1 Which of the following is an SI base unit?

- ☐ **A** ampere
- ☐ **B** charge
- ☐ **C** coulomb
- ☐ **D** current

(Total for Question 1 = 1 mark

2 A cell with emf $\mathcal{E}$ and internal resistance r has a potential difference V across its terminals when the current is I.

The internal resistance r is given by

- ☐ **A** $\frac{\mathcal{E}}{I}$
- ☐ **B** $\frac{V}{I}$
- ☐ **C** $\frac{\mathcal{E} + V}{I}$
- ☐ **D** $\frac{\mathcal{E} - V}{I}$

$\mathcal{E} = Ir + V$

$r = \frac{\mathcal{E} - V}{I}$

(Total for Question 2 = 1 mar

A rechargeable cell is labelled 1500 mA h.

If the current is 1500 mA for 1 hour, the charge transferred is

$1500 \times 10^{-3} \times 60 \times 60$

- ☐ **A** 1.5 C
- ☐ **B** 90 C
- ☐ **C** 1500 C
- ☐ **D** 5400 C

4 The level of detail in an ultrasound scan can be increased by using a

- ☐ **A** higher frequency.
- ☐ **B** higher wave speed.
- ☐ **C** longer pulse duration.
- ☐ **D** longer wavelength.

(Total for Question 4 = 1 mar

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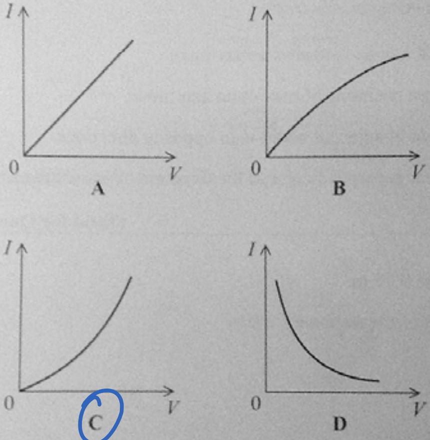
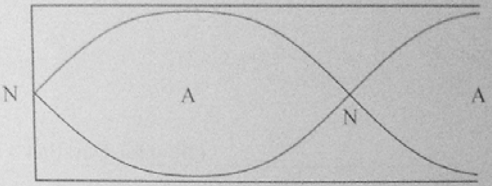
5 Which graph correctly shows how the current *I* varies with the potential difference *V* for a negative temperature coefficient thermistor?



Questions 6 and 7 refer to the diagram below.

The diagram represents a stationary sound wave in a pipe closed at one end.



Nodes are labelled N and antinodes are labelled A.

6 Which of the following statements is true?

☐ **A** The amplitude at a node is always a maximum.

☐ **B** The antinodes are positions of maximum amplitude.

☐ **C** The displacement at adjacent nodes is in opposite directions.

☐ **D** The displacement is perpendicular to the direction of wave travel.

(Total for Questio

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7 The length of the pipe is 0.75 m.

What is the wavelength of the stationary wave?

☐ **A** 0.25 m

☐ **B** 0.50 m

☐ **C** 1.00 m

☐ **D** 1.50 m

$\frac{3\lambda}{4} = 0.75$

8 When a charge of 2.0 C passes through a light bulb, 5.0 J of energy is transferred.

What is the potential difference across the bulb?

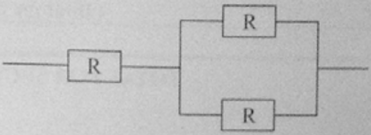
- ☐ **A** 0.4 V
- ☐ **B** 2.5 V
- ☐ **C** 3.0 V
- ☐ **D** 10 V

$W = QV$

$V = \frac{5}{2}$

(Total for Question 8 =

9 The diagram shows a combination of three resistors each of resistance R.



The total resistance of the combination can be found using

- ☐ **A** $R + \frac{1}{R} + \frac{1}{R}$
- ☐ **B** $R + \frac{1}{\left(\frac{1}{R} + \frac{1}{R}\right)}$
- ☐ **C** $\frac{1}{\left(\frac{1}{R} + \frac{1}{(R+R)}\right)}$
- ☐ **D** $\frac{1}{R} + \frac{1}{\left(\frac{1}{R} + \frac{1}{R}\right)}$

10 An ambulance is moving towards an observer with its siren sounding.

Which row of the table correctly describes the apparent changes in wave properties of the sound from the siren caused by the Doppler effect?

	Wave speed	Frequency	Wavelength
☒ A	no change	increases	decreases
☒ B	decreases	decreases	increases
☒ C	no change	decreases	increases
☒ D	increases	increases	decreases

11 The list of data, formulae and relationships states

Current $I = nqvA$

Show that the units on each side of the equation are consistent.

(3)

LHS: A

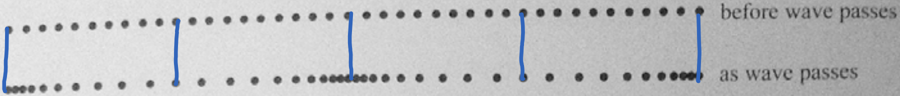
RHS: $m^{-3} \cdot C \cdot ms^{-1} \cdot m^2$

$= m^{-3} \cdot m^3 \cdot As \cdot s^{-1}$

$= A$

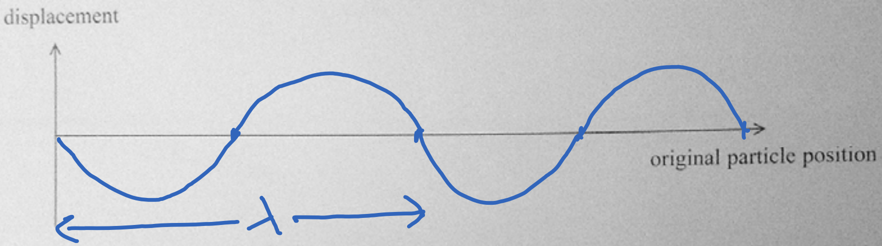
(Total for Question 11 = 3 marks)

12 The diagram represents the position of particles before a progressive wave passes and as the wave passes.



(a) On the axes below, draw a corresponding graph of displacement against original particle position and label the wavelength.

(2)



(b) Suggest what type of progressive wave could be represented by the diagram.

(1)

longitudinal

(Total for Question 12 = 3 marks)

13 Surveyors sometimes use laser rangefinders to measure the distance to objects such as buildings and trees.

A reflector is placed on the object. The rangefinder emits pulses of light and detects them when they return after being reflected.

(a) State why the laser light is emitted in pulses.

(1)

So that emitted and detected light are separate

(b) The rangefinder measures distances between 50 cm and 1 km.

Calculate the longest pulse duration that would allow this range of measurements.

(3)

$$t = \frac{2d}{c} = \frac{2 \times 0.5}{3 \times 10^8}$$

$$= 3.3\text{ns}$$

Pulse duration = ...

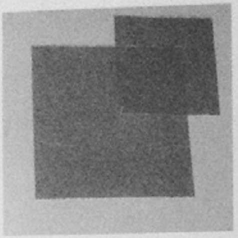
(c) Distances inside buildings, such as the length of a room, are often measured using ultrasound.

Suggest a reason why a laser rangefinder would be more suitable than one using ultrasound for measuring the distance to a tree 1 km away.

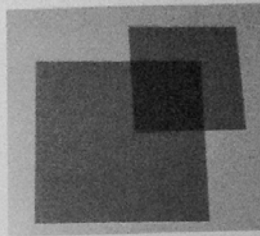
(1)

- The pulse would take longer if ultrasound is used
- Less diffraction for laser

*14 The photographs show two polarising filters on a light background. Between Photograph 1 and Photograph 2 being taken, one of the polarising filters is rotated through 90°.



Photograph 1



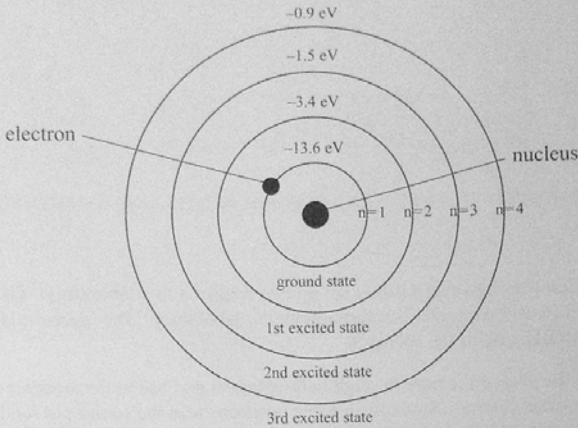
Photograph 2

State what is meant by polarisation and explain the observed difference between the appearance of the polarising filters in the two photographs.

(5)

- Restricting oscillations of a transverse wave in one plane
- Background is seen darker through polarisers, as some light is blocked
- When polarisers are at 90° to each other, all light that passes through one is blocked by the other so the region appears black

15 In 1913 Niels Bohr proposed the model of the hydrogen atom represented in the diagram.



In this model an electron can orbit the nucleus at different energy levels, some of which are shown in the diagram.

(a) State what is meant by excited with reference to this model.

(1)

Having more energy than the lowest possible

(b) Calculate the highest frequency of radiation that could be emitted by electrons involved in transitions between energy levels shown in the diagram.

(4)

$\Delta E = hf$

$f = \dfrac{(13.6 - 0.9) \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$

$= 3.1 \times 10^{15}$ Hz

16 (a) State what is meant by the principle of superposition of waves.

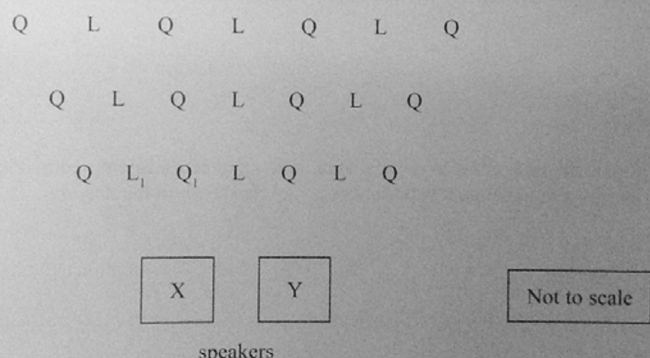
(2)

When waves come together, the resultant amplitude is the vector sum of the amplitudes of individual waves.

(b) A teacher demonstrating superposition set up two speakers in a laboratory. The students stood in different positions throughout the laboratory. The teacher played a single note through one of the speakers.

The teacher then played the note through both speakers and asked the students to describe their observations. Students in some positions said the sound got louder and students in other positions said the sound got quieter.

The students noted positions of louder sound L and quieter sound Q. Their results are shown in the diagram.



(i) The wavelength of the note was 0.8 m.
The following distances were measured:

X to L_1 = 1.6 m

Y to L_1 = 2.4 m

X to Q_1 = 1.7 m

Y to Q_1 = 2.1 m

Using the distances given, explain why the sound is loud at L_1 and quiet at Q_1.

(4)

• Path difference at L_1: $2.4 - 1.6 = 0.8 = \lambda$

Waves from X and Y arrive at L_1 in phase so they interfere constructively

• Path difference at Q_1: $2.1 - 1.7 = 0.4 = \frac{\lambda}{2}$

Waves from X and Y arrive at Q_1 in anti-phase so they interfere destructively

(ii) Explain why this pattern is **not** observed when the speakers are playing music.

(2)

• Music has many different wavelengths.

• Points of constructive/destructive interference are not fixed

17*(a) A metal surface is illuminated with light of a single frequency. This frequency is above the threshold frequency of the metal and so electrons are emitted. The rate of electron emission is measured.

The intensity of the incident light is then decreased but its frequency remains unchanged.

Describe the change in electron emission that would be observed and how this change would be explained by the wave theory and by the particle theory of light.

(3)

- Rate of emission reduced
- Wave: Intensity $\propto$ energy. Less energy emits less electrons
- Particle: Intensity $\propto$ no. of photons. One-to-one emission so less electrons emitted

(b) Light of frequency 7.3×10^{14} Hz is incident on the surface of the metal. The maximum kinetic energy observed for emitted electrons is 1.8×10^{-19} J.

Calculate the work function energy for the metal in J.

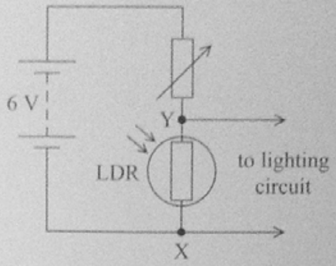
(2)

$$hf = \phi + KE_{max}$$

$$\phi = 6.63 \times 10^{-34} \times 7.3 \times 10^{14} - 1.8 \times 10^{-19}$$

$$= 3.0 \times 10^{-19} \text{ J}$$

18 A student designed a circuit to switch on a light when it gets dark.
The circuit contained a light dependent resistor (LDR) in series with a variable resistor to control the light level at which the lighting circuit is switched on.



The resistance of the LDR decreases as the radiation flux of the incident light increases.

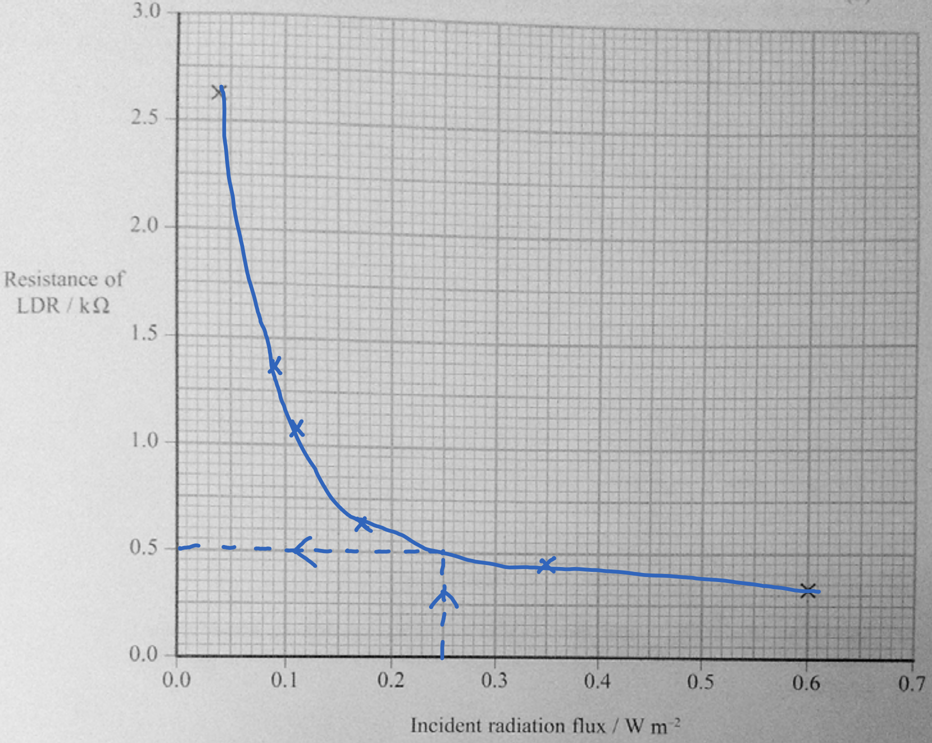
The student placed a lamp at different distances from the LDR. For each distance the radiation flux incident on the LDR was measured using a light meter and the resistance of the LDR was measured.

The results are shown in the table.

Incident radiation flux / W m^{-2}	Resistance of LDR / kΩ
0.04	2.62
0.09	1.37
0.11	1.08
0.17	0.63
0.35	0.44
0.60	0.32

(a) Use the results in the table to complete the graph.

(3)



(b) The lighting circuit will switch on when the potential difference across XY is 0.60 V.

Determine the required resistance R of the variable resistor so that the lighting circuit will switch on when the incident radiation flux is 0.25 W m^{-2}.

(3)

When flux is 0.25 Wm^{-2}, resistance is 500 Ω

$$0.6 = 6 \times \frac{500}{500 + R}$$

$$500 + R = 5000$$

$$R = 4500\ \Omega$$

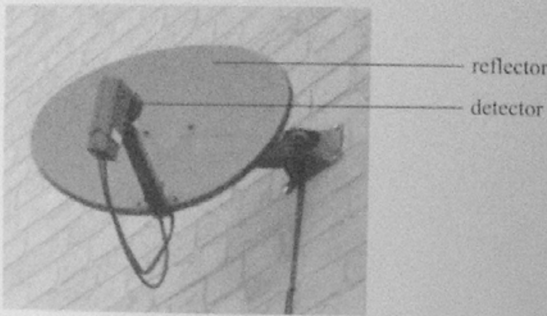
Resistance = ...

(c) Apart from eliminating human error, suggest how using a resistance sensor and a radiation flux sensor connected to a data logger could have improved the quality of the graph.

(2)

More readings can be taken, which would provide more points on the graph

19 The photograph shows a satellite television dish.



Electromagnetic radiation from a communications satellite is reflected from the reflector to the detector.

(a) The radiation used has a frequency of 12.6 GHz.

(i) Show that the wavelength of the radiation is about 2 cm.

(2)

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{12.6 \times 10^9} = 2.4\text{ cm}$

(ii) State the region of the electromagnetic spectrum to which this radiation belongs.

(1)

microwave

(b) The radiation incident on the reflector has a radiation flux of 4.8×10^{-13} W m^{-2}.

Calculate the power of the incident radiation.

area of the reflector = 0.27 m^2

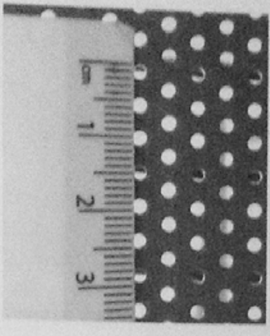
(2)

$P = 4.8 \times 10^{-13} \times 0.27$

$= 1.3 \times 10^{-13}$ W

(c) The reflector contains many small holes.

(i) Use the photograph to estimate the diameter of the holes.



(1)

d = 2 mm

(ii) It is important that the radiation is reflected to the detector with the maximum possible power.

Use the idea of diffraction effects to explain why the radiation is reflected as if from solid metal.

(2)

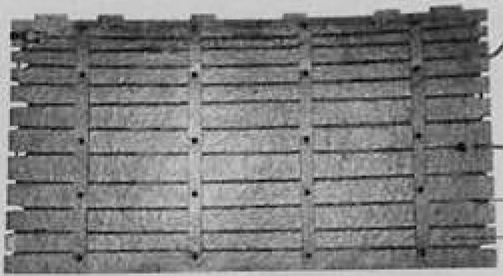
Holes are much smaller than the wavelength so not much diffraction occurs so most radiation is reflected rather than transmitted

(iii) Suggest a reason for having holes in the reflector, rather than using solid metal.

(1)

- Makes it lighter
- Affected less by the wind

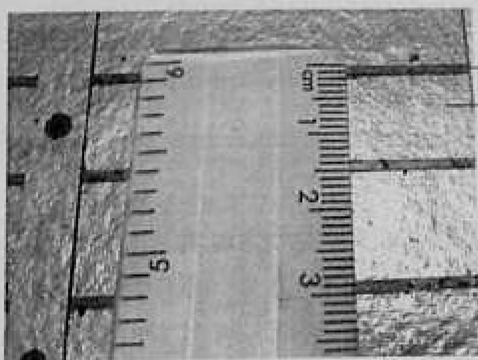
20 The photograph shows a heating section from a toaster. This consists of a long, thin metal strip mounted on an insulating material.



The metal strip carries a large current producing a high temperature. As a result, infrared radiation is emitted which toasts bread.

(a) A student is asked to identify the metal used for the strip by calculating its resistivity. The student takes measurements of the resistance and dimensions of the metal strip.

(i) The photograph shows the student measuring the width of the metal strip.



Comment on the use of this method to measure the width of the metal strip.

(2)

The precision of ruler is 1mm, which creates a large percentage error. A micrometer is more suitable

(ii) The student obtained the following measurements for a sample of the metal strip.

resistance = 1.8 Ω
length = 48.5 cm
width = 1.5 mm
thickness = 0.24 mm

Calculate the resistivity of the metal in Ω m.

(2)

$$\rho = \frac{RA}{l} = \frac{1.8 \times 1.5 \times 10^{-3} \times 0.24 \times 10^{-3}}{48.5 \times 10^{-2}}$$

$$= 1.3 \times 10^{-6}\ \Omega m$$

Resistivity = ... Ω

(b) The following information is shown on the toaster.

1400 W, 230 V

Calculate the total resistance of the metal strips in the toaster.

(2)

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

$$R = \frac{230^2}{1400} = 38\ \Omega$$

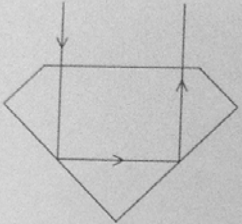
Total resistance = ...

(c) Explain why the resistance of the metal strips in the toaster increases as the temperature increases.

(3)

- metal ions gain kinetic energy and vibrate more
- more collisions between electrons and ions
- Drift velocity decreases so there's less current for a given p.d.

21 Cut gemstones used in jewellery 'sparkle' because a large proportion of the incident light undergoes total internal reflection. An example of total internal reflection in a cut gemstone is shown in the diagram.



(a) Diamond is a popular gemstone because it has a very high refractive index.

Show that the refractive index of diamond is about 2.4.

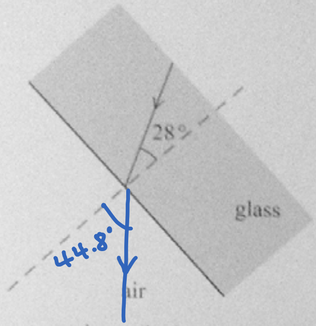
speed of light in diamond = 1.24×10^8 m s^{-1}

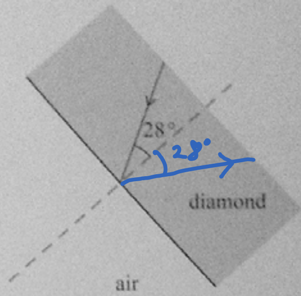
(2)

$n = \frac{c}{v} = \frac{3.00 \times 10^8}{1.24 \times 10^8} = 2.42$

(b) Imitation gemstones can be made from glass.

The diagrams show incident light at a boundary of glass with air and at a boundary of diamond with air. The angle of incidence is 28° in each case.





Use appropriate calculations to determine what happens to the light in each case and complete the diagrams to show this, labelling the relevant angles.

refractive index of glass = 1.50

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

(6)

Diamond: $\sin \theta_c = \frac{1}{2.42}$

$\theta_c = 24.4° \Rightarrow$ Reflection

Glass: $\sin \theta_c = \frac{1}{1.5}$

$\theta_c = 41.8° \Rightarrow$ Refraction

$n = \frac{\sin \theta_r}{\sin \theta_i}$

$1.5 = \frac{\sin \theta_r}{\sin 28}$

$\theta_r = 44.8°$

(c) Suggest why diamonds sparkle more than imitations made from glass.

(2)

Diamond has a lower critical angle so more light undergoes total internal reflection