Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 30 minutes

Paper reference **WPH12/01**

Physics

International Advanced Subsidiary/Advanced Level
UNIT 2: Waves and Electricity

You must have:
Scientific calculator, ruler, protractor

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- Show all your working out in calculations and include units where appropriate.

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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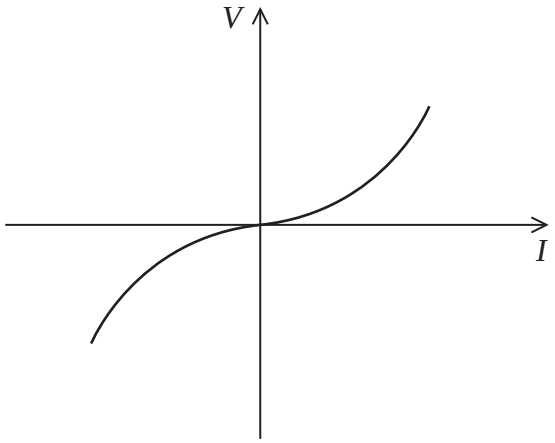
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SECTION A

Answer ALL questions.

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

1 The graph shows how potential difference V varies with current I for an electrical component.



Which electrical component is represented by this graph?

☒ **A** diode

☒ **B** filament lamp

☒ **C** ohmic conductor

☒ **D** thermistor

(Total for Question 1 = 1 mark)

2 A student determines the wavelength of the light emitted by a laser. She uses the laser, a diffraction grating and a screen.

Which of the following measurements is **not** required?

☒ **A** the distance from the diffraction grating to the screen

☒ **B** the distance from the central maximum to the first order maximum

☒ **C** the distance from the laser to the diffraction grating

☒ **D** the distance between the slits in the diffraction grating

(Total for Question 2 = 1 mark)

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3 The equation $I = nqvA$ relates the current in a sample of a material to the movement of free charge carriers in the sample.

Which of the following is a correct definition of one of the terms in this equation?

- ☒ **A** n represents the number of charge carriers in the sample.
- ☒ **B** q represents the total charge stored in the sample.
- ☒ **C** v represents the drift velocity of the charge carriers in the sample.
- ☒ **D** A represents the surface area of the sample.

(Total for Question 3 = 1 mark)

4 The temperature of a thermistor is increased.

Which row in the table identifies the effect of the temperature increase on the number of conduction electrons and the amplitude of lattice vibrations?

	Number of conduction electrons	Amplitude of lattice vibrations
☒ **A**	increases	increases
☒ **B**	decreases	increases
☒ **C**	increases	stays the same
☒ **D**	decreases	stays the same

(Total for Question 4 = 1 mark)

5 The unit of resistance is the ohm.

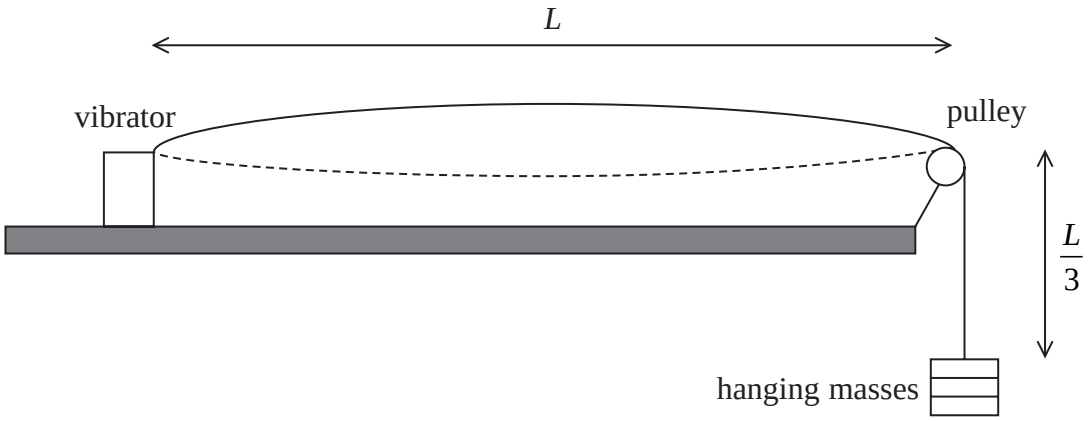
Which of the following is equivalent to the ohm?

- ☒ **A** $JC^{-2}s$
- ☒ **B** $JC^{2}s^{-1}$
- ☒ **C** $JC^{-1}s^{-1}$
- ☒ **D** JCs

(Total for Question 5 = 1 mark)

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6 The speed of waves on a vibrating string is investigated using the apparatus shown.



length of string between vibrator and pulley = L

length of string between pulley and hanging masses = $\frac{L}{3}$

mass of whole string = m
mass of hanging masses = M

Which of the following expressions represents the speed of the waves on the string?

☒ **A** $\sqrt{\left(\frac{4MgL}{3m}\right)}$

☒ **B** $\sqrt{\left(\frac{2MgL}{3m}\right)}$

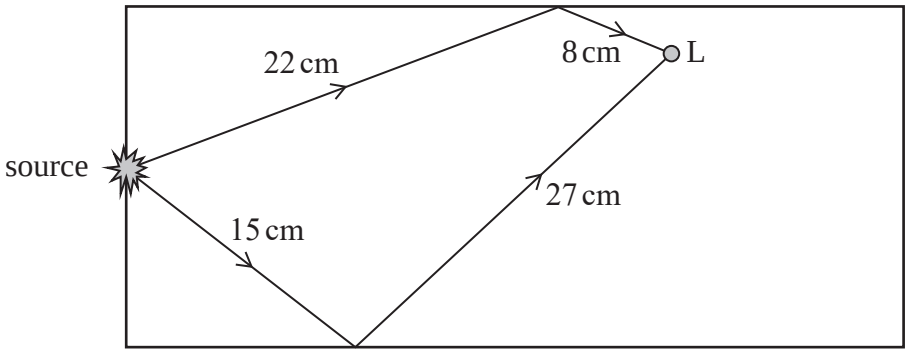
☒ **C** $\sqrt{\left(\frac{MgL}{m}\right)}$

☒ **D** $\sqrt{\left(\frac{MgL}{3m}\right)}$

(Total for Question 6 = 1 mark)

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7 A microwave oven has a source that emits microwaves in all directions into the oven. The diagram shows the paths of two microwave rays that meet at point L as shown.



The interference between the waves following these two paths could cause heating effects at L depending on the wavelength of the microwaves.

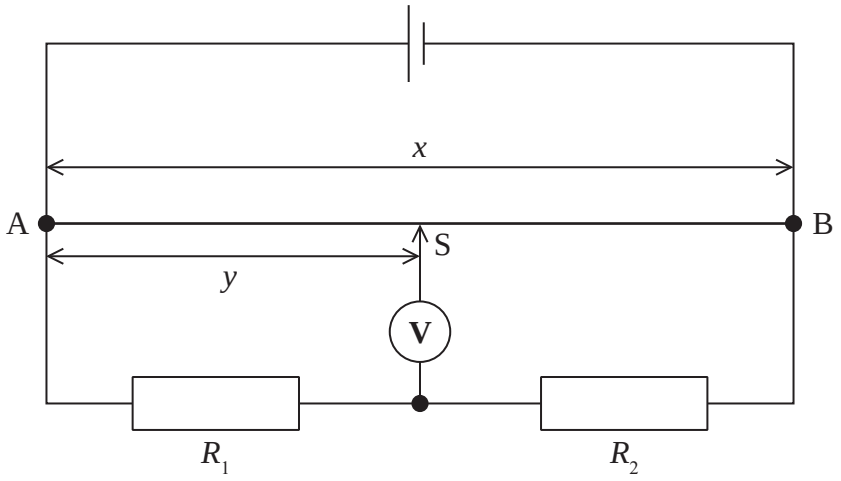
Which row of the table is possible at point L?

	Heating effect at L	Wavelength / cm
☒ **A**	maximum heating	24
☒ **B**	maximum heating	18
☒ **C**	no heating	24
☒ **D**	no heating	18

(Total for Question 7 = 1 mark)

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8 A current-carrying wire AB of length x and uniform diameter is connected in a circuit as shown.



The slider S is moved along the wire until the reading on the voltmeter is 0 V.

Which of the following equations is correct?

☒ **A** $\frac{y}{x} = \frac{R_1}{R_2}$

☒ **B** $\frac{y}{x - y} = \frac{R_1}{R_2}$

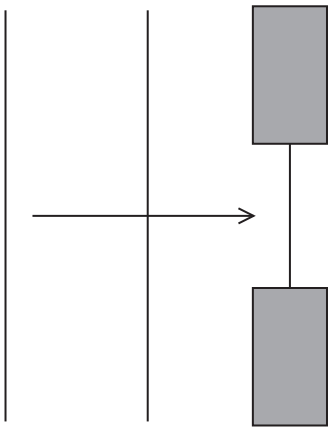
☒ **C** $\frac{x}{y} = \frac{R_1}{R_2}$

☒ **D** $\frac{x}{y} = \frac{R_1}{R_1 + R_2}$

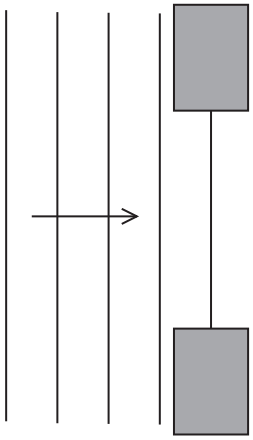
(Total for Question 8 = 1 mark)

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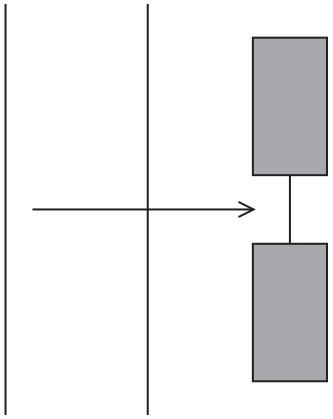
9 The wavefront diagrams show consecutive waves approaching gaps of different sizes.



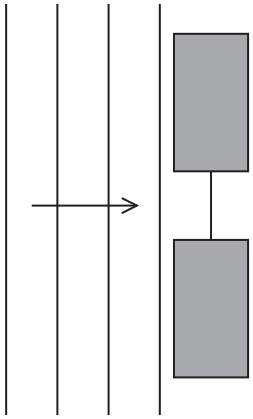
A



B



C



D

The wavefronts diffract as they pass through each gap.

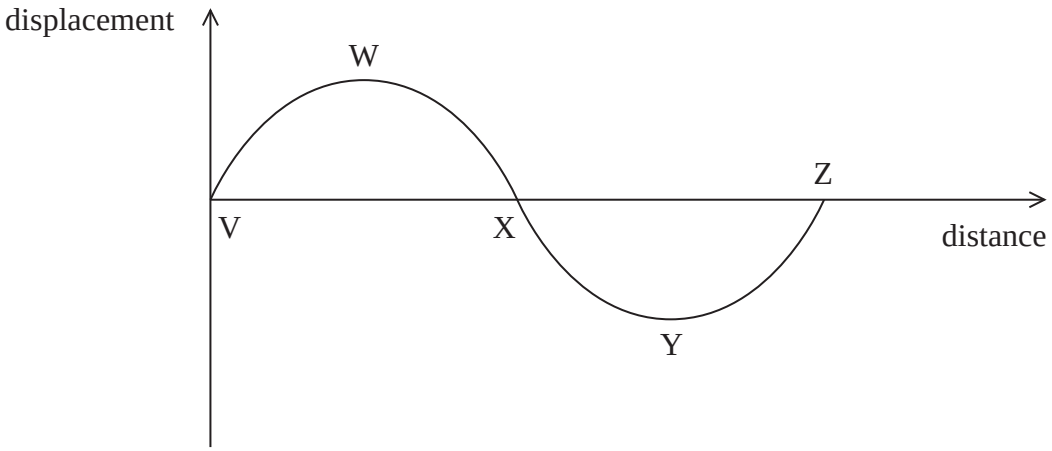
In which diagram will the diffracted wavefronts **not** be semicircular?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 9 = 1 mark)

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10 A sound wave travels through air. The diagram represents the displacement of air particles along the wave at an instant in time.



There is a compression at position V.

At which position is there also a compression?

☒ **A** W

☒ **B** X

☒ **C** Y

☒ **D** Z

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

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SECTION B

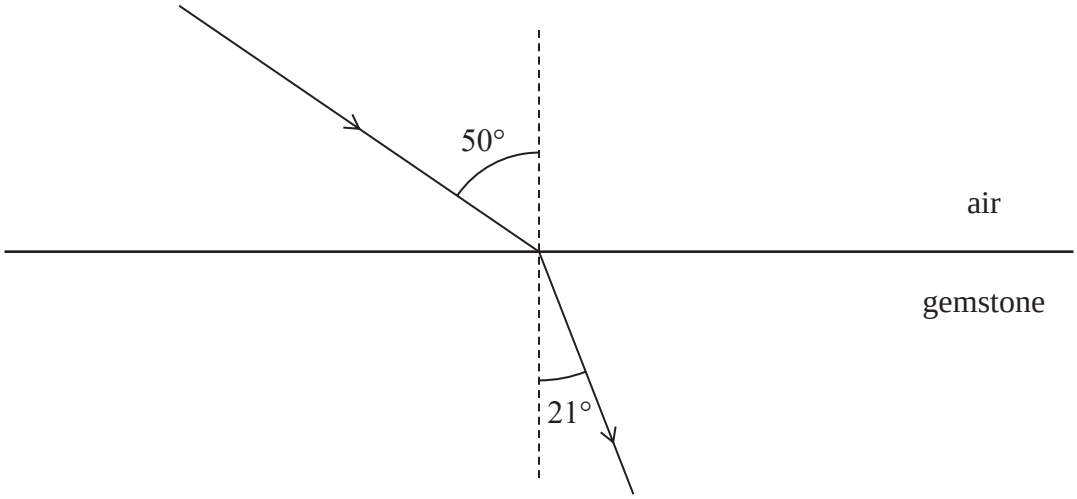
Answer ALL questions in the spaces provided.

11 Diamonds, cubic zirconia and silicon carbide can be used as gemstones in jewellery.

The speed of light in these materials is shown in the table.

	diamond	**cubic zirconia**	**silicon carbide**
speed of light / m s^{-1}	1.24×10^8	1.39×10^8	1.15×10^8

(a) In order to identify the material used, a ray of light is directed towards a boundary between air and the gemstone.

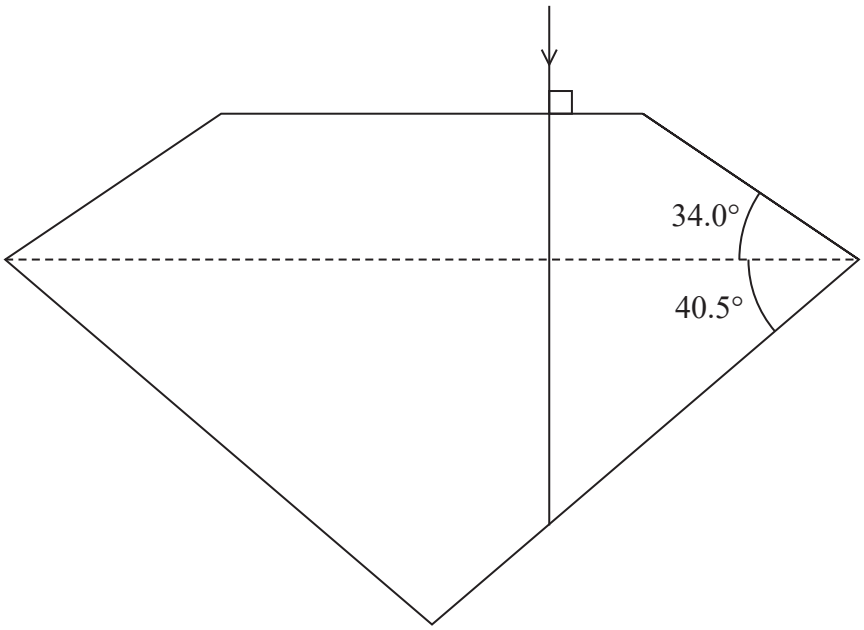


Deduce the material used for the gemstone.

(3)

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(b) Diamonds are cut into different shapes so that they 'sparkle' when light shines on them.
The diagram shows a ray of light entering a diamond and incident on a boundary between diamond and air.



(i) Add to the diagram to show the path of the ray of light as it leaves this boundary. Your answer should include a calculation.

(4)

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(ii) Explain what would happen to the ray at this boundary if the material used was silicon carbide instead of diamond.

(2)

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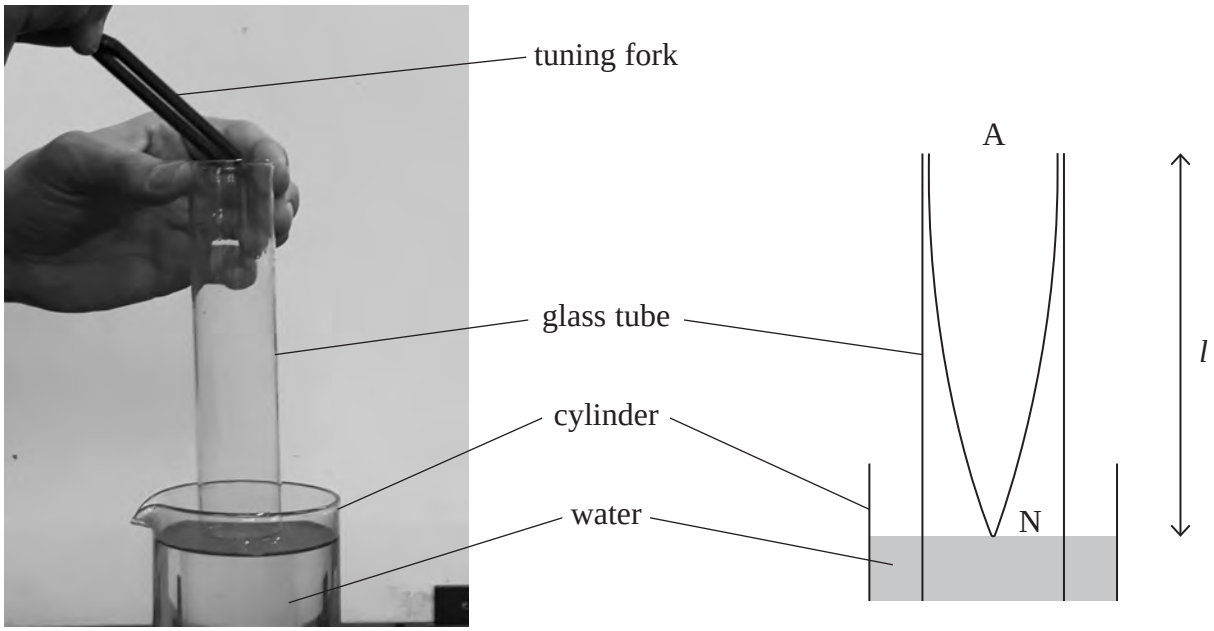
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(Total for Question 11 = 9 marks)

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12 In an experiment to determine the speed of sound in air, a student held a vibrating tuning fork above a glass tube. The air column in the tube could be adjusted by raising or lowering the tube into a cylinder containing water. When the length of the air column was l, a stationary wave with one node and one antinode was produced as shown. This caused a sound to be heard.



(a) Explain how the stationary wave was formed in this experiment.

(2)

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(b) (i) A sound was heard when l was 19.3 cm.

Determine a value for the speed of sound in air.

frequency of tuning fork = 440 Hz

(3)

Speed of sound in air = ...

(ii) The antinode is slightly further from the water than the end of the glass tube.

Explain how this would affect the accuracy of your calculated value for the speed of sound.

(2)

(Total for Question 12 = 7 marks)

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13 A filament lamp is marked 12 V 60 W. The filament is made from a long metal wire with a diameter of 0.25 mm. The metal has a resistivity of $5.6 \times 10^{-8}\,\Omega\,m$ when the wire is at normal operating temperature.

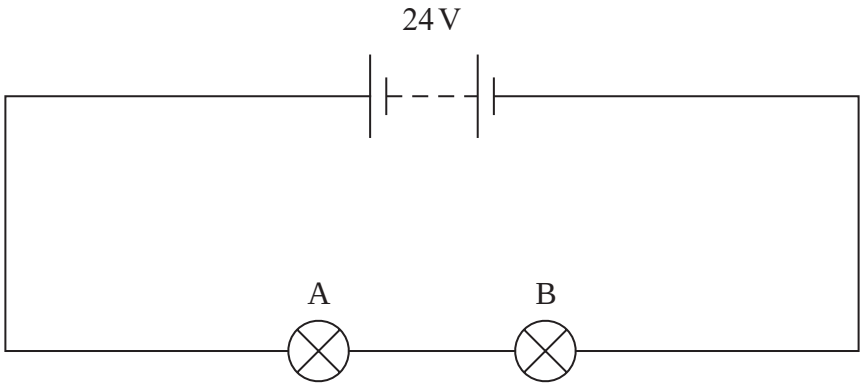
(a) Calculate the length of the wire in the filament.

(4)

Length of wire = ...

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(b) A student has two filament lamps. Lamp A is marked 12 V 60 W and lamp B is marked 12 V 30 W. The student sets up the circuit shown.



The student states that both lamps will operate normally.

Evaluate whether the student's statement is correct.

(3)

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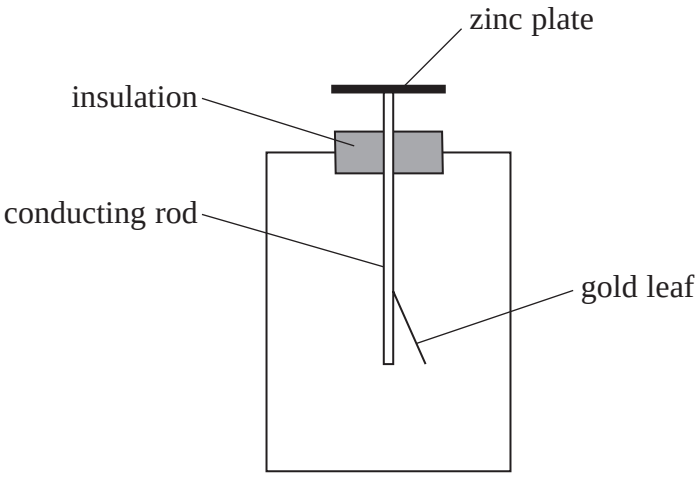
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(Total for Question 13 = 7 marks)

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14 A gold leaf electroscope is used to demonstrate the photoelectric effect. When the zinc plate of the electroscope is given a negative charge, the conducting rod and gold leaf also become negatively charged. The gold leaf deflects away from the metal stem as shown. The deflection of the gold leaf depends on the amount of charge on the zinc plate and the conducting rod.



A beam of ultraviolet radiation is incident on the zinc plate. The gold leaf immediately begins to fall back to the conducting rod.

(a) Explain why this observation cannot be explained by the wave model of electromagnetic radiation.

(2)

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(b) Photons of ultraviolet radiation with an energy of 9.3×10^{-19} J are directed towards the zinc plate.

(i) Calculate the maximum speed with which electrons are released from the plate.

work function of zinc = 4.3 eV

(4)

Maximum speed of electrons = ...

(ii) A student suggests that a greater maximum speed of electrons could have been achieved if both:
– a metal with a lower work function than zinc was used
– ultraviolet radiation with a greater wavelength was used.

Discuss the student's suggestion.

(3)

(Total for Question 14 = 9 marks)

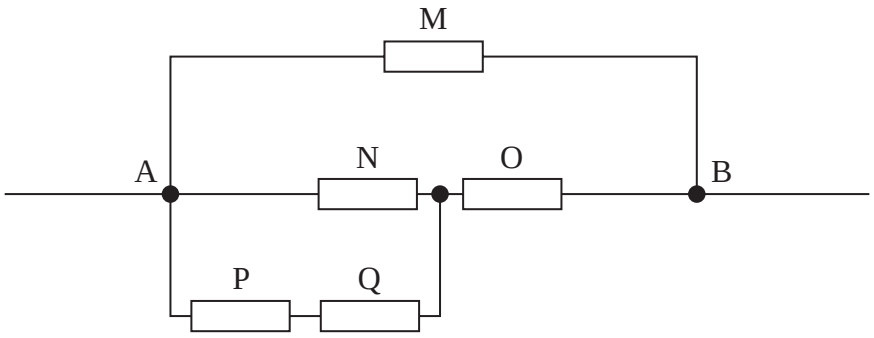
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15 (a) Two resistors of resistance R_1 and R_2 are connected in parallel in a circuit.

Derive a formula for the total resistance R_T of the combination.

(3)

(b) The diagram shows a combination of five resistors, M, N, O, P and Q. Each resistor has a resistance of 5.0 Ω.



(i) Show that the resistance between points A and B is about 3 Ω.

(3)

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(ii) A student is told to modify the combination of resistors so that the combined resistance between A and B is greater than 5.0 Ω. She cannot change the arrangement of the resistors, but she can replace one of the 5.0 Ω resistors with a 20.0 Ω resistor.

Explain, without further calculations, which of the five resistors should be replaced.

(2)

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(Total for Question 15 = 8 marks)

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16 After an atom of hydrogen has been exposed to suitable electromagnetic radiation, the atom can emit visible light. The emitted light contains a small number of different wavelengths of visible light.

*(a) Explain the process that results in the emission of different wavelengths of visible light. Your answer should include reference to energy levels in atoms.

(6)

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(b) It is also possible to make the atoms in a sample of air emit visible light.

Explain why the light emitted by the air has a large number of different wavelengths.

(2)

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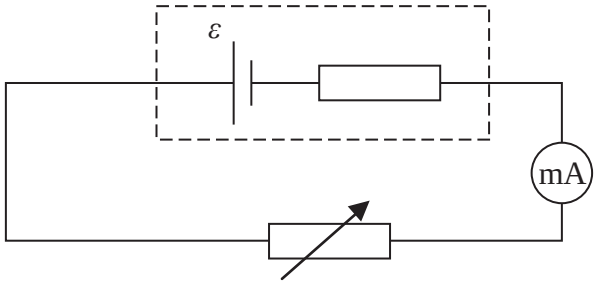
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(Total for Question 16 = 8 marks)

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17 A cell of e.m.f. ε is connected in series with a variable resistor with resistance R as shown. The internal resistance of the cell is r.



When R is 12 Ω, the reading on the ammeter is 107 mA. The circuit is switched on for 300 seconds. In this time, 50 J of energy is transferred by the cell.

(a) Calculate r.

(5)

r = ...

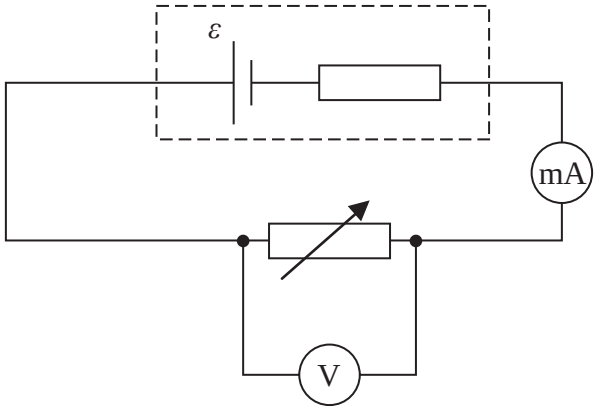
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(b) Increasing R would make the terminal potential difference value closer to ε.

Explain why, without further calculation.

(2)

(c) A voltmeter is added to the circuit as shown.



Explain how this circuit can be used to determine a value for r using a graphical method.

(4)

(Total for Question 17 = 11 marks)

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18 ICESat-2 is a satellite launched into space by NASA in 2018. One purpose of the satellite is to measure the thickness of ice on the Earth's surface. The satellite is powered using solar panels. A laser in the satellite produces a beam of photons, which travel to the Earth and back.

(a) Calculate the intensity of solar radiation as it reaches ICESat-2.

distance from the Sun to ICESat-2 = 1.50×10^{11} m
power of the Sun = 3.83×10^{26} W

(3)

Intensity of solar radiation = ...

(b) The laser emits light with a wavelength of 532 nm. Calculate the energy, in J, of each photon.

(3)

Energy of photon = ... J

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(c) The photons released by the laser are directed towards the Earth. The mean time for these photons to return to the satellite is 3.20 ms.

(i) Calculate the height that ICESat-2 orbits above the surface of the Earth.

(2)

Height above Earth = ...

(ii) When photons arriving at the satellite are detected, only those with a wavelength of exactly 532 nm are used in the analysis of the results.

Suggest why.

(1)

(d) At one point, ICESat-2 passes over a flat ice sheet. The ice sheet is 1000 m above sea level.

Explain how the measurements taken by ICESat-2 can be used to show that the ice sheet has a flat surface and is higher than sea level.

(2)

(Total for Question 18 = 11 marks)

TOTAL FOR SECTION B = 70 MARKS
TOTAL FOR PAPER = 80 MARKS

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List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^9\ \text{N m}^2\ \text{C}^{-2}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^8\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Unit 1

Mechanics

Kinematic equations of motion

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

$$v = u + at$$

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

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

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

$$\Delta W = F\Delta s$$

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

$$\Delta E_{grav} = mg\Delta h$$

Power

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

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

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Efficiency

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Materials

Density $\rho = \frac{m}{V}$

Stokes' law $F = 6\pi\eta rv$

Hooke's law $\Delta F = k\Delta x$

Elastic strain energy $\Delta E_{el} = \frac{1}{2} F\Delta x$

Young modulus $E = \frac{\sigma}{\varepsilon}$ where

Stress $\sigma = \frac{F}{A}$

Strain $\varepsilon = \frac{\Delta x}{x}$

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Unit 2

Waves

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\frac{T}{\mu}}$
Intensity of radiation	$I = \frac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \frac{c}{v}$
Critical angle	$\sin C = \frac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

Potential difference	$V = \frac{W}{Q}$
Resistance	$R = \frac{V}{I}$
Electrical power, energy	$P = VI$
	$P = I^2R$
	$P = \frac{V^2}{R}$
	$W = VIt$
Resistivity	$R = \frac{\rho l}{A}$
Current	$I = \frac{\Delta Q}{\Delta t}$
	$I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Particle nature of light

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$
de Broglie wavelength	$\lambda = \frac{h}{p}$

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