allow ECF from first two marking points)*

Examiners report

This was poorly done from two points of view. It was clear that there was widespread misunderstanding of the relationship between energy and power units. Many candidates could get no further forward than calculating the energy used by the house in the four-hour time period. Most were unable to recognise that the energy supplied to the grid was related to the area under the graph.

40c. The power *P* produced by the array is calculated from the generated emf *V* and the fixed resistance *R* of the array using the equation $\frac{V^2}{R}$. The uncertainty in the value of *R* is 2%. Calculate the percentage uncertainty in *V* at 12:00. *[3 marks]*

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Markscheme

read-off error bar at 12:00 hour as 0.4;

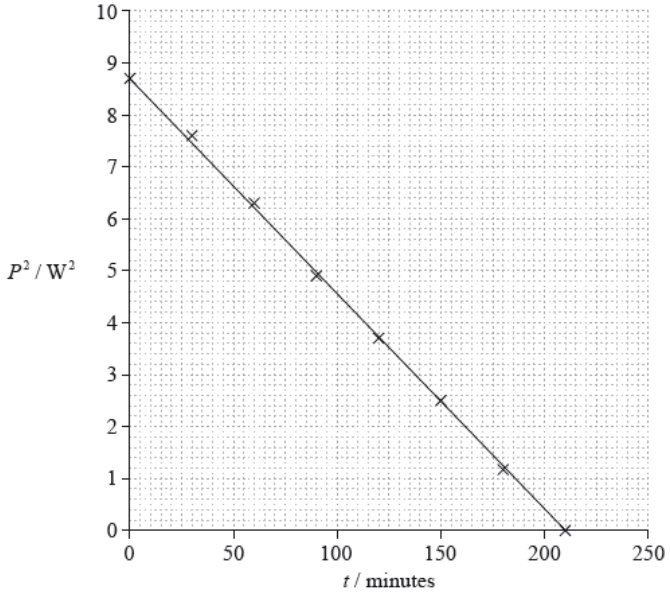
calculate uncertainty in $P = \left(\frac{100 \times 0.4}{6.0} =\right)\ 6.6\%$;

$\frac{\Delta V}{V} = \frac{\left[\frac{\Delta P}{P} - \frac{\Delta R}{R}\right]}{2} = 2.3\%$;

Examiners report

Candidates were usually able to read the error bar as having a total length of 0.8 units and could use this to calculate the uncertainty in *P*. Some were able to work through to the correct answer but many made a sign error in the calculation.

40d. Later that day a second set of data was collected starting at $t = 0$. The variation of P^2 with time t since the start of this second data collection is shown in the graph. *[3 marks]*



Using the graph, determine the relationship between P^2 and t.

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Markscheme

intercept 8.7 ± 0.1;

gradient equals $\left(\frac{8.7}{210} =\right)\ (-)0.041$; *(allow ECF from first marking point)*

$P^2 = 8.7 - 0.041t$; } *(negative sign essential) (allow ECF from first and second marking points)*

Do not accept "inverse" relationship or "linear".

*Award **[3]** for a bald correct answer.*

*Award **[2 max]** if gradient is left as a fraction.*

Examiners report

A number of past data-analysis questions have asked for a simple statement of the proportionality or otherwise of a provided graph. The use of the command verb "determine should have indicated to student that this question required more. The full relationship was required for full marks. For example, a determination of the gradient and the intercept (or solution from data points) to yield the equation relating P and t for the graph.