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Mark

EP29/AH/01 Physics

Date — Not applicable

Duration — 2 hours 30 minutes

EP29AH01

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 140

Attempt ALL questions.

Reference may be made to the Physics Relationships Sheet and the Data Sheet on *Page 02*.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9\cdot8\ \mathrm{m\,s^{-2}}$	Mass of electron	m_e	$9\cdot11 \times 10^{-31}\ \mathrm{kg}$
Radius of Earth	R_E	$6\cdot4 \times 10^{6}\ \mathrm{m}$	Charge on electron	e	$-1\cdot60 \times 10^{-19}\ \mathrm{C}$
Mass of Earth	M_E	$6\cdot0 \times 10^{24}\ \mathrm{kg}$	Mass of neutron	m_n	$1\cdot675 \times 10^{-27}\ \mathrm{kg}$
Mass of Moon	M_M	$7\cdot3 \times 10^{22}\ \mathrm{kg}$	Mass of proton	m_p	$1\cdot673 \times 10^{-27}\ \mathrm{kg}$
Radius of Moon	R_M	$1\cdot7 \times 10^{6}\ \mathrm{m}$	Mass of alpha particle	m_α	$6\cdot645 \times 10^{-27}\ \mathrm{kg}$
Mean Radius of Moon Orbit		$3\cdot84 \times 10^{8}\ \mathrm{m}$	Charge on alpha particle		$3\cdot20 \times 10^{-19}\ \mathrm{C}$
Solar radius		$6\cdot955 \times 10^{8}\ \mathrm{m}$	Planck's constant	h	$6\cdot63 \times 10^{-34}\ \mathrm{J\,s}$
Mass of Sun		$2\cdot0 \times 10^{30}\ \mathrm{kg}$			
1 AU		$1\cdot5 \times 10^{11}\ \mathrm{m}$	Permittivity of free space	ε_0	$8\cdot85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
Stefan-Boltzmann constant	σ	$5\cdot67 \times 10^{-8}\ \mathrm{W\ m^{-2}K^{-4}}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
Universal constant of gravitation	G	$6\cdot67 \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}$	Speed of light in vacuum	c	$3\cdot0 \times 10^{8}\ \mathrm{m\,s^{-1}}$
			Speed of sound in air	v	$3\cdot4 \times 10^{2}\ \mathrm{m\,s^{-1}}$

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49	Magnesium Fluoride	1·38

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ $\mathrm{kg\,m^{-3}}$	*Melting Point*/ K	*Boiling Point*/K	*Specific Heat Capacity*/ $\mathrm{J\,kg^{-1}\,K^{-1}}$	*Specific Latent Heat of Fusion*/ $\mathrm{J\,kg^{-1}}$	*Specific Latent Heat of Vaporisation*/ $\mathrm{J\,kg^{-1}}$
Aluminium	$2\cdot70 \times 10^{3}$	933	2623	$9\cdot02 \times 10^{2}$	$3\cdot95 \times 10^{5}$	....
Copper	$8\cdot96 \times 10^{3}$	1357	2853	$3\cdot86 \times 10^{2}$	$2\cdot05 \times 10^{5}$	....
Glass	$2\cdot60 \times 10^{3}$	1400	....	$6\cdot70 \times 10^{2}$	....	....
Ice	$9\cdot20 \times 10^{2}$	273	....	$2\cdot10 \times 10^{3}$	$3\cdot34 \times 10^{5}$	....
Glycerol	$1\cdot26 \times 10^{3}$	291	563	$2\cdot43 \times 10^{3}$	$1\cdot81 \times 10^{5}$	$8\cdot30 \times 10^{5}$
Methanol	$7\cdot91 \times 10^{2}$	175	338	$2\cdot52 \times 10^{3}$	$9\cdot9 \times 10^{4}$	$1\cdot12 \times 10^{6}$
Sea Water	$1\cdot02 \times 10^{3}$	264	377	$3\cdot93 \times 10^{3}$	....	....
Water	$1\cdot00 \times 10^{3}$	273	373	$4\cdot19 \times 10^{3}$	$3\cdot34 \times 10^{5}$	$2\cdot26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9\cdot0 \times 10^{-2}$	14	20	$1\cdot43 \times 10^{4}$	....	$4\cdot50 \times 10^{5}$
Nitrogen	1·25	63	77	$1\cdot04 \times 10^{3}$	....	$2\cdot00 \times 10^{5}$
Oxygen	1·43	55	90	$9\cdot18 \times 10^{2}$	....	$2\cdot40 \times 10^{4}$

The gas densities refer to a temperature of 273 K and a pressure of $1\cdot01 \times 10^{5}$ Pa.

MARKS DO NOT WRITE IN THIS MARGIN

Total marks — 140 marks

Attempt ALL questions

1. The acceleration of a particle moving in a straight line is described by the expression

$$a = 1{\cdot}2t.$$

At time, $t = 0\,\text{s}$, the displacement of the particle is $0\,\text{m}$ and the velocity is $1{\cdot}4\,\text{m}\,\text{s}^{-1}$.

(a) Show that the velocity of the particle at time t is given by the expression

$$v = 0{\cdot}6\,t^2 + 1{\cdot}4.$$ **3**

Space for working and answer

(b) Calculate the displacement of the particle when its velocity is $3{\cdot}8\,\text{m}\,\text{s}^{-1}$. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. A motorised model plane is attached to a light string anchored to a ceiling. The plane follows a circular path of radius 0·35 m as shown in Figure 2.

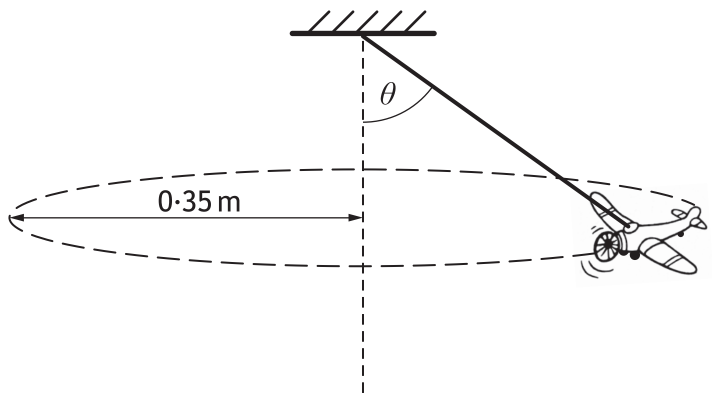

Figure 2

The plane has a mass of 0·20 kg and moves with a constant angular velocity of 6·0 rad s^{-1}.

(a) Calculate the central force acting on the plane. **3**

Space for working and answer

(b) Calculate the angle θ of the string to the vertical. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(c) State the effect a decrease in the plane's speed would have on angle θ.
Justify your answer. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

3. A student uses two methods to calculate the moment of inertia of a cylinder about its central axis.

(a) In the first method the student measures the mass of the cylinder to be 0·115 kg and the diameter to be 0·030 m.

Calculate the moment of inertia of the cylinder. **3**

Space for working and answer

(b) In a second method the student allows the cylinder to roll down a slope and measures the final speed at the bottom of the slope to be 1·6 m s^{-1}. The slope has a height of 0·25 m, as shown in Figure 3.

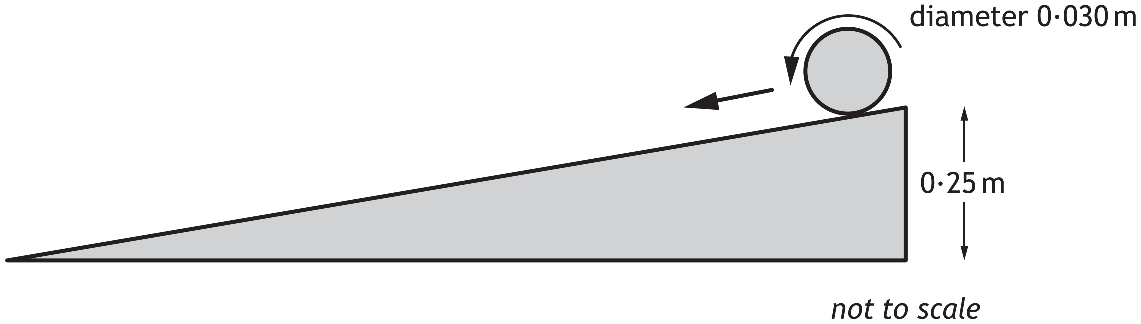

Figure 3

Using the conservation of energy, calculate the moment of inertia of the cylinder. **5**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

3. (continued)

(c) Explain why the moment of inertia found in part (b) is greater than in part (a). **1**

4. On a trip to a theme park, a student described what happened in the fairground spinner shown in Figure 4.

"You get thrown outwards by centrifugal force — you can feel it — it pushes you into the wall."

Figure 4

Use your knowledge of physics to discuss this statement. **3**

5. A team of astrophysicists from a Scottish University has discovered, orbiting a nearby star, an exoplanet with the same mass as Earth.

By considering the escape velocity of the exoplanet, the composition of its atmosphere can be predicted.

(a) Explain the term *escape velocity*. **1**

(b) Derive the expression for escape velocity in terms of the exoplanet's mass and radius. **3**

(c) The radius of the exoplanet is $1{\cdot}09 \times 10^{7}$ m.

Calculate the escape velocity of the exoplanet. **3**

Space for working and answer

6. (a) The world lines for three objects A, B and C are shown in Figure 6A

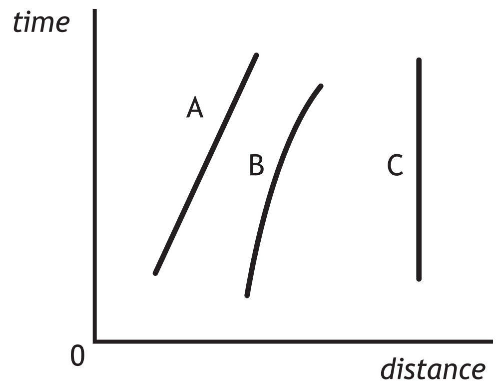

Figure 6A

To which of these objects does the General Theory of Relativity apply? Explain your choice. **2**

(b) A rocket ship is accelerating through space. Clocks P and Q are at opposite ends of the ship as shown in Figure 6B. An astronaut inside the rocket ship is beside clock P and can also observe clock Q.

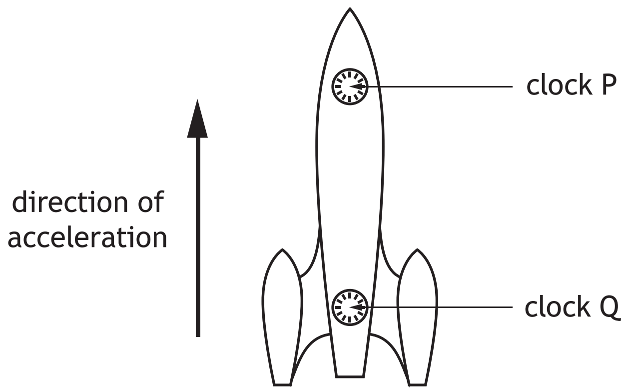

Figure 6B

What does the astronaut observe about the passage of time on these clocks?

Justify your answer. **2**

6. (continued)

(c) Part of an astronaut's training is to experience the effect of "weightlessness". This can be achieved inside an aircraft that follows a path as shown in Figure 6C.

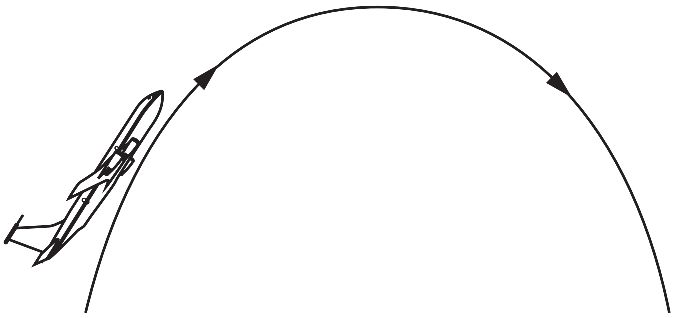

Figure 6C

Use the equivalence principle to explain how this "weightlessness" is achieved. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

7. Cygnus X-1 is an X-ray source in the constellation Cygnus that astrophysicists believe contains a black hole. An artist's impression is shown in Figure 7A.

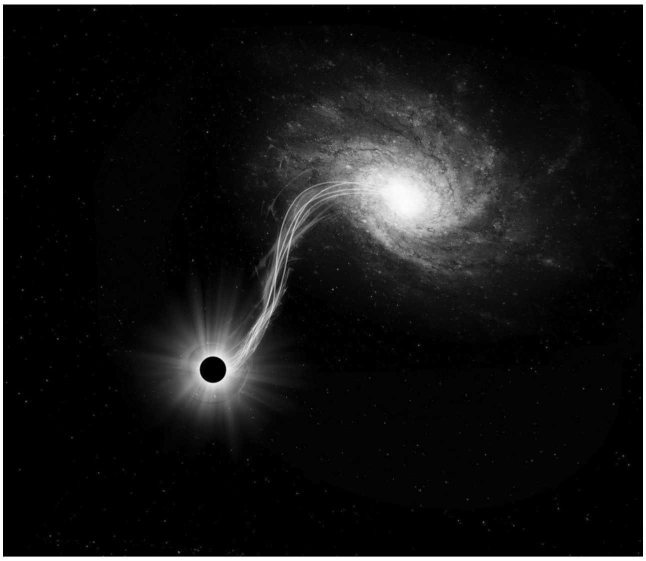

Figure 7A

The mass of the black hole has been determined to be 14·8 solar masses.

(a) (i) State what is meant by the Schwarzschild radius of a black hole. **1**

(ii) Calculate the Schwarzschild radius of the black hole in Cygnus X-1. **4**

Space for working and answer

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7. (continued)

(b) The Hertzsprung-Russell (H-R) diagram shown in Figure 7B shows the relationship between the luminosity and the surface temperature of stars.

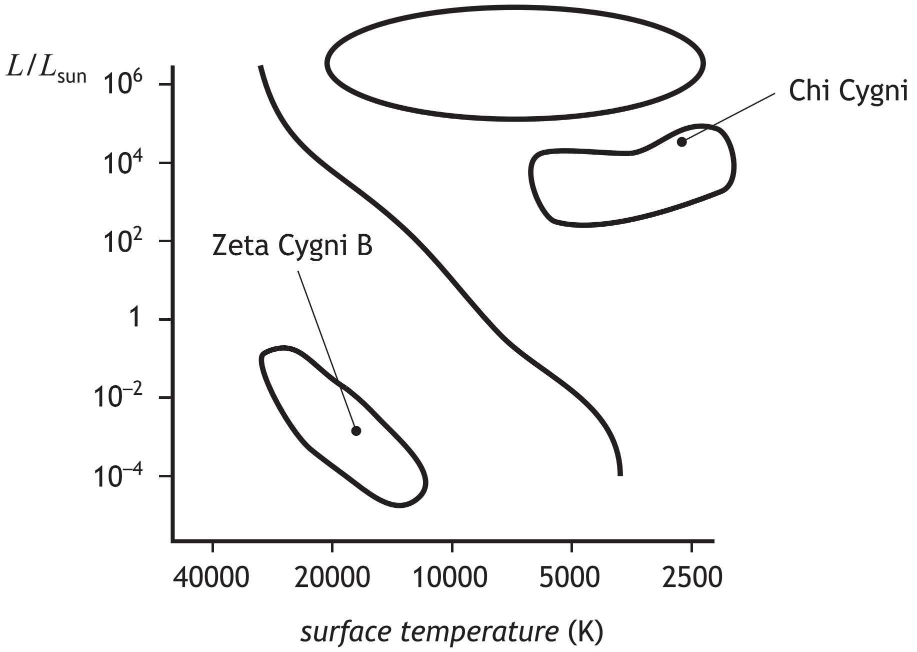

Figure 7B

Zeta Cygni B and Chi Cygni are two stars in the constellation Cygnus. They are shown on the H-R diagram. Chi Cygni is more luminous than Zeta Cygni B.

Describe **two** other differences between these stars. **2**

8. In 1928 Davisson and Germer fired a beam of electrons through a very thin layer of nickel in a vacuum, which resulted in the production of a diffraction pattern.

(a) (i) State what can be concluded from the results of their experiment. **1**

(ii) Give **one** example of experimental evidence that photons of light exhibit particle properties. **1**

(b) Calculate the de Broglie wavelength of an electron travelling at $4{\cdot}4 \times 10^{6}\,\mathrm{m\,s^{-1}}$. **3**

Space for working and answer

(c) A 20 g bullet travelling at $300\,\mathrm{m\,s^{-1}}$ passes through a 500 mm gap in a target.

Using the data given, explain why no diffraction pattern is observed. **3**

9. The Sun is constantly losing mass through nuclear fusion. Particles also escape from the corona as shown in Figure 9A. This stream of particles radiating from the Sun is known as the solar wind and its main constituent, by mass, is protons.

Figure 9A

A proton in the solar wind has energy of 3·6 MeV.

(a) Calculate the velocity of this proton. **4**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) The proton enters the magnetic field round the Earth at an angle of 50° as shown in Figure 9B. The magnetic field strength is 58 μT.

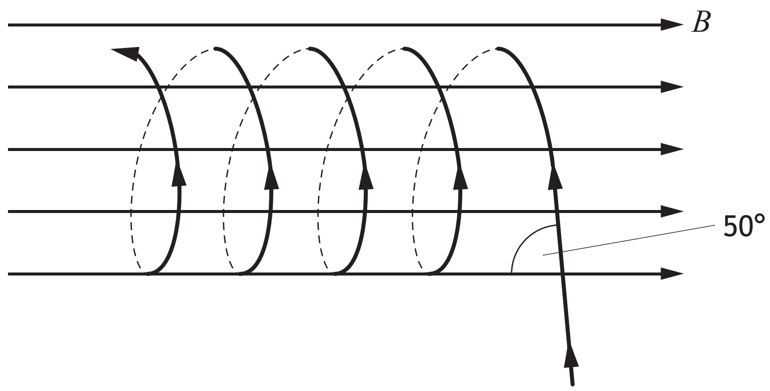

Figure 9B

(i) Explain the shape of the path followed by the proton in the magnetic field. **2**

9. (b) (continued)

(ii) Calculate the radius of curvature of this path. **4**

Space for working and answer

(iii) An antiproton of energy 3·6 MeV enters the same region of the Earth's magnetic field at an angle of 30° to the field.

Describe **two** differences in the paths taken by the antiproton and the original proton. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

10. A "saucer" swing consists of a bowl-shaped seat of mass 1·2 kg suspended by four ropes of negligible mass as shown in Figure 10A.

Figure 10A

When the empty seat is pulled back slightly from its rest position and released its motion approximates to simple harmonic motion.

(a) State what is meant by *simple harmonic motion*. **1**

10. (continued)

(b) The acceleration-time graph for the seat with no energy loss is shown in Figure 10B.

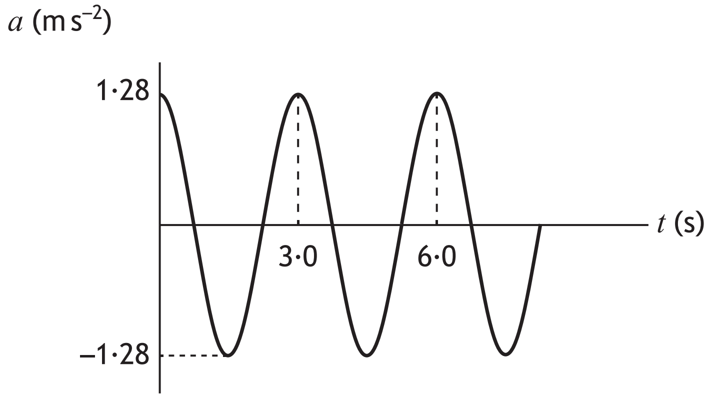

Figure 10B

(i) Show that the amplitude of the motion is 0·29 m. **5**

Space for working and answer

(ii) Calculate the velocity of the seat when its displacement is 0·10 m. **3**

Space for working and answer

11. A water wave of frequency 2·5 Hz travels from left to right. Figure 11 represents the displacement y of the water at one instant in time.

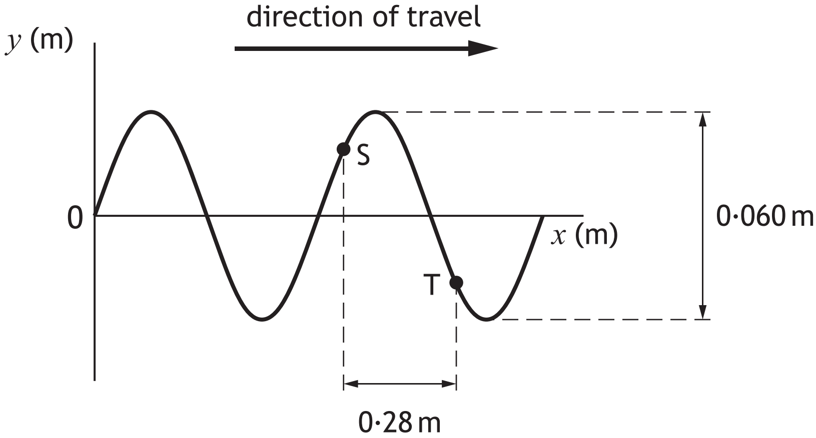

Figure 11

Points S and T are separated by a horizontal distance of 0·28 m.

The phase difference between these two points is 3·5 radians.

(a) Calculate the wavelength of this wave. **3**

Space for working and answer

(b) A second water wave with double the frequency travels in the same direction through the water. This wave transfers five times the energy of the wave in part (a).

(i) Calculate the speed of this wave. **1**

Space for working and answer

11. (b) (continued)

(ii) Calculate the amplitude of this wave. **3**

Space for working and answer

12. A series of coloured LEDs are used in the Young's slits experiment as shown in Figure 12. The distance from the slits to the screen is $(2{\cdot}50 \pm 0{\cdot}05)$ m. The slit separation is $(3{\cdot}0 \pm 0{\cdot}1) \times 10^{-4}$ m.

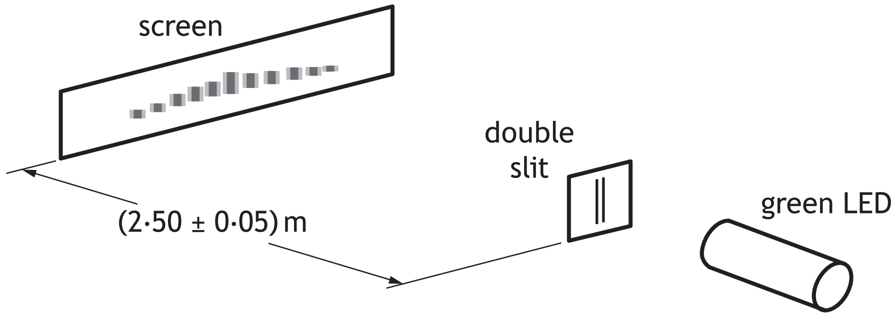

Figure 12

colour of LED	wavelength (nm)
red	650 ± 2
green	510 ± 2
blue	470 ± 2

(a) State whether the pattern on the screen is caused by the division of wavefront or the division of amplitude. **1**

(b) (i) Calculate the fringe separation observed on the screen when the green LED is used. **3**

Space for working and answer

12. (b) (continued)

(ii) Calculate the absolute uncertainty in the fringe separation. **5**

Space for working and answer

13. A student, wearing polarising sunglasses, is using a tablet outdoors. The orientation of the tablet seems to affect the image observed by the student.

Two orientations are shown in Figure 13A.

Figure 13A

(a) In landscape mode the image appears bright and in portrait mode it appears dark.

(i) State what may be concluded about the light emitted from the tablet screen. **1**

(ii) The student slowly rotates the tablet. Describe the change in the brightness observed by the student as it is rotated through 180°. **2**

13. (continued)

(b) Unpolarised sunlight is incident on a water surface as shown in Figure 13B.

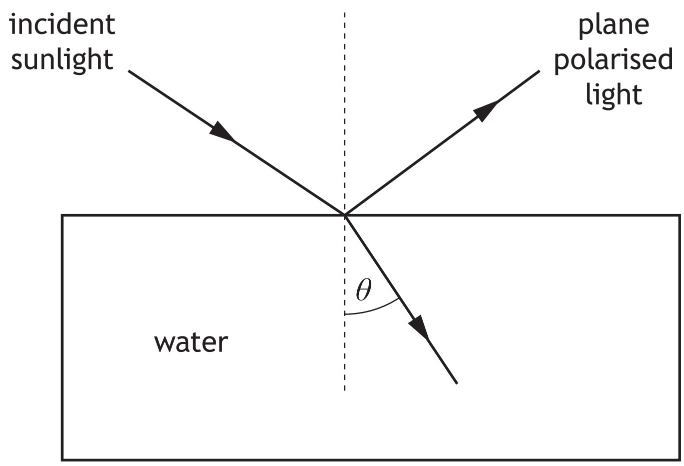

Figure 13B

The light is 100% plane polarised on reflection.

Calculate the angle of refraction θ. **4**

Space for working and answer

14. A group of students were evaluating an experiment to investigate the relationship between the mass on a spring and its period of oscillation. Figure 14 shows some of the apparatus used.

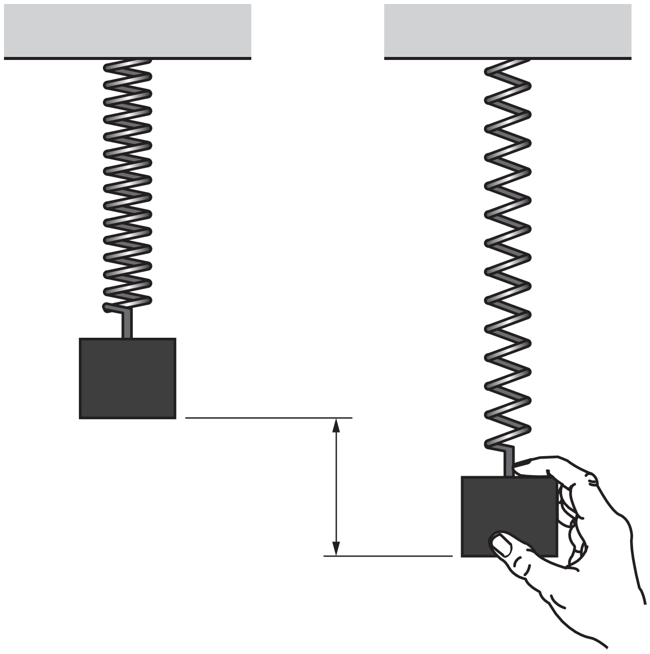

Figure 14

Student A stated "*I think we should use a balance that reads to 0·001 g instead of 0·1 g. This will give us a more accurate answer*".

Student B stated "*I think we should repeat the time measurement and calculate a mean value*".

Student C stated "*I think we should time the pendulum for 10 oscillations and divide this value by 10 to get the time for one complete oscillation. This will give us a more precise answer*".

Student D stated "*I think it would be good to check the mass on another balance*".

Using your knowledge of experimental analysis, comment on these statements. **3**

15. (a) An uncharged conducting sphere is suspended from a fixed point X by an insulating thread of negligible mass as shown in Figure 15A.

A charged plate is then placed close to the sphere as shown in Figure 15B.

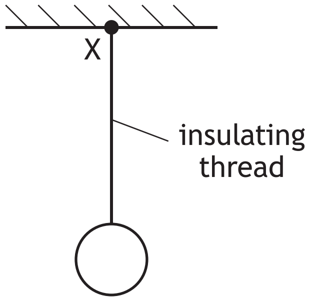

Figure 15A

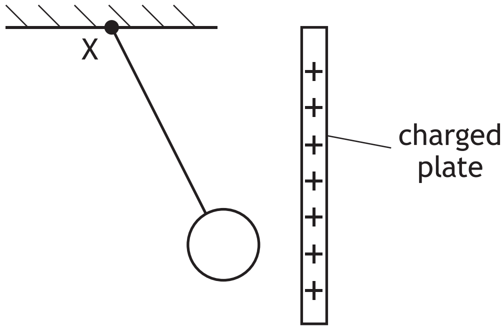

Figure 15B

Explain why the uncharged sphere is attracted to the charged plate. You may use a diagram to help explain your answer. **1**

15. (continued)

(b) The sphere is now given a negative charge of 140 nC and placed between a pair of parallel plates with a separation of 42 mm as shown in Figure 15C.

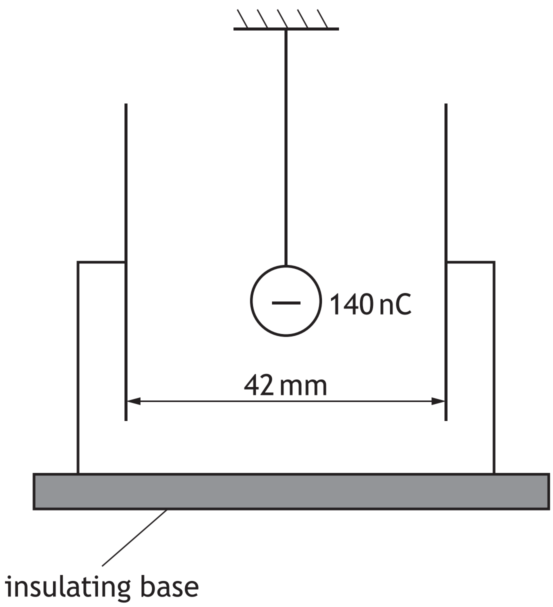

Figure 15C

When a potential difference is applied to the plates the sphere is deflected through an angle θ as shown in Figure 15D.

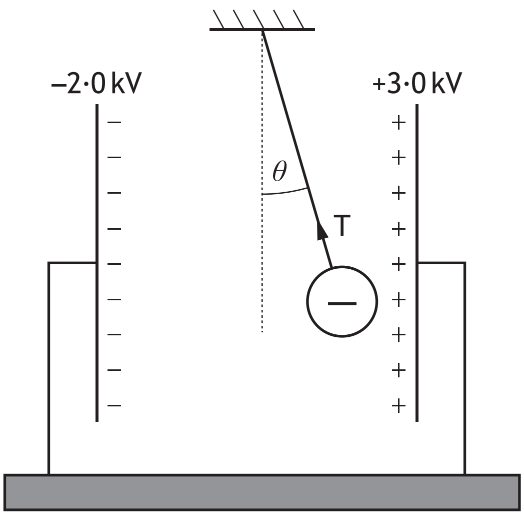

Figure 15D

15. (b) (continued)

(i) Calculate the electric field strength between the plates. **3**

Space for working and answer

(ii) Calculate the electrostatic force acting on the sphere due to the electric field. **3**

Space for working and answer

(iii) The mass of the sphere is $4{\cdot}0 \times 10^{-3}$ kg.

Calculate the magnitude and direction of the tension T in the supporting thread. **4**

Space for working and answer

(c) The plates are now moved a short distance to the right without touching the sphere. The distance between the plates is unchanged.

State whether the angle θ increases, decreases or stays the same.

You must justify your answer. **2**

16. A student is investigating the charging and discharging of a capacitor. The circuit used is shown in Figure 16A.

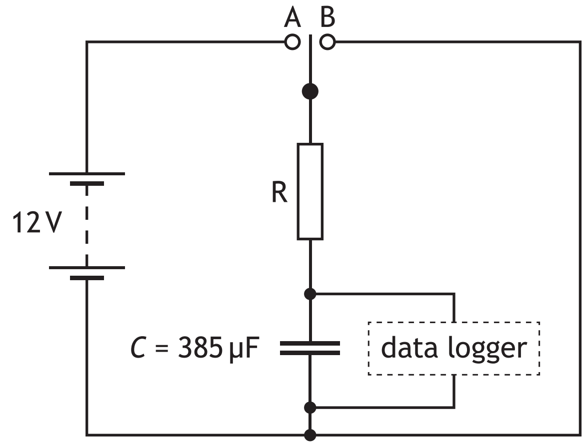

Figure 16A

With the switch in position A, the capacitor charges. To discharge the capacitor the switch is moved to position B. The data logger monitors the voltage across the capacitor.

The graph in Figure 16B shows how the voltage across the capacitor changes during discharge.

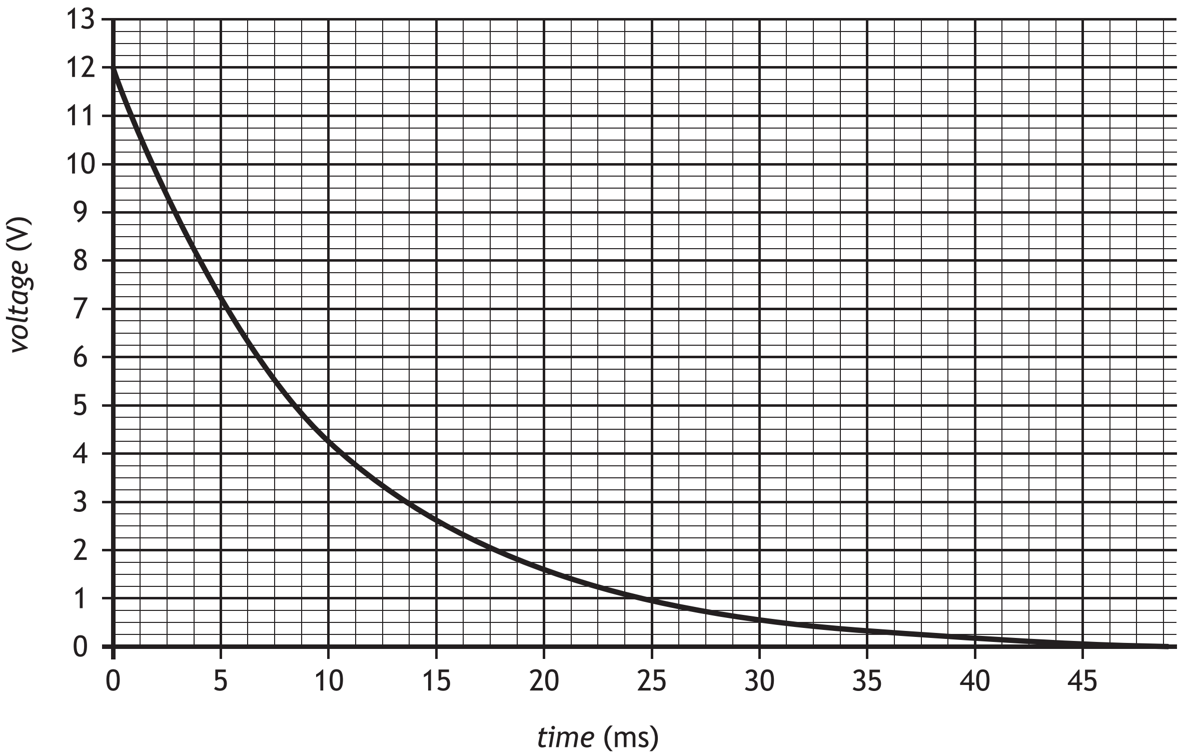

Figure 16B

16. (continued)

(a) Determine the time constant from the graph. **2**

Space for working and answer

(b) Calculate the resistance of resistor R. **3**

Space for working and answer

17. A student sets up an LC circuit, as shown in Figure 17A.

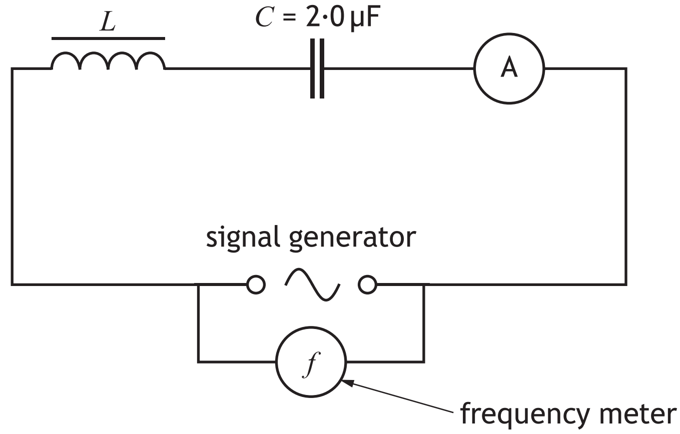

Figure 17A

Maximum current occurs at the resonant frequency f_0. Resonance occurs when the capacitive reactance equals the inductive reactance. The student varies the supply frequency and records the corresponding current.

A graph of current against frequency is shown in Figure 17B.

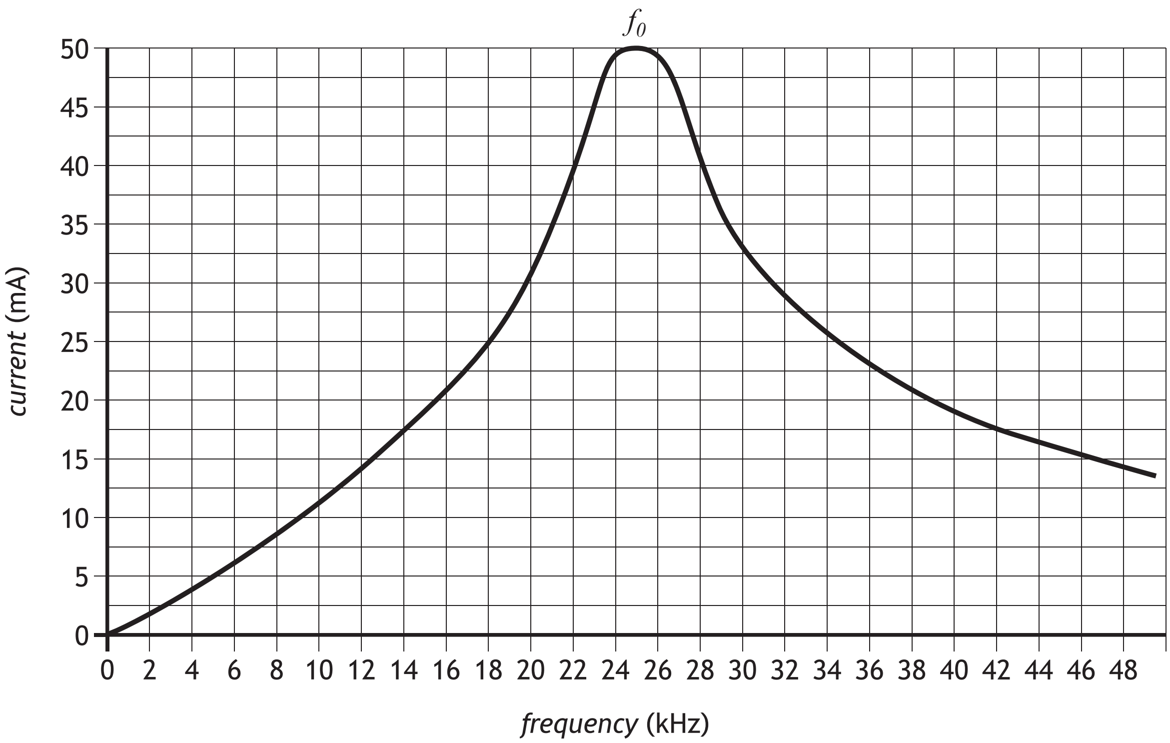

Figure 17B

MARKS | DO NOT WRITE IN THIS MARGIN

17. (continued)

(a) Show that the resonant frequency f_0 is given by **2**

$$f_0 = \frac{1}{2\pi\sqrt{LC}}.$$

(b) The capacitance of C is 2·0 μF. Calculate the inductance of L. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

17. (continued)

(c) The student wants to change the design of this circuit in order to double the resonant frequency. Describe, in detail, a change the student could make to achieve this. **2**

MARKS DO NOT WRITE IN THIS MARGIN

18. As part of a physics project to determine the speed of light in a vacuum, a student finds the permittivity of free space (ε_0) and the permeability of free space (μ_0) by experiment. The student's results are shown below.

permittivity of free space (ε_0) = $9 \cdot 2 \times 10^{-12}\ \text{F m}^{-1} \pm 10\%$

permeability of free space (μ_0) = $1 \cdot 1 \times 10^{-6}\ \text{H m}^{-1} \pm 3\%$

(a) Using these results, determine a value for the speed of light in a vacuum. **3**

Space for working and answer

(b) State the percentage uncertainty in this value. **1**

19. A student carries out an experiment to determine Young's modulus for a wire. The experimental set up is shown in Figure 19.

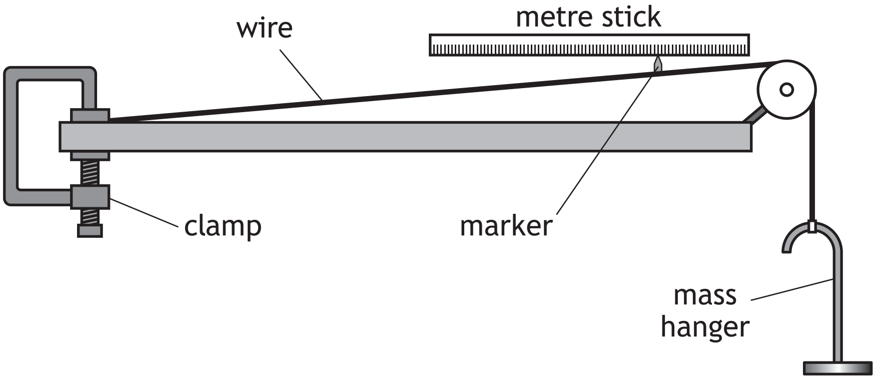

Figure 19

Young's modulus E can be determined by applying the formula

$$E = \frac{FL_0}{A_0 \Delta L}.$$

Where

F = forces applied
L_0 = distance from clamp to marker
ΔL = length of extension wire
A_0 = original cross-sectional area of wire

The student attaches a mass hanger to the wire and fixes a marker on the wire at a distance of 2·00 m from the clamp. Masses are added to the hanger and the extension of the wire is measured by noting the distance moved by the marker along the metre stick.

The masses are removed and the experiment repeated.

The length of the wire is measured using a tape measure.
The diameter of the wire is measured using a micrometer.

An extract from the student's workbook is shown.

Uncertainties: Combined scale and calibration

tape measure	$\pm$ 5 mm
metre stick	$\pm$ 1 mm
balance	$\pm$ 0·1 kg
micrometer	$\pm$ 0·01 mm

19. (continued)

mass (kg)	*force* (N)	*wire extension* (mm)			E ($\times 10^9$ N m^{-2})
		1	2	mean	
0·8	7·84	3	3	3	69
1·2	11·76	4	5	4·5	69
1·6	15·68	5	5	5	83
2·0	19·6	7	7	7	74
2·4	23·52	8	9	8·5	73

wire diameter = 0·31 mm area = $7·6 \times 10^{-8}$ m^2
distance from clamp to marker = 2·00 m

conclusion — the mean value of E is 74×10^9 N m^{-2}.

(a) Suggest **two** improvements that could be made to the experimental procedure. **2**

(b) State which quantity the student should measure more precisely to have the most significant impact on the percentage uncertainty. **1**

(c) (i) The student realises that calculating the mean for the individual measurements of E is an inappropriate method for estimating Young's modulus for the wire.

On the square-ruled paper on *Page 39*, draw a graph the student could use to determine a value for Young's modulus for the wire. **3**

19. (c) (continued)

(ii) Use information from your graph to determine a value for Young's modulus for the wire.

The uncertainty in your value is **not** required. **3**

Space for working and answer

[END OF EXEMPLAR QUESTION PAPER]

EP29AH0141

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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EP29/AH/01 **Physics**

Marking Instructions

These Marking Instructions have been provided to show how SQA would mark this Exemplar Question Paper.

General Marking Principles for Advanced Higher Physics

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this paper. These principles must be read in conjunction with the detailed Marking Instructions, which identify the key features required in candidate responses.

(a) Marks for each candidate response must always be assigned in line with these general marking principles and the detailed Marking Instructions for this assessment.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

(c) There are **no half marks** awarded.

(d) Where a wrong answer to part of a question is carried forward and the wrong answer is then used correctly in the following part, the candidate should be given credit for the subsequent part or "follow on".

(e) Unless a numerical question specifically requires evidence of working to be shown, full marks should be awarded for a correct final answer (including units if required) on its own.

(f) Credit should be given where a diagram or sketch conveys correctly the response required by the question. It will usually require clear and correct labels (or the use of standard symbols).

(g) Marks are provided for knowledge of relevant relationships alone, but when a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values, no mark can be awarded.

(h) Marks should be awarded for non-standard symbols where the symbols are defined and the relationship is correct, or where the substitution shows that the relationship used is correct. This must be clear and unambiguous.

(i) Where a triangle type "relationship" is written down and then not used or used incorrectly, then any mark for a relationship should not be awarded.

(j) Significant figures.
Data in question is given to 3 significant figures.
Correct final answer is 8·16 J.
Final answer 8·2 J or 8·158 J or 8·1576 J — Award the final mark.
Final answer 8 J or 8·15761 J — Do not award the final mark.
Candidates should not be credited for a final answer that includes:

- three or more figures too many
  or
- two or more figures too few, **ie accept two more and one fewer.**

(k) The incorrect spelling of technical terms should usually be ignored and candidates should be awarded the relevant mark, provided that answers can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, the mark should not be awarded. Two specific examples of this would be when the candidate uses a term that might be interpreted as "reflection", "refraction" or "diffraction" (eg "defraction") or one that might be interpreted as either "fission" or "fusion" (eg "fussion").

(l) Marks are awarded only for a valid response to the question asked. For example, in response to questions that ask candidates to:

- **describe**, they must provide a statement or structure of characteristics and/or features;

- **determine** or **calculate**, they must determine a number from given facts, figures or information;
- **estimate**, they must determine an approximate value for something;
- **explain**, they must relate cause and effect and/or make relationships between things clear;
- **identify**, **name**, **give**, or **state**, they need only name or present in brief form;
- **justify**, they must give reasons to support their suggestions or conclusions, eg this might be by identifying an appropriate relationship and the effect of changing variables;
- **predict**, they must suggest what may happen based on available information;
- **show that/derive**, they must use physics [and mathematics] to prove something, eg a given value — *all steps, including the stated answer, must be shown*;
- **suggest**, they must apply their knowledge and understanding of physics to a new situation. A number of responses are acceptable: marks will be awarded for any suggestions that are supported by knowledge and understanding of physics;
- **use your knowledge of physics or aspect of physics to comment on/discuss**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example, by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). They will be rewarded for the breadth and/or depth of their conceptual understanding.

(m) Marking in calculations

Question:

The current in a resistor is 1·5 amperes when the potential difference across it is 7·5 volts. Calculate the resistance of the resistor (3 marks).

	Candidate answer	**Mark & comment**
1	$V = IR$	1 mark: relationship
	$7\cdot5 = 1\cdot5R$	1 mark: substitution
	$R = 5\cdot0\ \Omega$	1 mark: correct answer
2	$5\cdot0\ \Omega$	3 marks: correct answer
3	$5\cdot0$	2 marks: unit missing
4	$4\cdot0\ \Omega$	0 marks: no evidence, wrong answer
5	$\_\_\ \Omega$	0 marks: no working or final answer
6	$R = \frac{V}{I} = \frac{7\cdot5}{1\cdot5} = 4\cdot0\ \Omega$	2 marks: arithmetic error
7	$R = \frac{V}{I} = 4\cdot0\ \Omega$	1 mark: relationship only
8	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9	$R = \frac{V}{I} = \frac{7\cdot5}{1\cdot5} = \_\_\ \Omega$	2 marks: relationship & subs, no final answer

10	$R = \frac{V}{I} = \frac{7 \cdot 5}{1 \cdot 5} = 4 \cdot 0$	2 marks: relationship & subs, wrong answer
11	$R = \frac{V}{I} = \frac{1 \cdot 5}{7 \cdot 5} = 5 \cdot 0\ \Omega$	1 mark: relationship but wrong substitution
12	$R = \frac{V}{I} = \frac{75}{1 \cdot 5} = 5 \cdot 0\ \Omega$	1 mark: relationship but wrong substitution
13	$R = \frac{I}{V} = \frac{1 \cdot 5}{7 \cdot 5} = 5 \cdot 0\ \Omega$	0 marks: wrong relationship
14	$V = IR$ $7 \cdot 5 = 1 \cdot 5 \times R$ $R = 0 \cdot 2\ \Omega$	2 marks: relationship & subs, arithmetic error
15	$V = IR$ $R = \frac{I}{V} = \frac{1 \cdot 5}{7 \cdot 5} = 0 \cdot 2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Detailed Marking Instructions for each question

Question			Expected response	Max mark	Additional guidance
1	a		$a=\frac{dv}{dt}=1\cdot 2t$ $\int \frac{dv}{dt}\cdot dt=\int 1\cdot 2t.dt$ **(1)** $v=0\cdot 6t^2+c$ **(1)** At t = 0, v = 1·4, c = 1·4 **(1)** $v=0\cdot 6t^2+1\cdot 4$	3	Alternative for step 1 $a=1\cdot 2t$ $\int a.dt=\int 1\cdot 2t.dt$ Alternative for step 2 $\int_{1\cdot 4}^{v} dv=\int_{0}^{t} 1\cdot 2t.dt$ $v-1\cdot 4=0\cdot 6t^2$ Final line must be shown, otherwise, maximum of **2 marks**
1	b		$3\cdot 8=0\cdot 6t^2+1\cdot 4$ $t=\sqrt{\frac{2\cdot 4}{0\cdot 6}}$ **(1)** $t=2\cdot 0$ (s) **(1)** $\frac{ds}{dt}=0\cdot 6t^2+1\cdot 4$ $\frac{ds}{dt}.dt=\ \ 0\cdot 6t^2+1\cdot 4.dt$ $s=0\cdot 2t^3+1\cdot 4t+c$ **(1)** $t=0, s=0, c=0$ $s=0\cdot 2(2\cdot 0)^3+2\cdot 8$ $s=4\cdot 4$ m **(1)**	4	$s=\int_0^2 0\cdot 6t^2+1\cdot 4.dt$ $s=0\cdot 2(2\cdot 0)^3+2\cdot 8$ $v=0\cdot 6t^2+1\cdot 4$ $\int v.dt=\int 0\cdot 6t^2+1\cdot 4.dt$ Alternative $s=\int_0^2 0\cdot 6t^2+1\cdot 4.dt$ $s=0\cdot 2(2\cdot 0)^3+2\cdot 8$
2	a		central force $=m\omega^2 r$ **(1)** $=0\cdot 2\times 6\cdot 0^2\times 0\cdot 35$ **(1)** $=\ 2\cdot 5$ N **(1)**	3	Accept: 3, 2·52, 2·520
2	b		$\tan\theta=\frac{F_c}{F_w}$ **(1)** $\tan\theta=\frac{2\cdot 5}{mg}=\frac{2\cdot 5}{0\cdot 35\times 9\cdot 8}$ **(1)** $\theta=36°$ **(1)**	3	Accept: 40, 36·1,36·09
2	c		θ would decrease **(1)** Central force decreases, weight stays the same. **(1)**	2	

Question			Expected response	Max mark	Additional guidance
3	a		$I=\frac{1}{2}mr^2$ **(1)** $I=0\cdot5\times0\cdot115\times0\cdot015^2$ **(1)** $I=1\cdot3\times10^{-5}\,\text{kg m}^2$ **(1)**	3	
3	b		$\omega=\frac{v}{r}$ **(1)** $\omega=\frac{1\cdot60}{0\cdot015}$ **(1)** $\omega=1\cdot1\times10^2\ (\text{rad s}^{-1})$ - $mgh=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$ **(1)** $0\cdot28=0\cdot1472+\frac{1}{2}I(1\cdot1\times10^2)^2$ **(1)** $I=\frac{2\times0\cdot1328}{(1\cdot1\times10^2)^2}$ $I=2\cdot2\times10^5\ \text{kg m}^2$ **(1)**	5	
3	c		Energy is lost. Or Calculation assumes no energy is lost. **(1)**	1	
4			The whole candidate response should be read to establish its overall quality in terms of accuracy and relevance to the problem/situation presented. There may be strengths and weaknesses in the candidate response: assessors should focus as far as possible on the strengths, taking account of weaknesses (errors or omissions) only when they detract from the overall answer in a significant way, which should then be taken into account when determining whether the response demonstrates reasonable, limited or no understanding. Assessors should use their professional judgement to apply the guidance below to the wide range of possible candidate responses.	3	This open-ended question requires comment on the statement “You get thrown outwards by centrifugal force — you can feel it — it pushes you into the wall”. Candidate responses may include one or more of: centripetal acceleration; centripetal force in the inertial frame of reference; Newton’s third law; centrifugal force in the non-inertial frame of reference, or other relevant ideas/ concepts.

Question			Expected response	Max mark	Additional guidance
			3 marks: The candidate has demonstrated a **good** conceptual understanding of the physics involved, providing a logically correct response to the problem/situation presented. This type of response might include a statement of principle(s) involved, a relationship or equation, and the application of these to respond to the problem/situation. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.		In response to this question, a **good** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one relevant physics idea/concept, in a **detailed/ developed** response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • makes judgement(s) on suitability based on a range of relevant physics ideas/ concepts, in a response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • otherwise demonstrates a good understanding of the physics involved.
			2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification of a relevant relationship or equation.		In response to this question, a **reasonable** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s),

Question			Expected response	Max mark	Additional guidance
					in a response that is **largely correct** but has **weaknesses** which detract to a small extent from the overall response, **OR** • otherwise demonstrates a reasonable understanding of the physics involved.
			1 mark: The candidate has demonstrated a **limited** understanding of the physics involved, showing that a little of the physics that is relevant to the problem/situation is understood. The candidate has made some statement(s) that is/are relevant to the problem/situation.		In response to this question, a **limited** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that has **weaknesses** which detract to a large extent from the overall response **OR** • otherwise demonstrates a limited understanding of the physics involved.
			0 marks: The candidate has demonstrated **no** understanding of the physics that is relevant to the problem/situation. The candidate has made no statement(s) that is/are relevant to the problem/situation.		Where the candidate has *only* demonstrated knowledge and understanding of physics **that is not relevant to the problem/situation presented,** **0 marks** should be awarded.
5	a		The (minimum) velocity/speed that a mass must have to escape the gravitational field (of a planet). **(1)**	1	Do not accept *escape gravitational force*. Accept: *escape gravitational*

Question			Expected response	Max mark	Additional guidance
					well, *velocity required to reach infinity,* *velocity required to give a total energy of* 0 J
5	b		$E_k + E_p = 0$ **(1)** $\frac{1}{2}mv^2 - \frac{GMm}{r} = 0$ **(1)** $v^2 = \frac{2GM}{r}$ $v = \sqrt{\frac{2GM}{r}}$ **(1)**	3	$E_k = E_p$ award **0 marks** Start with $\frac{1}{2}mv^2 = \frac{GMm}{r}$ award **0 marks**
5	c		$v = \sqrt{\frac{2GM}{r}}$ **(1)** $v = \sqrt{\frac{2 \times 6 \cdot 67 \times 10^{-11} \times 6 \cdot 0 \times 10^{24}}{1 \cdot 09 \times 10^{7}}}$ **(1)** $v = 8 \cdot 6 \times 10^{3}\ \mathrm{m\,s^{-1}}$ **(1)**	3	Accept: 9, 8·57, 8·569
6	a		Line B. **(1)** Object B is accelerating or in a non-inertial frame of reference. **(1)**	2	Curved lines on spacetime graphs correspond to non-inertial frames of reference (accelerating) which is governed by the General Theory of Relativity
6	b		Time on clock P will appear to move faster. Or Time on clock Q will appear to move slower. **(1)** Time passes more slowly at the rear of an accelerating object. Or Time between pulses from clock Q would take longer to arrive at the astronaut. **(1)**	2	
6	c		The effects of gravity are exactly equivalent to the effects of acceleration. **(1)**	2	

Question			Expected response	Max mark	Additional guidance
			The plane accelerating downwards exactly "cancels out" the effects of being in a gravitational field. Or Plane and passengers are falling at the same rate due to the gravitational field (are in "free fall"). **(1)**		
7	**a**	**i**	The distance from the centre of a black hole at which not even light can escape. Or The distance from the centre of a black hole to the event horizon. **(1)**	**1**	
7	**a**	**ii**	$R_{Schwarzchild} = \frac{2GM}{c^2}$ **(1)** $R_S = \frac{2\times 6\cdot 67\times 10^{-11}\times(14\cdot 8\times 2\times 10^{30})}{(3\times 10^8)^2}$ **(1)** **(1)** $R_S = 4\cdot 4\times 10^4$ m **(1)**	**4**	Independent **(1)** mark for $(14\cdot 8\times 2\times 10^{30})$ Accept: 4, 4·39, 4·387
7	**b**		Chi Cygni is red compared to Zeta Cygni B which is blue-white. Or Chi Cygni is larger than Zeta Cygni B. Or Chi Cygni has a lower temperature than Zeta Cygni B. **Any two statements for 1 mark each.**	**2**	
8	**a**	**i**	Electrons behave like waves. **(1)**	**1**	
8	**a**	**ii**	Photoelectric effect. Or Compton scattering. Or Indication of collision and transfer of energy. **(1)**	**1**	

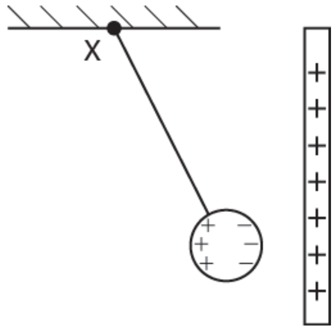
Question			Expected response	Max mark	Additional guidance
8	b		$\lambda = \dfrac{h}{p}$ or $\lambda = \dfrac{h}{mv}$ **(1)** $\lambda = \dfrac{6\cdot 63\times 10^{-34}}{4\cdot 4\times 10^{6}\times 9\cdot 11\times 10^{-31}}$ **(1)** $\lambda = 1\cdot 7\times 10^{-10}\ \text{m}$ **(1)**	3	Accept: 2, 1·65,1·654
8	c		$\lambda = \dfrac{h}{p}$ $\lambda = \dfrac{6\cdot 63\times 10^{-34}}{300\times 0\cdot 02}$ **(1)** $\lambda = 1\cdot 1\times 10^{-34}\ \text{m}$ **(1)** This value is so small (that no diffraction would be seen). Or The de Broglie wavelength of the bullet is much smaller than the gap. **(1)**	3	
9	a		$\frac{1}{2}mv^2 = E$ **(1)** $v = \sqrt{\dfrac{2E}{m}}$ $v = \sqrt{\dfrac{2\times 3\cdot 6\times 10^{6}\times 1\cdot 6\times 10^{-19}}{1\cdot 673\times 10^{-27}}}$ **(1)** **(1)** $v = 2\cdot 6\times 10^{7}\ \text{m}\,\text{s}^{-1}$ **(1)**	4	Independent **(1)** mark for ($3\cdot 6 \times 10^{6}$ x $1\cdot 6 \times 10^{-19}$) Accept: 3, 2·62, 2·624
9	b	i	The perpendicular component of velocity results in circular motion. Or The perpendicular component of velocity results in a central or centripetal force. **(1)** The parallel component of velocity is constant. Or The parallel component of velocity is not subject to a horizontal force or equivalent. **(1)**	2	

Question			Expected response	Max mark	Additional guidance
9	b	ii	$v = 2\cdot6\times10^{-27}\times\sin 50 = 2\cdot0\times10^{7}$ **(1)** $\frac{mv^2}{r} = qvB$ **(1)** $\frac{1\cdot673\times10^{-27}\times(2\cdot0\times10^{7})^2}{r}$ $= 1\cdot60\times10^{-19}\times2\cdot0\times10^{7}\times58\times10^{-6}$ **(1)** $r = 3\cdot6\times10^{3}$ m **(1)**	4	Accept: 4, 3·61, 3·606
9	b	iii	The anti proton will turn in the opposite direction. Or The anti proton helix pitch will be greater. Or The radius of curvature of the anti proton will be smaller. **Any two statements for 1 mark each.**	2	
10	a		Acceleration or unbalanced force is directly proportional, and in the opposite direction to displacement. **(1)**	1	$a = -ky,\ F = -ky$ acceptable
10	b	i	$\omega = \frac{2\pi}{T}$ **(1)** $\omega = \frac{2\pi}{3}$ **(1)** $\omega = 2\cdot1\ (\text{rad s}^{-1})$ **(1)** $a = (-)\omega^2 y$ **(1)** $1\cdot28 = (-)2\cdot1^2\times y$ **(1)** $y = 0\cdot29$ m	5	Accept: 0·3, 0·290, 0·2902
10	b	ii	$v = (\pm)\omega\sqrt{A^2 - y^2}$ **(1)** $v = (\pm)2\cdot1\sqrt{0\cdot29^2 - 0\cdot10^2}$ **(1)** $v = (\pm)0\cdot57\ m\,s^{-1}$ **(1)**	3	Accept: 0·6, 0·572, 0·5716
11	a		$\varphi = \frac{2\pi x}{\lambda}$ **(1)** $3\cdot5 = \frac{2\pi\times0\cdot28}{\lambda}$ **(1)** $\lambda = 0\cdot50$ m **(1)**	3	Accept: 0·5, 0·503, 0·5027

Question			Expected response	Max mark	Additional guidance
11	b	i	$\lambda = 0\cdot25$ $v = f\lambda$ $v = 5\cdot0 \times 0\cdot25$ $v = 1\cdot3\ \text{m s}^{-1}$ **(1)**	1	Accept: 1, 1·25, 1·250
11	b	ii	$\frac{I_1}{A_1^2} = \frac{I_2}{A_2^2}$ or I is proportional to A^2 **(1)** $\frac{I_1}{0\cdot03^2} = \frac{5I_1}{A_2^2}$ **(1)** $A_2 = 0\cdot07\ \text{m}$ **(1)**	3	Accept: 0·1, 0·067, 0·0671
12	a		Division of wavefront. **(1)**	1	
12	b	i	$\Delta x = \frac{\lambda D}{d}$ **(1)** $\Delta x = \frac{510\times10^{-9}\times2\cdot5}{3\cdot0\times10^{-4}}$ **(1)** $\Delta x = 4\cdot3\times10^{-3}\ \text{m}$ **(1)**	3	Accept: 4, 4·25, 4·250
12	b	ii	%Uncertainty in $\lambda = \frac{2\times100}{510} = 0\cdot40\%$ **(1)** %Uncertainty in D$= \frac{0\cdot05\times100}{2\cdot5} = 2\%$ **(1)** %Uncertainty in d$= \frac{0\cdot00001\times100}{0\cdot0003} = 3\cdot33\%$ **(1)** %Uncertainty in $\Delta x = \sqrt{2^2 + 3\cdot3^2} = 3\cdot9\%$ **(1)** Absolute uncertainty in $\Delta x = 3\cdot9\% \times 4\cdot3\times10^{-3}$ Absolute uncertainty in $\Delta x = 1\cdot7\times10^{-4}\ \text{m}$ **(1)**	5	Accept: 2, 1·68, 1·677
13	a	i	The tablet emits plane polarised light. **(1)**	1	
13	a	ii	The brightness would gradually reduce from a maximum at 0° to no intensity at 90°. **(1)** It would then gradually increase in intensity from 90° to 180° where it would again be a maximum. **(1)**	2	

Question			Expected response	Max mark	Additional guidance
13	b		$\tan\theta_1 = n$ **(1)** $\theta_1 =$ Brewster's angle $\tan\theta_1 = 1\cdot 33$ **(1)** $\theta_1 = 53\cdot 1°$ **(1)** $\theta = 90 - 53\cdot 1 = 36\cdot 9°$ **(1)**	4	Accept: 37, 36·94, 36·939
14			The whole candidate response should be read to establish its overall quality in terms of accuracy and relevance to the problem/situation presented. There may be strengths and weaknesses in the candidate response: assessors should focus as far as possible on the strengths, taking account of weaknesses (errors or omissions) only when they detract from the overall answer in a significant way, which should then be taken into account when determining whether the response demonstrates reasonable, limited or no understanding. Assessors should use their professional judgement to apply the guidance below to the wide range of possible candidate responses.	3	This open-ended question requires comment on a number of student's evaluative statements. Candidate responses may include one or more of: the meanings of *precision* and *accuracy*; the effect on accuracy of repeating measurements; the effect on uncertainty of repeating measurements; relative significance of uncertainties in a series of measurements, or other relevant ideas/concepts.
			3 marks: The candidate has demonstrated a **good** conceptual understanding of the physics involved, providing a logically correct response to the problem/situation presented. This type of response might include a statement of principle(s) involved, a relationship or equation, and the application of these to respond to the problem/situation. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.		In response to this question, a **good** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one relevant physics idea/concept, in a **detailed/ developed** response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR**

Question				Expected response	Max mark	Additional guidance
						• makes judgement(s) on suitability based on a range of relevant physics ideas/concepts, in a response that is **correct or largely correct** (any weaknesses are minor and do not detract from the overall response), **OR** • otherwise demonstrates a good understanding of the physics involved.
				2 marks: The candidate has demonstrated a **reasonable** understanding of the physics involved, showing that the problem/situation is understood. This type of response might make some statement(s) that is/are relevant to the problem/situation, for example, a statement of relevant principle(s) or identification of a relevant relationship or equation.		In response to this question, a **reasonable** understanding might be demonstrated by a candidate response that: • makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that is **largely correct** but has **weaknesses** which detract to a small extent from the overall response, **OR** • otherwise demonstrates a reasonable understanding of the physics involved.
				1 mark: The candidate has demonstrated a **limited** understanding of the physics involved, showing that a little of the physics that is relevant to the problem/situation is understood. The candidate has made some statement(s) that is/are relevant to the problem/situation.		In response to this question, a **limited** understanding might be demonstrated by a candidate response that:

Question			Expected response	Max mark	Additional guidance
					• makes a judgement on suitability based on one or more relevant physics idea(s)/concept(s), in a response that has **weaknesses** which detract to a large extent from the overall response **OR** • otherwise demonstrates a limited understanding of the physics involved.
			0 marks: The candidate has demonstrated **no** understanding of the physics that is relevant to the problem/situation. The candidate has made no statement(s) that is/are relevant to the problem/situation.		Where the candidate has *only* demonstrated knowledge and understanding of physics **that is not relevant to the problem/situation presented,** **0 marks** should be awarded.
15	**a**			**1**	Must have roughly equal numbers of + and - charges for mark. Any indication of sphere charged. **(0)** Movement of protons/positively charged particles. **(0)** Movement of positive charges. **(1)**
15	**b**	**i**	$E = \frac{V}{d}$ **(1)** $E = \frac{5000}{0 \cdot 042}$ **(1)** $E = 1 \cdot 2 \times 10^5 \text{ V m}^{-1}$ **(1)**	**3**	Accept: 1, 1·19, 1·190
15	**b**	**ii**	$F = QE$ **(1)** $F = 1 \cdot 4 \times 10^{-7} \times 1 \cdot 2 \times 10^5$ **(1)** $F = 1 \cdot 7 \times 10^{-2} \text{ N}$ **(1)**	**3**	Accept: 2, 1·68, 1·680

Question			Expected response	Max mark	Additional guidance
15	b	iii	$mg = 4\cdot0\times10^{-3}\times9\cdot8$ **(1)** $mg = 3\cdot92\times10^{-2}$ (N) $T^2 = (3\cdot92\times10^{-2})^2 + (1\cdot7\times10^{-2})^2$ **(1)** $T = 4\cdot3\times10^{-2}$ N **(1)** $\theta = \tan^{-1}\dfrac{(1\cdot7\times10^{-2})}{(3\cdot92\times10^{-2})}$ $\theta = 23°$ **(1)**	4	Accept: 4, 4·27, 4·272 Accept: 20, 23·4, 23·45
15	c		θ stays the same **(1)** *E* unchanged Or *V* and *d* unchanged **(1)**	2	
16	a		$0\cdot37$ or 37% **(1)** $0\cdot37\times12 = 4\cdot44$ (V) From graph, $t = 9\cdot5$ ms **(1)**	2	Accept: 9 ms - 10 ms
16	b		$t = CR$ **(1)** $9\cdot5\times10^{-3} = 385\times10^{-6}\times R$ **(1)** $R = 25\ \Omega$ **(1)**	3	Accept: follow through consistent with 16(a) Accept: 20, 24·7, 24·68
17	a		$X_C = \dfrac{1}{2\pi fC}$ *and* $X_L = 2\pi fL$ **(1)** $2\pi f_0 L = \dfrac{1}{2\pi f_0 C}$ **(1)** $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$	2	Show question
17	b		From graph, f_0 = 2500 (Hz) **(1)** $2500 = \dfrac{1}{2\pi\sqrt{L\times2\cdot0\times10^{-6}}}$ **(1)** $L = 2\cdot0\times10^{-3}$ H **(1)**	3	Accept: f_0 = 2400 – 2600 Accept: 2, 2·03. 2·026
17	c		Replace the capacitor **(1)** with another with capacitance ¼ of the original/ 5×10^{-7} F **(1)** Or Replace the inductor **(1)** with another with inductance ¼ of the original/ 5×10^{-4} H **(1)**	2	

Question			Expected response	Max mark	Additional guidance
18	a		$c=\dfrac{1}{\sqrt{\varepsilon_0\mu_0}}$ **(1)** $c=\dfrac{1}{\sqrt{9\cdot2\times10^{-12}\times1\cdot1\times10^{-6}}}$ **(1)** $c=3\cdot1\times10^{8}\ \mathrm{m\,s^{-1}}$ **(1)**	3	Accept: 3, 3·14, 3·143
18	b		$\pm$10% **(1)**	1	
19	a		Repeat extension measurement more than twice. Or Have the wire horizontal. Or Use a travelling microscope to measure wire extension. Or Have a greater number of mass values. Or Measure the diameter at a number of different points on the wire. **Any two statements for 1 mark each.**	2	
19	b		The measurement of ΔL. **(1)**	1	
19	c	i	Graph of F (y-axis) against mean ΔL (x-axis) with axes labelled and scaled appropriately. **(1)** Five points accurately plotted. **(1)** Line of best fit drawn **(1)**	3	
19	c	ii	$Gradient=2\cdot8\times10^{3}$ **(1)** $E=\dfrac{gradient\times L_0}{A_0}$ $E=\dfrac{2\cdot8\times10^{3}\times2\cdot00}{7\cdot6\times10^{-8}}$ **(1)** $E=7\cdot4\times10^{9}\ \mathrm{N\,m^{-2}}$ **(1)**	3	Accept: gradient range $2\cdot6\times10^{3}$ - $3\cdot0\times10^{3}$ Gives range for E $6\cdot8\times10^{9}$-$7\cdot9\times10^{9}$ Accept: 7, 7·37, 7·368

[END OF EXEMPLAR MARKING INSTRUCTIONS]

National
Qualifications
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EP29/AH/11

Physics
Relationships Sheet

Date — Not applicable

EP29AH11

Relationships required for Physics Advanced Higher

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

$$v = u + at$$

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

$$v^2 = u^2 + 2as$$

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\omega = \omega_o + \alpha t$$

$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_o{}^2 + 2\alpha\theta$$

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$F = \frac{mv^2}{r} = mr\omega^2$$

$$T = Fr$$

$$T = I\alpha$$

$$L = mvr = mr^2\omega$$

$$L = I\omega$$

$$E_K = \frac{1}{2}I\omega^2$$

$$F = G\frac{Mm}{r^2}$$

$$V = -\frac{GM}{r}$$

$$v = \sqrt{\frac{2GM}{r}}$$

$$\text{apparent brightness}, b = \frac{L}{4\pi r^2}$$

$$\text{Power per unit area} = \sigma T^4$$

$$L = 4\pi r^2 \sigma T^4$$

$$r_{Schwarzschild} = \frac{2GM}{c^2}$$

$$E = hf$$

$$\lambda = \frac{h}{p}$$

$$mvr = \frac{nh}{2\pi}$$

$$\Delta x\, \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta E\, \Delta t \geq \frac{h}{4\pi}$$

$$F = qvB$$

$$\omega = 2\pi f$$

$$a = \frac{d^2y}{dt^2} = -\omega^2 y$$

$y = A\cos\omega t$ or $y = A\sin\omega t$

$v = \pm\omega\sqrt{(A^2 - y^2)}$

$E_K = \frac{1}{2}m\omega^2(A^2 - y^2)$

$E_P = \frac{1}{2}m\omega^2 y^2$

$y = A\sin 2\pi(ft - \frac{x}{\lambda})$

$\phi = \frac{2\pi x}{\lambda}$

optical path difference $= m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$

where $m = 0, 1, 2....$

$\Delta x = \frac{\lambda l}{2d}$

$d = \frac{\lambda}{4n}$

$\Delta x = \frac{\lambda D}{d}$

$n = \tan i_P$

$F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$

$E = \frac{Q}{4\pi\varepsilon_o r^2}$

$V = \frac{Q}{4\pi\varepsilon_o r}$

$F = QE$

$V = Ed$

$F = IlB\sin\theta$

$B = \frac{\mu_o I}{2\pi r}$

$c = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$

$t = RC$

$X_C = \frac{V}{I}$

$X_C = \frac{1}{2\pi fC}$

$\mathcal{E} = -L\frac{dI}{dt}$

$E = \frac{1}{2}LI^2$

$X_L = \frac{V}{I}$

$X_L = 2\pi fL$

$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$

$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$

$$d = \bar{v}t$$

$$s = \bar{v}t$$

$$v = u + at$$

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

$$v^2 = u^2 + 2as$$

$$s = \frac{1}{2}(u+v)t$$

$$W = mg$$

$$F = ma$$

$$E_W = Fd$$

$$E_P = mgh$$

$$E_K = \frac{1}{2}mv^2$$

$$P = \frac{E}{t}$$

$$p = mv$$

$$Ft = mv - mu$$

$$F = G\frac{Mm}{r^2}$$

$$t' = \frac{t}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$$

$$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$$

$$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$$

$$z = \frac{v}{c}$$

$$v = H_0 d$$

$$E_W = QV$$

$$E = mc^2$$

$$E = hf$$

$$E_K = hf - hf_0$$

$$E_2 - E_1 = hf$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

$$d\sin\theta = m\lambda$$

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$\sin\theta_c = \frac{1}{n}$$

$$I = \frac{k}{d^2}$$

$$I = \frac{P}{A}$$

path difference $= m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$ where $m = 0,\ 1,\ 2...$

random uncertainty $= \dfrac{\text{max. value - min. value}}{\text{number of values}}$

$$V_{peak} = \sqrt{2}V_{rms}$$

$$I_{peak} = \sqrt{2}I_{rms}$$

$$Q = It$$

$$V = IR$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$R_T = R_1 + R_2 + ...$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ...$$

$$E = V + Ir$$

$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)V_S$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$C = \frac{Q}{V}$$

$$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

Additional Relationships

Circle

$circumference = 2\pi r$

$area = \pi r^2$

Sphere

$area = 4\pi r^2$

$volume = \frac{4}{3}\pi r^3$

Trigonometry

$$\sin\theta = \frac{opposite}{hypotenuse}$$

$$\cos\theta = \frac{adjacent}{hypotenuse}$$

$$\tan\theta = \frac{opposite}{adjacent}$$

$$\sin^2\theta + \cos^2\theta = 1$$

Moment of inertia

point mass
$I = mr^2$

rod about centre
$I = \frac{1}{12}ml^2$

rod about end
$I = \frac{1}{3}ml^2$

disc about centre
$I = \frac{1}{2}mr^2$

sphere about centre
$I = \frac{2}{5}mr^2$

Table of standard derivatives

$f(x)$	$f'(x)$
$\sin ax$	$a\cos ax$
$\cos ax$	$-a\sin ax$

Table of standard integrals

$f(x)$	$\int f(x)dx$
$\sin ax$	$-\frac{1}{a}\cos ax + C$
$\cos ax$	$\frac{1}{a}\sin ax + C$

Electron Arrangements of Elements

Key

Atomic number Symbol Electron arrangement Name

Transition Elements

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1 **H** 1 Hydrogen																	2 **He** 2 Helium
3 **Li** 2, 1 Lithium	4 **Be** 2, 2 Beryllium											5 **B** 2, 3 Boron	6 **C** 2, 4 Carbon	7 **N** 2, 5 Nitrogen	8 **O** 2, 6 Oxygen	9 **F** 2, 7 Fluorine	10 **Ne** 2, 8 Neon
11 **Na** 2, 8, 1 Sodium	12 **Mg** 2, 8, 2 Magnesium											13 **Al** 2, 8, 3 Aluminium	14 **Si** 2, 8, 4 Silicon	15 **P** 2, 8, 5 Phosphorus	16 **S** 2, 8, 6 Sulphur	17 **Cl** 2, 8, 7 Chlorine	18 **Ar** 2, 8, 8 Argon
19 **K** 2, 8, 8, 1 Potassium	20 **Ca** 2, 8, 8, 2 Calcium	21 **Sc** 2, 8, 9, 2 Scandium	22 **Ti** 2, 8, 10, 2 Titanium	23 **V** 2, 8, 11, 2 Vanadium	24 **Cr** 2, 8, 13, 1 Chromium	25 **Mn** 2, 8, 13, 2 Manganese	26 **Fe** 2, 8, 14, 2 Iron	27 **Co** 2, 8, 15, 2 Cobalt	28 **Ni** 2, 8, 16, 2 Nickel	29 **Cu** 2, 8, 18, 1 Copper	30 **Zn** 2, 8, 18, 2 Zinc	31 **Ga** 2, 8, 18, 3 Gallium	32 **Ge** 2, 8, 18, 4 Germanium	33 **As** 2, 8, 18, 5 Arsenic	34 **Se** 2, 8, 18, 6 Selenium	35 **Br** 2, 8, 18, 7 Bromine	36 **Kr** 2, 8, 18, 8 Krypton
37 **Rb** 2, 8, 18, 8, 1 Rubidium	38 **Sr** 2, 8, 18, 8, 2 Strontium	39 **Y** 2, 8, 18, 9, 2 Yttrium	40 **Zr** 2, 8, 18, 10, 2 Zirconium	41 **Nb** 2, 8, 18, 12, 1 Niobium	42 **Mo** 2, 8, 18, 13, 1 Molybdenum	43 **Tc** 2, 8, 18, 13, 2 Technetium	44 **Ru** 2, 8, 18, 15, 1 Ruthenium	45 **Rh** 2, 8, 18, 16, 1 Rhodium	46 **Pd** 2, 8, 18, 18, 0 Palladium	47 **Ag** 2, 8, 18, 18, 1 Silver	48 **Cd** 2, 8, 18, 18, 2 Cadmium	49 **In** 2, 8, 18, 18, 3 Indium	50 **Sn** 2, 8, 18, 18, 4 Tin	51 **Sb** 2, 8, 18, 18, 5 Antimony	52 **Te** 2, 8, 18, 18, 6 Tellurium	53 **I** 2, 8, 18, 18, 7 Iodine	54 **Xe** 2, 8, 18, 18, 8 Xenon
55 **Cs** 2, 8, 18, 18, 8, 1 Caesium	56 **Ba** 2, 8, 18, 18, 8, 2 Barium	57 **La** 2, 8, 18, 18, 9, 2 Lanthanum	72 **Hf** 2, 8, 18, 32, 10, 2 Hafnium	73 **Ta** 2, 8, 18, 32, 11, 2 Tantalum	74 **W** 2, 8, 18, 32, 12, 2 Tungsten	75 **Re** 2, 8, 18, 32, 13, 2 Rhenium	76 **Os** 2, 8, 18, 32, 14, 2 Osmium	77 **Ir** 2, 8, 18, 32, 15, 2 Iridium	78 **Pt** 2, 8, 18, 32, 17, 1 Platinum	79 **Au** 2, 8, 18, 32, 18, 1 Gold	80 **Hg** 2, 8, 18, 32, 18, 2 Mercury	81 **Tl** 2, 8, 18, 32, 18, 3 Thallium	82 **Pb** 2, 8, 18, 32, 18, 4 Lead	83 **Bi** 2, 8, 18, 32, 18, 5 Bismuth	84 **Po** 2, 8, 18, 32, 18, 6 Polonium	85 **At** 2, 8, 18, 32, 18, 7 Astatine	86 **Rn** 2, 8, 18, 32, 18, 8 Radon
87 **Fr** 2, 8, 18, 32, 18, 8, 1 Francium	88 **Ra** 2, 8, 18, 32, 18, 8, 2 Radium	89 **Ac** 2, 8, 18, 32, 18, 9, 2 Actinium	104 **Rf** 2, 8, 18, 32, 32, 10, 2 Rutherfordium	105 **Db** 2, 8, 18, 32, 32, 11, 2 Dubnium	106 **Sg** 2, 8, 18, 32, 32, 12, 2 Seaborgium	107 **Bh** 2, 8, 18, 32, 32, 13, 2 Bohrium	108 **Hs** 2, 8, 18, 32, 32, 14, 2 Hassium	109 **Mt** 2, 8, 18, 32, 32, 15, 2 Meitnerium									

Lanthanides	57 **La** 2, 8, 18, 18, 9, 2 Lanthanum	58 **Ce** 2, 8, 18, 20, 8, 2 Cerium	59 **Pr** 2, 8, 18, 21, 8, 2 Praseodymium	60 **Nd** 2, 8, 18, 22, 8, 2 Neodymium	61 **Pm** 2, 8, 18, 23, 8, 2 Promethium	62 **Sm** 2, 8, 18, 24, 8, 2 Samarium	63 **Eu** 2, 8, 18, 25, 8, 2 Europium	64 **Gd** 2, 8, 18, 25, 9, 2 Gadolinium	65 **Tb** 2, 8, 18, 27, 8, 2 Terbium	66 **Dy** 2, 8, 18, 28, 8, 2 Dysprosium	67 **Ho** 2, 8, 18, 29, 8, 2 Holmium	68 **Er** 2, 8, 18, 30, 8, 2 Erbium	69 **Tm** 2, 8, 18, 31, 8, 2 Thulium	70 **Yb** 2, 8, 18, 32, 8, 2 Ytterbium	71 **Lu** 2, 8, 18, 32, 9, 2 Lutetium
Actinides	89 **Ac** 2, 8, 18, 32, 18, 9, 2 Actinium	90 **Th** 2, 8, 18, 32, 18, 10, 2 Thorium	91 **Pa** 2, 8, 18, 32, 20, 9, 2 Protactinium	92 **U** 2, 8, 18, 32, 21, 9, 2 Uranium	93 **Np** 2, 8, 18, 32, 22, 9, 2 Neptunium	94 **Pu** 2, 8, 18, 32, 24, 8, 2 Plutonium	95 **Am** 2, 8, 18, 32, 25, 8, 2 Americium	96 **Cm** 2, 8, 18, 32, 25, 9, 2 Curium	97 **Bk** 2, 8, 18, 32, 27, 8, 2 Berkelium	98 **Cf** 2, 8, 18, 32, 28, 8, 2 Californium	99 **Es** 2, 8, 18, 32, 29, 8, 2 Einsteinium	100 **Fm** 2, 8, 18, 32, 30, 8, 2 Fermium	101 **Md** 2, 8, 18, 32, 31, 8, 2 Mendelevium	102 **No** 2, 8, 18, 32, 32, 8, 2 Nobelium	103 **Lr** 2, 8, 18, 32, 32, 9, 2 Lawrencium