1. (a) A 12 V 36 W lamp is lit to normal brightness using a 12 V car battery of negligible internal resistance. The lamp is switched on for one hour (3600 s). For the time of 1 hour, calculate

(i) the energy supplied by the battery

energy = ... J

[2]

(ii) the charge passing through the lamp

charge = ... unit ....

[3]

(iii) the total number of electrons passing through the lamp.

number of electrons = ...

[2]

(b) The wires connecting the 36 W lamp to the 12 V battery are made of copper. They have a cross-sectional area of 1.1×10^{-7} m^2. The current in the wire is 3.0 A. The number *n* of free electrons per m^3 for copper is 8.0×10^{28} m^{-3}.

(i) Describe what is meant by the term *mean drift velocity* of the electrons in the wire

....

....

....

[2]

(ii) Calculate the mean drift velocity v of the electrons in this wire.

v = ... m s^{-1}

[3]

[Total 12 marks]

2. Define the *resistivity* ρ of a metal wire.

....

....

....

[Total 2 marks]

3. (a) In the UK the National Grid is used to transmit electric power. Each pylon supports 24 cables. See Fig. 1. Each cable consists of 38 strands of aluminium. See Fig. 2.

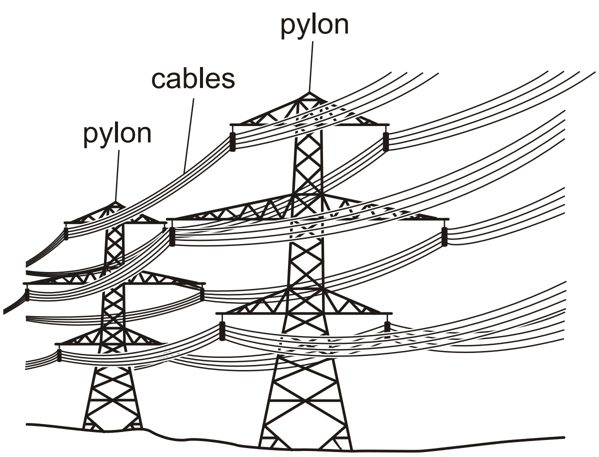


Fig. 1

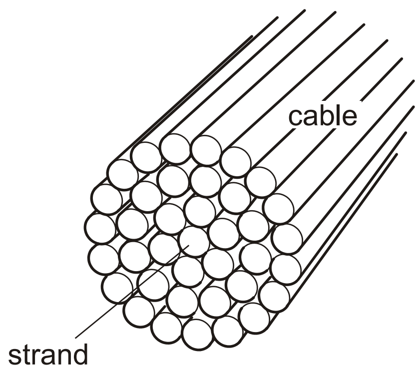


Fig. 2

(i) The resistance per km of a cable is 0.052 Ω km^{-1}. Explain why the resistance per km of a single strand is approximately 2.0 Ω km^{-1}.

....

....

....

[2]

(ii) The resistivity of aluminium is 2.6 × 10^{-8} Ω m. Calculate the cross-sectional area *A* of a single strand of the cable.

A = ... m^2

[2]

(b) The input voltage to each cable in Fig. 1 is 400 kV. The cable carries a current of 440 A. Calculate

(i) the input power to one cable

input power = ... W

[2]

(ii) the number of cables required to transmit the power from a 2000 MW power station

number of cables = ...

[1]

(iii) the power lost as heat per km of cable

lost power = ...

[3]

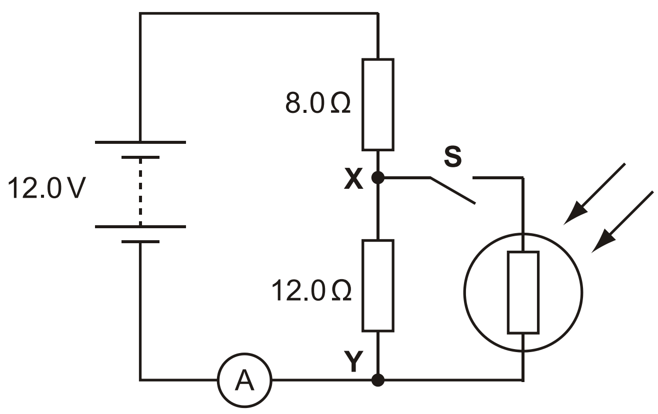
(iv) the percentage of the input power that is available at a distance of 100 km from the power station.

percentage of power =................................. %

[2]

[Total 12 marks]

4. The figure below shows a circuit containing a battery of e.m.f. 12 V, two resistors, a light-dependent resistor (LDR), an ammeter and a switch **S**. The battery has negligible internal resistance.



(a) When the switch **S** is open, show that the potential difference between the points **X** and **Y** is 7.2 V.

[2]

(b) The switch **S** is now closed. Describe and explain the change to each of the following when the intensity of light falling on the LDR is increased:

(i) the ammeter reading

....

....

....

[2]

(ii) the potential difference across **XY**.

....

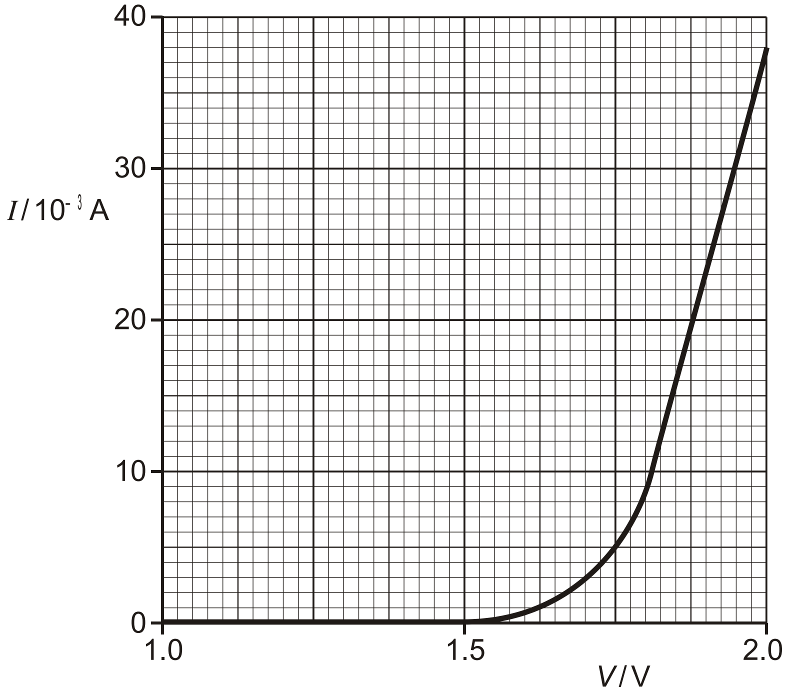
....

....

[2]

[Total 6 marks]

5. The figure below shows the I-V characteristic of a light-emitting diode (LED).



(i) Describe the significant features of the graph in terms of current, voltage and resistance.

✎ *In your answer you should make clear how the features of the graph are related to the action of an LED*.

....

....

....

....

....

....

....

....

[5]

(ii) Calculate the resistance of the LED

1 at 1.2 V

resistance = ... Ω

[1]

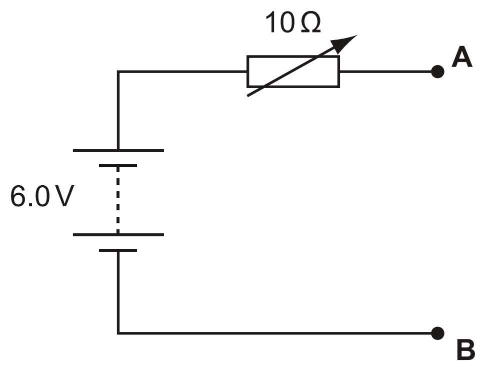
2 at 1.9 V

resistance = ... Ω

[2]

[Total 8 marks]

6. (a) In order to carry out an investigation to determine the *I-V* characteristic of an LED a student connects the circuit shown in the figure below.



On the figure above add an LED with a 100 Ω resistor in series, an ammeter and a voltmeter to complete the circuit between terminals **A** and **B**.

[3]

(b) In order to carry out an investigation to determine the I-V characteristic of an LED a student connects the circuit shown in Fig. 1.

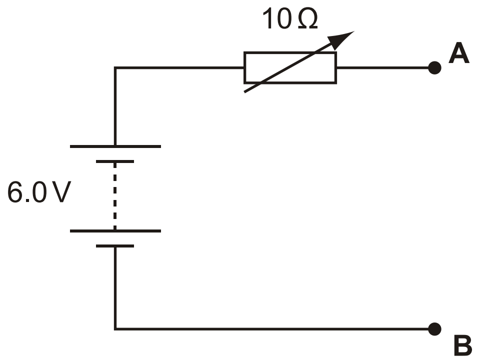


Fig. 1

Another student uses the 10 Ω variable resistor as a potentiometer (potential divider) as shown in Fig. 2. The rest of the circuit is then completed between terminals **A** and **B** as for Fig. 1.

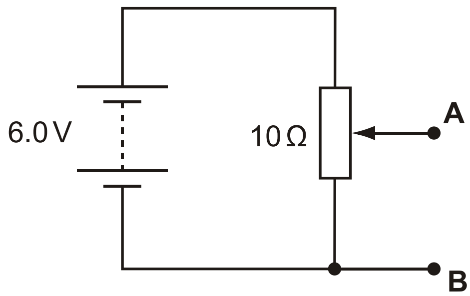


Fig. 2

Explain why the circuit of Fig. 2 is more suitable for obtaining the I-V characteristic of the LED than the circuit of Fig. 1.

....

....

....

....

....

[3]

[Total 6 marks]

7. When designing a circuit which includes an LED, it is normal practice to connect a resistor in series with the LED, in this case 100 Ω. Suggest and explain the purpose of this resistor.

....

....

....

[Total 2 marks]

8. (i) Define the terms *wavelength, frequency* and *speed* used to describe a progressive wave.

wavelength, λ ....

....

frequency, f ....

....

speed, v ....

....

[3]

(ii) Hence derive the wave equation $v = f\lambda$ which relates these terms together.

[2]

[Total 5 marks]

9. (i) Explain what is meant by *infra-red radiation*.

....

....

.... [2]

(ii) For infra-red radiation emitted at a frequency of 6.7×10^{13} Hz, calculate

1 its wavelength

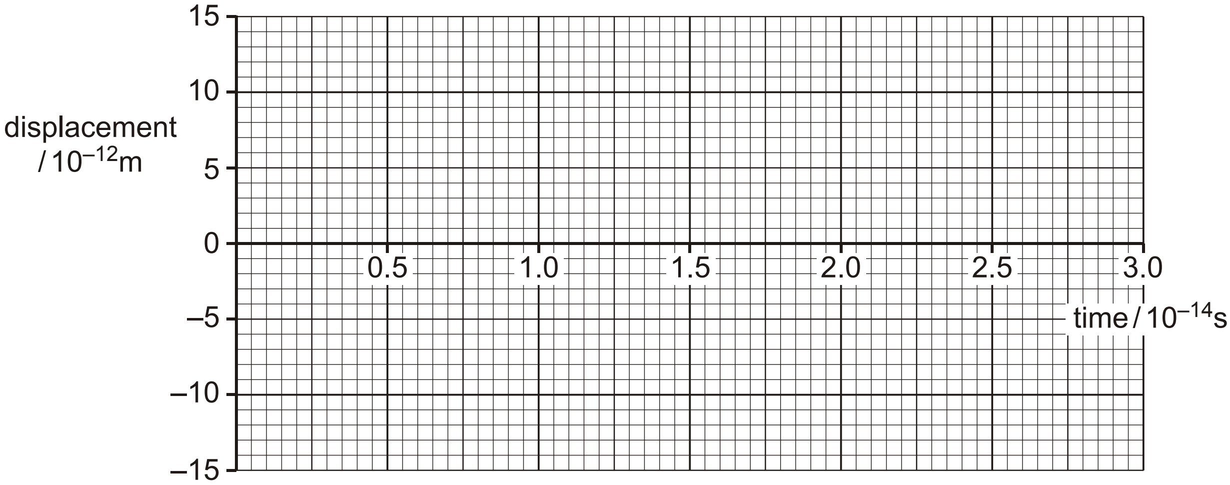
wavelength = ... m [2]

2 its period of oscillation.

period = ... s [2]

(iii) Infra-red radiation is absorbed by molecular ions in a crystal causing them to vibrate at a frequency of 6.7×10^{13} Hz. The amplitude of oscillation of the ions is 8.0×10^{-12} m.

On the grid below sketch a graph showing the variation with time of the displacement of an ion.



[3]

[Total 9 marks]

10. Interference of waves from two sources can only be observed when the waves are coherent.

Explain the meaning of

(i) *interference*

....

....

....

[2]

(ii) coherence.

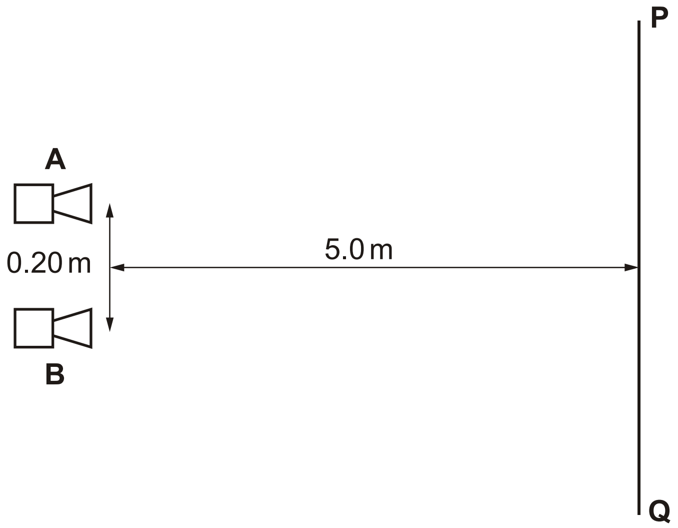
....

....

[1]

[Total 3 marks]

11. The figure below shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of equal amplitude in phase and of wavelength 30 mm. A detector, moved along the line **PQ** at a distance of 5.0 m from **AB**, detects regions of high and low intensity forming an interference pattern.



(i) Use the ideas of path difference or phase difference to explain how the interference pattern is formed.

....

....

....

....

....

....

[3]

(ii) Calculate the separation between one region of high intensity and the next along the line **PQ**.

separation = ... m

[2]

(iii) State the effect, if any, on the position and intensity of the maxima when each of the following changes is made, separately, to the experiment.

1 The amplitude of the transmitted waves is doubled.

....

....

....

[2]

2 The separation between the transmitters is halved.

....

....

....

[2]

3 The phase of transmitter **A** is reversed so that there is now a phase difference of 180° between the waves from **A** and **B**.

....

....

....

[2]

[Total 11 marks]

12. (a) A helium-neon laser emits red light of wavelength 6.3×10^{-7} m.

(i) Show that the energy of a single photon is about 3×10^{-19} J.

[2]

(ii) The power of the laser beam is 1.0 mW. Show that about 3×10^{15} photons are emitted by the laser each second.

[1]

(iii) The photons of red light are emitted by the neon atoms in the gas inside the laser.

Explain what *energy levels* are and how they can be used to explain the emission of photons from atoms.

✎ In your answer take care to make your explanation clear.

....

....

....

....

....

....

....

....

[4]

(iv) Another laser emits blue light. The power in its beam is also 1.0 mW.

Explain why the laser emitting blue light emits fewer photons per second compared with a laser of the same power emitting red light.

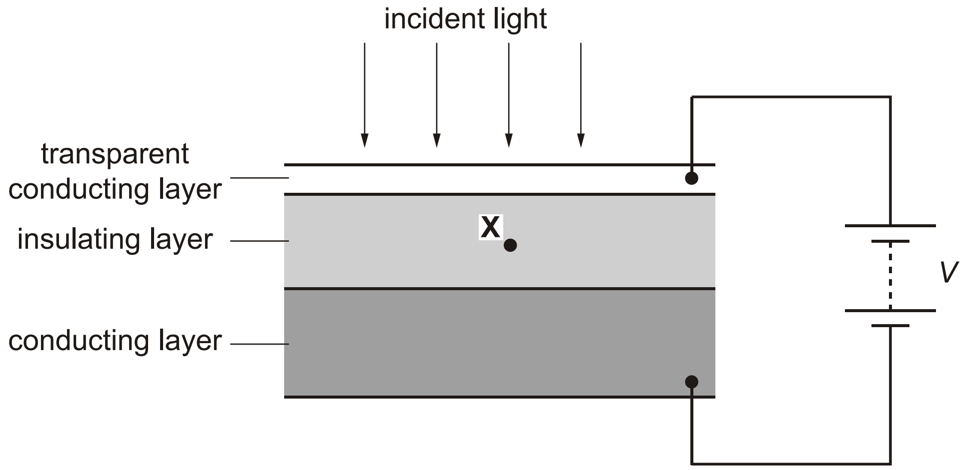
....

....

....

[2]

(b) A photodiode is a circuit component which can be used to convert a light signal into an electrical one. The figure below shows an enlarged cross-section through a photodiode to illustrate how it is constructed. Light incident on the thin transparent conducting surface layer of the diode passes through it to be absorbed in the insulating layer. The energy of each photon is sufficient to release one electron in the insulating layer. The potential difference *V* applied across the insulating layer causes these electrons to move to one of the conducting layers.



(i) Draw an arrow on the figure above to show the direction of motion of an electron released at point **X** in the centre of the insulating layer.

[1]

A helium-neon laser emits red light of wavelength 6.3×10^{-7} m.

(ii) The red light from the laser is incident on the photodiode. Experiments show that only 20% of the red light photons release electrons in the insulating layer and hence in the circuit of the figure above. Calculate the current through the photodiode.

current = ... A

[3]

(iii) Suggest one reason why the efficiency of the photodiode is less than 100%.

....

....

[1]

[Total 14 marks]

13. In 1927 it was shown by experiment that electrons can produce a diffraction pattern.

(a) (i) Explain the meaning of the term *diffraction*.

....

....

....

[1]

(ii) State the condition necessary for electrons to produce observable diffraction when passing through matter, e.g. a thin sheet of graphite in an evacuated chamber.

....

....

....

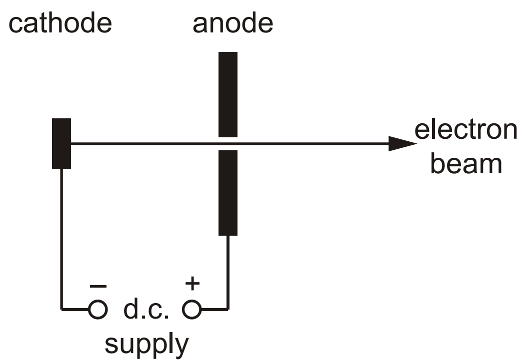
....

[2]

(b) Show that the speed of an electron with a de Broglie wavelength of 1.2×10^{-10} m is 6.0×10^{6} m s^{-1}.

[3]

(c) The electrons in (b) are accelerated to a speed of 6.0×10^{6} m s^{-1} using an electron gun shown diagrammatically in the figure below.



(i) Calculate the potential difference *V* across the d.c. supply between the cathode and the anode.

V = ... V

[3]

(ii) Suggest why, in an electron gun, the cathode is connected to the negative terminal of the supply rather than the positive terminal.

....

....

....

[1]

[Total 10 marks]

14. A set of Christmas tree lights consists of 40 identical filament lamps connected in series across a supply of 240 V.

(a) Define *resistance*.

....

....

[1]

(b) Each lamp when lit normally carries a current of 250 mA.

Calculate

(i) the potential difference *V* across a lamp

V = ... V

[1]

(ii) the resistance R of a lamp.

R = ... Ω

[2]

(c) Fig. 1 shows the results of an experiment to find how the current in one of the lamps varies with the potential difference across it.

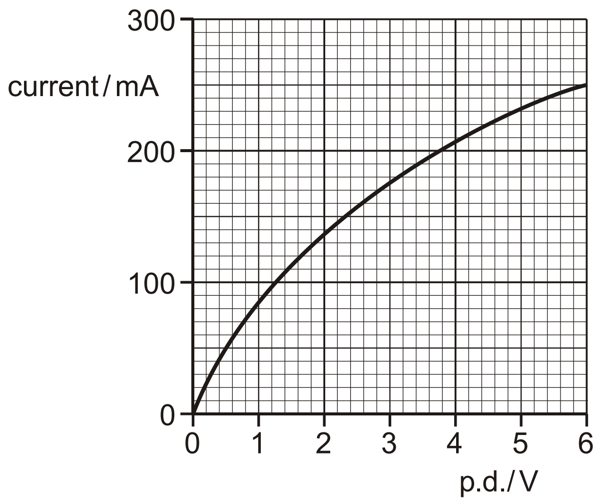


Fig. 1

(i) Draw a diagram of the circuit that you would use to perform this experiment.

[3]

(ii) The resistance of the lamp when at room temperature is 10 Ω. Using Fig. 1.1 sketch a graph on the axes of Fig. 2 of the variation of resistance *R* with current for the lamp.

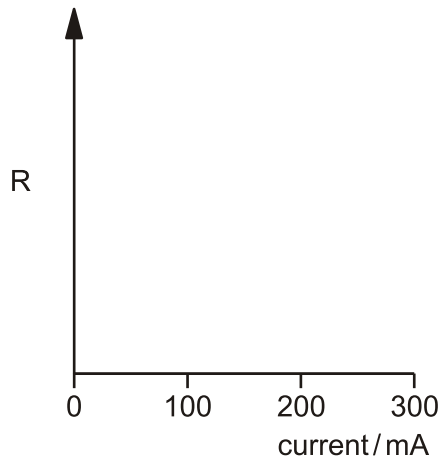


Fig. 2

[2]

(iii) Explain why the resistance of the lamp varies as shown by the graph you have drawn on Fig. 2.

....

....

....

....

[2]

(d) In an alternative design for the set of Christmas tree lights, a 100 Ω resistor is connected in parallel with each lamp.

(i) Describe what happens to the brightness in each set of lamps when one lamp filament burns out.

1 *original set*

....

....

[1]

2 *alternative set*

....

....

....

[1]

(ii) Calculate the current drawn from the supply for the alternative set of lamps with all lamps working.

current = ... A

[3]

[Total 16 marks]

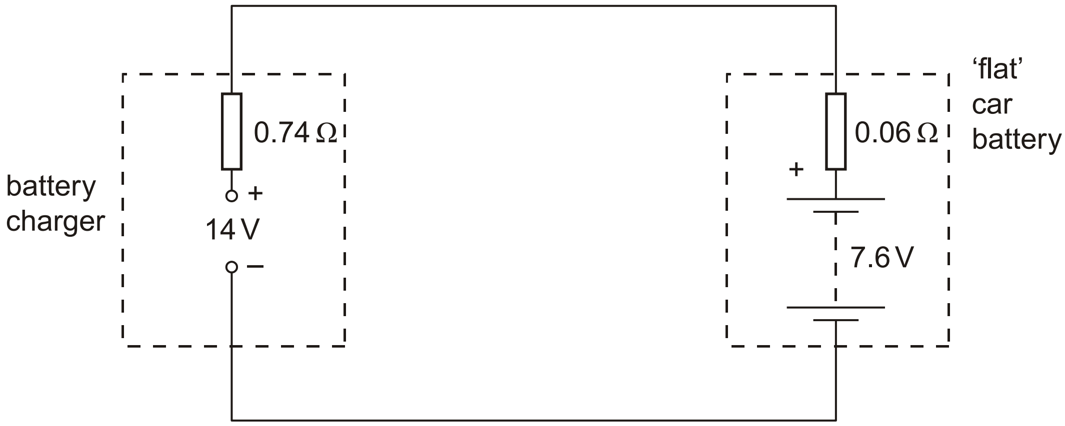
15. (a) A battery of e.m.f. E and internal resistance r delivers a current I to a circuit of resistance R.

Write down an equation for E in terms of r, I and R.

....

[1]

(b) A 'flat' car battery of internal resistance 0.06 Ω is to be charged using a battery charger having an e.m.f. of 14 V and internal resistance of 0.74 Ω, as shown in the figure below.



You can see that the battery to be charged has its positive terminal connected to the positive terminal of the battery charger.

At the beginning of the charging process, the e.m.f. of the 'flat' car battery is 7.6 V.

(i) For the circuit of the figure above, determine

1 the total resistance

resistance = ... Ω

[1]

2 the sum of the e.m.f.s in the circuit.

e.m.f. = ... V

[1]

(ii) State Kirchhoff's second law.

....

....

[1]

(iii) Apply the law to this circuit to calculate the initial charging current.

current = ... A

[2]

(c) For the majority of the charging time of the car battery in the circuit of the figure above, the e.m.f. of the car battery is 12 V and the charging current is 2.5 A. The battery is charged at this current for 6.0 hours. Calculate, for this charging time,

(i) the charge that passes through the battery

charge = ... C

[2]

(ii) the energy supplied by the battery charger of e.m.f. 14 V

energy = ... J

[2]

(iii) the percentage of the energy supplied by the charger which is dissipated in the internal resistances of the battery charger and the car battery.

percentage of energy = ... %

[2]

[Total 12 marks]

16. Fig. 1 shows a thermistor and fixed resistor of 200 Ω connected through a switch **S** to a 24 V d.c. supply of negligible internal resistance. The voltmeter across the fixed resistor has a very high resistance.

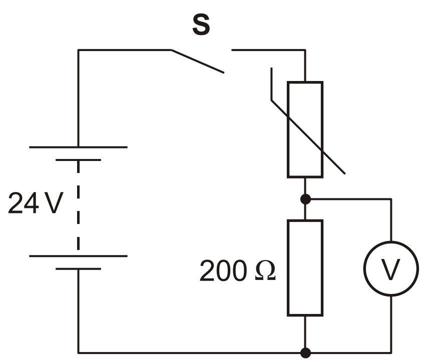


Fig. 1

(a) When the switch **S** is closed the voltmeter initially measures 8.0 V.

Calculate

(i) the current *I* in the circuit

I = ... A

[2]

(ii) the potential difference V_T across the thermistor

V_T = ... V

[1]

(iii) the resistance R_T of the thermistor

R_T = ... Ω

[2]

(iv) the power P_T dissipated in the thermistor.

P_T = ... W

[2]

(b) A few minutes after closing the switch **S** the voltmeter reading has risen to a steady value of 12 V. The value of the fixed resistor remains at 200 Ω.

Explain why

(i) the potential difference across the fixed resistor has increased

....

....

....

....

[3]

(ii) the resistance of the thermistor must now be 200 Ω.

....

....

[1]

(c) Sketch, on the labelled axes of Fig. 2 below, a possible *I*-*V* characteristic for:

(i) the fixed resistor. Label it **R**.

[2]

(ii) the thermistor. Label it **T**.

[2]

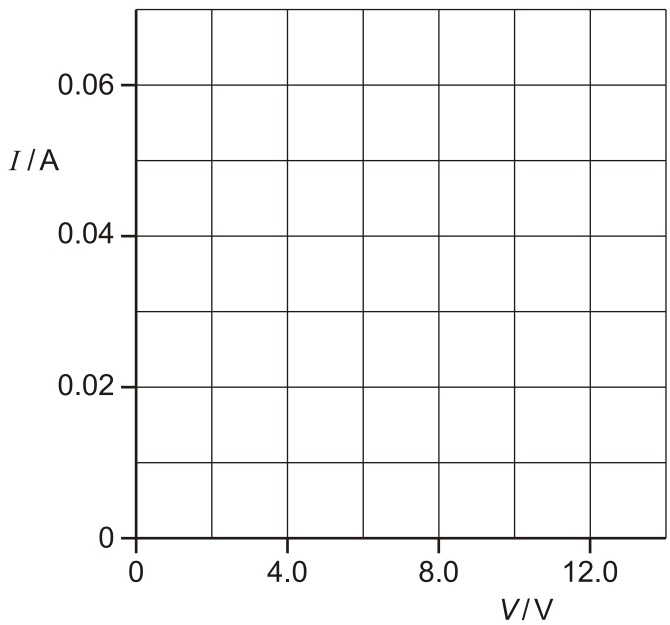


Fig. 2

[Total 15 marks]

17. (i) Both electromagnetic waves and sound waves can be **reflected**. State **two** other wave phenomena that apply to both electromagnetic waves and sound waves.

1 ....

2 ....

[2]

(ii) Explain why electromagnetic waves can be polarised but sound waves cannot be polarised.

....

....

[1]

(iii) Describe briefly an experiment to demonstrate the polarisation of microwaves in the laboratory.

✎ In your answer you should make clear how your observations demonstrate polarisation.

....

....

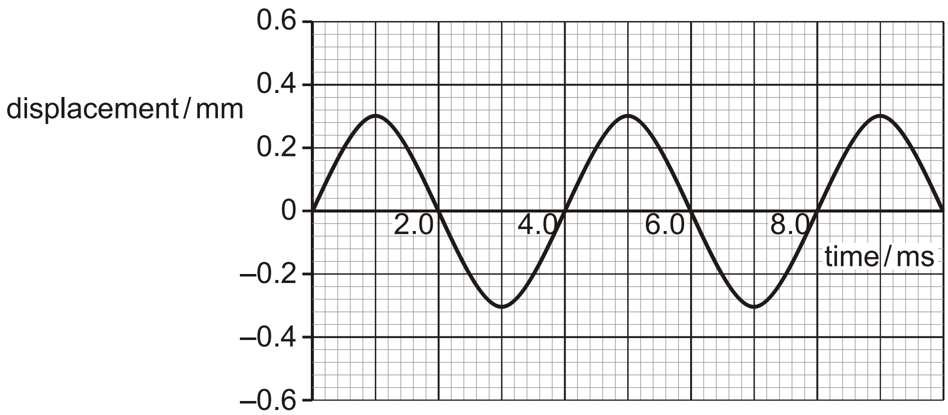
....

....

[4]

[Total 7 marks]

18. A sound wave emitted by a loudspeaker consists of a single frequency. The figure below shows the displacement against time graph of the air at a point **P** in front of the speaker.



(i) Use the figure to find

1 the amplitude of the air motion

amplitude = ... mm

[1]

2 the frequency of the sound wave.

frequency = ... Hz

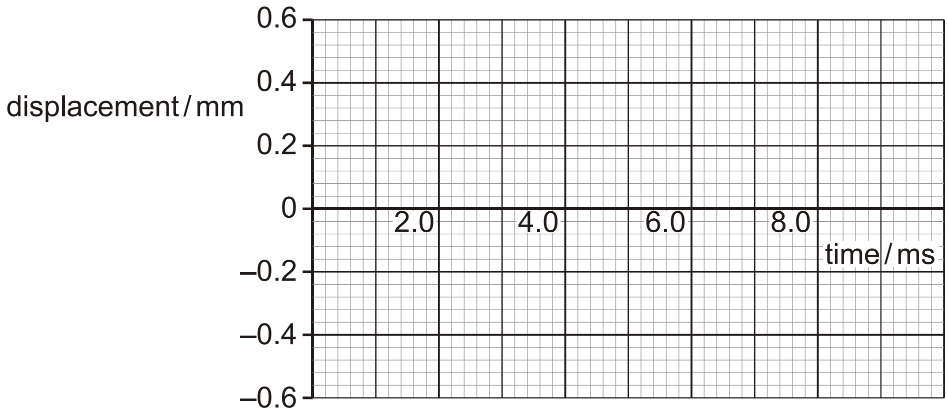
[2]

(ii) The sound generator is adjusted so that the loudspeaker emits a sound at the original frequency and twice the **intensity**. Sketch on the figure below the new displacement against time graph at point **P**. Explain your reasoning.

....

....

....



[3]

(iii) Suggest, with reasons, the apparatus that you would choose to detect and measure the frequency of the sound wave at **P**.

....

....

....

....

[2]

[Total 8 marks]

19. When used to describe stationary (standing) waves explain the terms

(i) node ....

....

[1]

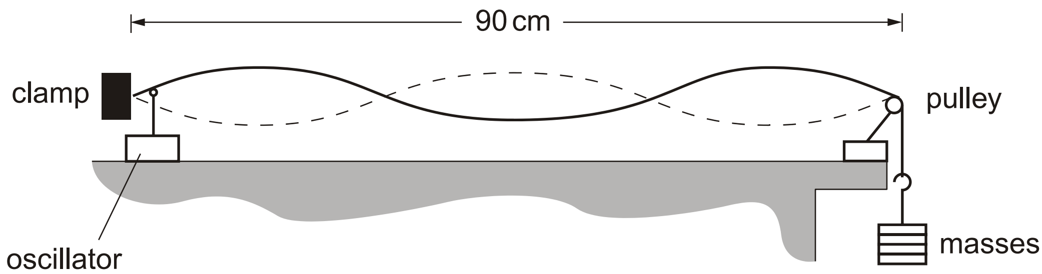
(ii) antinode. ....

....

[1]

[Total 2 marks]

20. (a) The figure below shows a string fixed at one end under tension. The frequency of the mechanical oscillator close to the fixed end is varied until a stationary wave is formed on the string.



(i) Explain with reference to a progressive wave on the string how the stationary wave is formed.

....

....

....

....

....

....

....

[3]

(ii) On the figure above label one node with the letter **N** and one antinode with the letter **A**.

[1]

(iii) State the number of antinodes on the string in the figure above.

number of antinodes = ...

[1]

(iv) The frequency of the oscillator causing the stationary wave shown in the figure is 120 Hz.

The length of the string between the fixed end and the pulley is 90 cm.

Calculate the speed of the progressive wave on the string.

speed = ... m s^{-1}

[3]

(b) The speed *v* of a progressive wave on a stretched string is given by the formula

$v = k\sqrt{W}$

where *k* is a constant for that string. *W* is the tension in the string which is equal to the weight of the mass hanging from the end of the string.

In (a) the weight of the mass on the end of the string is 4.0 N. The oscillator continues to vibrate the string at 120 Hz. Explain whether or not you would expect to observe a stationary wave on the string when the weight of the suspended mass is changed to 9.0 N.

....

....

....

....

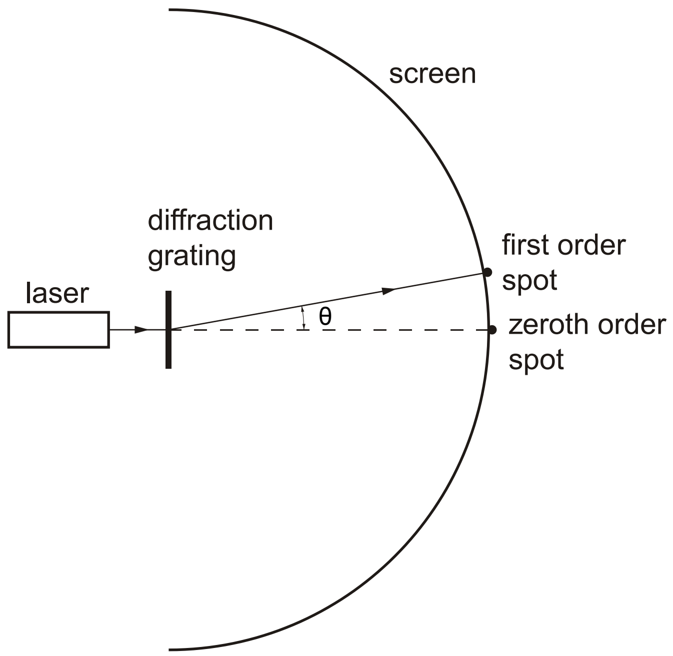
....

....

[3]

[Total: 11 marks]

21. (a) A parallel beam of red light of wavelength 6.3×10^{-7} m from a laser is incident normally on a diffraction grating as shown in the figure below.



Bright red spots are observed on the curved screen placed beyond the grating.

(i) The diffraction grating has 300 lines per millimetre. Show that the separation *d* between adjacent lines of the grating is 3.3×10^{-6} m.

[1]

(ii) Calculate the angle θ at which the first order red spot is seen. This is the first spot away from the straight through position.

θ = ... degrees

[3]

(iii) The screen curves around the full 180° in front of the grating. Explain why there are eleven bright red spots on the screen.

....

....

....

....

....

[3]

(b) Calculate

(i) the energy of each photon of light emitted by the laser at a wavelength of 6.3×10^{-7} m

energy = ... J

[2]

(ii) the number of photons emitted each second to produce a power of 0.50 mW.

number = ...

[2]

[Total: 11 marks]

22. (i) A beam of electrons in a vacuum can travel through a thin sheet of graphite perpendicular to the beam to produce a diffraction pattern of rings on a fluorescent screen beyond the graphite sheet. Explain why this pattern is produced.

....

....

....

....

....

[3]

(ii) Calculate

1 the speed *v* of electrons with a de Broglie wavelength of 5.0×10^{-11} m

v = ... m s^{-1}

[2]

2 the potential difference *V* required to accelerate the electrons to this speed.

V = ... V

[3]

[Total 8 marks]

23. In 1905 Einstein presented a theory to explain the photoelectric effect using the concept of quantisation of radiation proposed by Planck in 1900.

(a) Show, with the aid of a suitably labelled diagram, the arrangement of apparatus that could be used to demonstrate the photoelectric effect. Describe how you would use the apparatus and what would be observed.

✎ *In your answer you should make clear how your observations provide evidence for the photoelectric effect.*

[5]

(b) Describe how the photoelectric effect can be explained in terms of the physics of quantum behaviour.

....

....

....

....

....

....

....

....

....

....

....

....

[5]

[Total 10 marks]

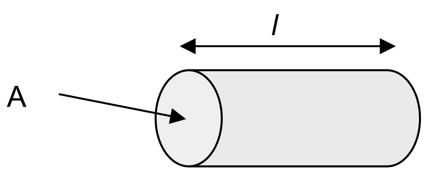
24. (a) Name the charge carriers responsible for electric current in a metal and in an electrolyte.

....

....

[2]

(b)



The diagram above shows a copper rod of length l = 0.080m, having a cross-sectional area $A = 3.0 \times 10^{-4}$ m^2.

The resistivity of copper is 1.7×10^{-8} Ω m.

The copper rod is used to transmit large currents. A charge of 650 C passes along the rod every 5.0 s. Calculate

1. the current in the rod

current = ... A

[2]

2. the total number of electrons passing any point in the rod per second.

number = ...

[2]

[Total 6 marks]

25. (a) (i) Define electrical *resistivity*.

....

....

....

....

[2]

(ii) Explain why the *resistivity* rather than the *resistance* of a material is given in tables of properties of materials.

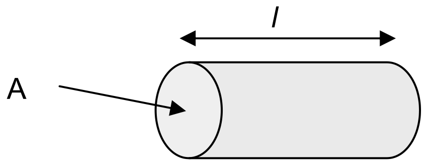
....

....

....

[1]

(b)



The diagram above shows a copper rod of length l = 0.080m, having a cross-sectional area $A = 3.0 \times 10^{-4}$ m^2.

The resistivity of copper is 1.7×10^{-8} Ω m.

Calculate the resistance between the ends of the copper rod.

resistance = ... Ω

[2]

[Total 5 marks]

26. (i) Use energy considerations to distinguish between potential difference (p.d.) and electromotive force (e.m.f.).

....

....

....

....

[2]

(ii) Here is a list of possible units for e.m.f. or p.d.

J s^{-1} J A^{-1} J C^{-1}

State which one is a correct unit: ....

[1]

[Total 3 marks]

27. Kirchhoff's second law is based on the conservation of a quantity. State the law and the quantity that is conserved.

....

....

....

[Total 2 marks]

28. (a) A battery is being tested. Fig. 1 shows the battery connected to a variable resistor R and two meters.

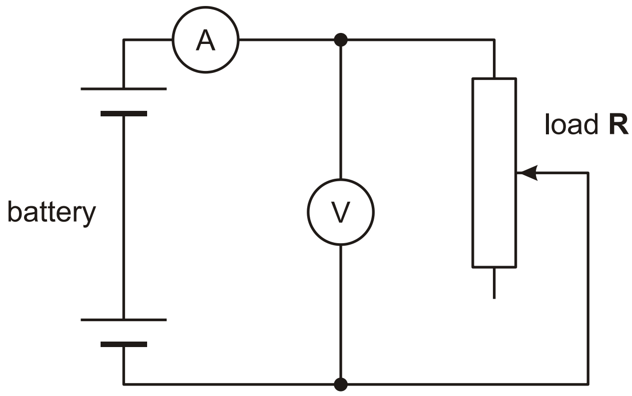


Fig. 1

The graph of Fig. 2 shows the variation of the p.d. *V* across the battery with the current *I* as R is varied.

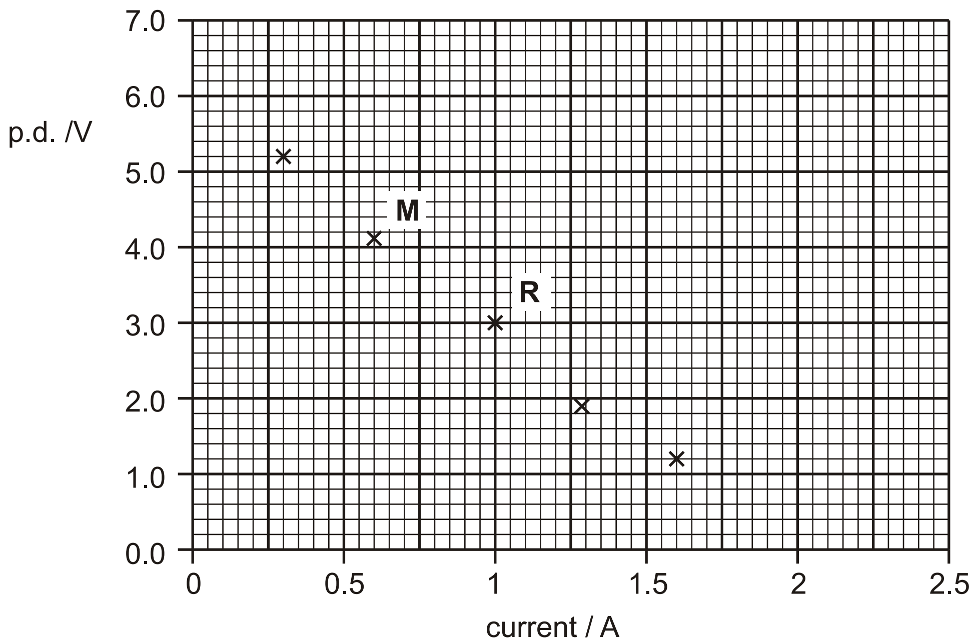


Fig. 2

(i) Draw the line of best fit on Fig. 2.

[1]

(ii) Use your line of best fit to determine

the e.m.f. ε of the battery

ε = ... V

[1]

the internal resistance *r* of the battery. Show your working clearly.

r = ...Ω

[3]

(b) The variable resistor R is adjusted to give the values at point **M** on Fig. 2.

Calculate

(i) the resistance of R at this point

R = ... Ω

[3]

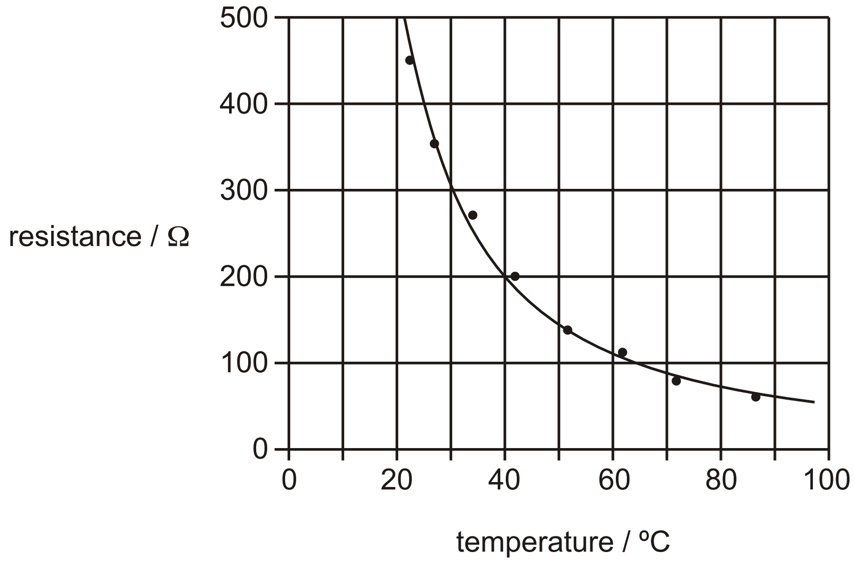
(ii) the power dissipated in R.

power =................ W

[2]

[Total 10 marks]

29. (a) The diagram below shows how the resistance of a thermistor varies with temperature.



(i) Describe qualitatively how the resistance of the thermistor changes as the temperature rises.

....

[1]

(ii) The change in resistance between 80 °C and 90 °C is about 15 Ω.

State the change in resistance between 30 °C and 40 °C.

....

[1]

(iii) Describe, giving a reason, how the sensitivity of temperature measurement using this circuit changes over the range of temperatures shown on the diagram.

....

....

....

[2]

(b) Fig. 1 shows how the resistance of a thermistor varies with temperature.

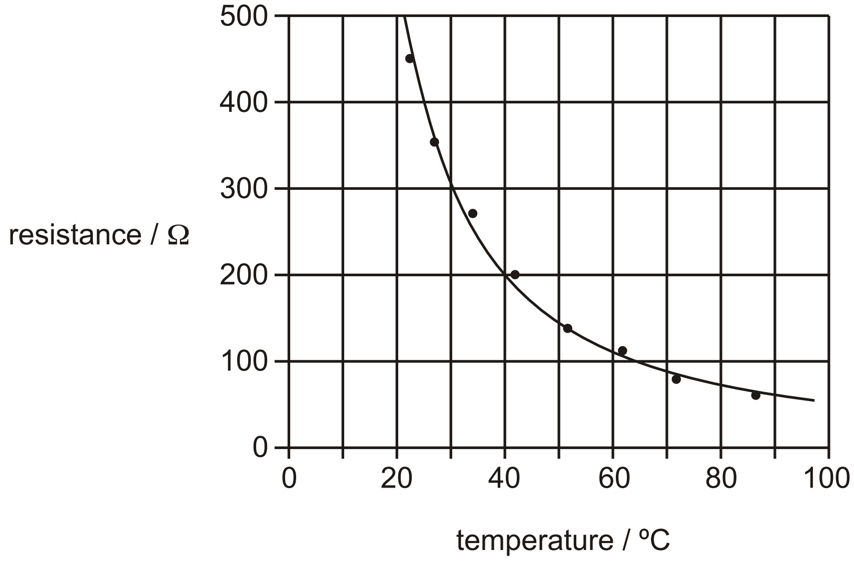


Fig. 1

Fig. 2 below shows a temperature sensing potential divider circuit where this thermistor may be connected, between terminals A and B, in series with a resistor.

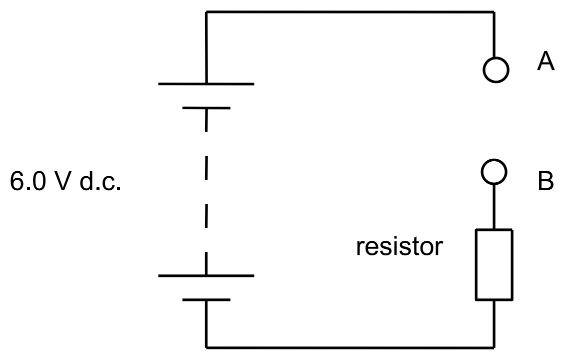


Fig. 2

(i) Draw the circuit symbol for a thermistor on Fig. 2 in the space between terminals **A** and **B**.

[1]

(ii) A voltmeter is to be connected to the circuit to indicate an increasing p.d. when the thermistor detects an increasing temperature. On Fig. 2, draw the circuit connections for a voltmeter to measure a p.d. that rises with increasing temperature.

[1]

(iii) The value of the resistor in Fig. 2 is 200 Ω. The thermistor is at 65 °C. Use data from Fig. 1 to show that the current in the circuit is about 0.02 A.

[3]

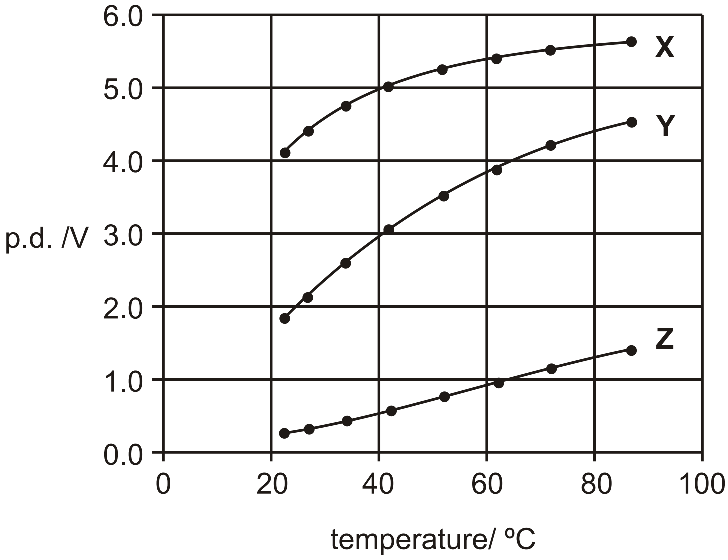
(iv) Calculate the p.d. across the 200 Ω resistor at 65 °C.

p.d. across resistor = ... V

[1]

[Total 10 marks]

30. The graphs **X**, **Y** and **Z** in Fig 3.3. show how the p.d. across the resistor varies with temperature, for three different values of the resistor.



(i) The values of resistance used are 20 Ω, 200 Ω and 1000 Ω.
State, explaining your reasoning clearly, which graph, **X**, **Y** or **Z,** is the curve for the 1000 Ω resistor.

....

....

....

[2]

(ii) State **one** advantage and **one** disadvantage of using output **Z** for the temperature sensing circuit.

advantage..

....

disadvantage ....

....

[2]

[Total 4 marks]

31. Fig. 1 shows the electromagnetic spectrum.

A	X-rays	u.v.	visible	B	microwaves	radiowaves

--→ increasing wavelength

Fig. 1

In the spaces in Fig. 2, identify the principal radiations **A** and **B** and for each suggest a typical value for the wavelength.

	principal radiation	λ/m
A		
B		

Fig. 2

[Total 4 marks]

32. State **two** features common to all types of radiation in the electromagnetic spectrum.

....

....

....

[Total 2 marks]

33. (i) Define the term *plane-polarisation* of visible light waves.

....

....

[1]

(ii) Explain why sound waves cannot be *plane-polarised*.

....

....

....

....

[2]

[Total 3 marks]

34. Fig. 1 shows a student observing a parallel beam of plane-polarised light that has passed through a polarising filter.

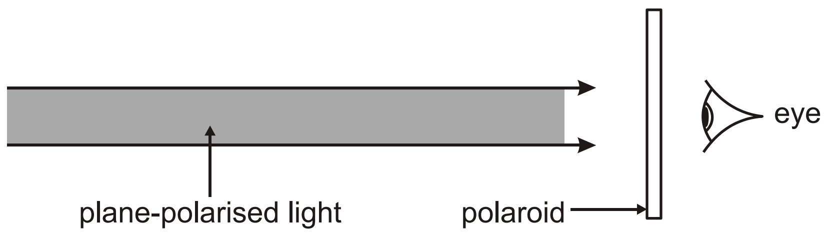


Fig. 1

(i) Fig. 2 shows how the intensity of the light reaching the student varies as the polarising filter is rotated through 360o in its own plane.

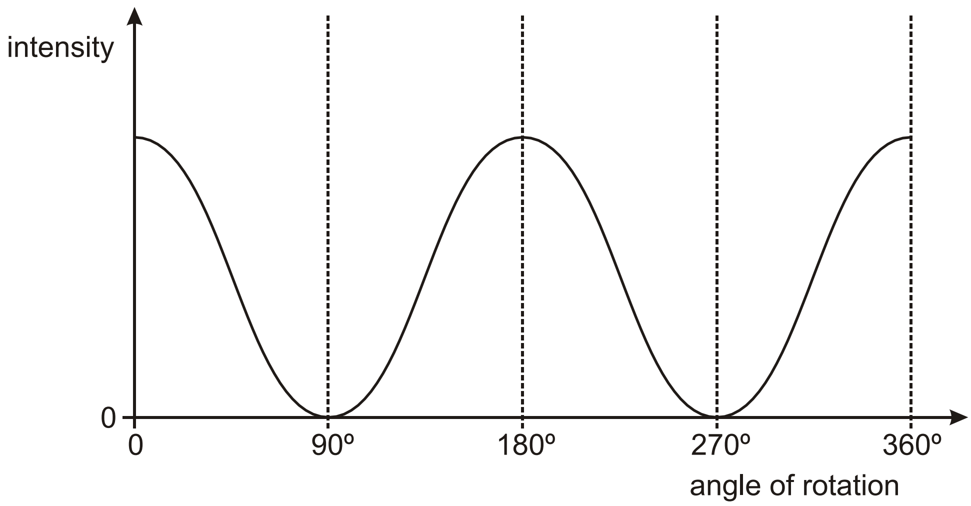


Fig. 2

Suggest why there is a series of maxima and minima in the intensity.

....

....

....

....

[2]

(ii) Hence explain how sunglasses using polarising filters reduce glare.

....

....

....

....

....

[2]

[Total 4 marks]

35. State an example of plane-polarisation that does **not** involve visible light and state how the polarised wave may be detected.

....

....

....

[Total 2 marks]

36. State and explain one difference between a progressive and a standing wave.

....

....

....

....

....

[Total 2 marks]

37. (a) In an investigation of standing waves, a loudspeaker is positioned above a long pipe containing water, causing sound waves to be sent down the pipe. The waves are reflected by the water surface. The water level is lowered until a standing wave is set up in the air in the pipe as shown in Fig. 1. A loud note is heard. The water level is then lowered further until a loud sound is again obtained from the air in the pipe. See Fig. 2.

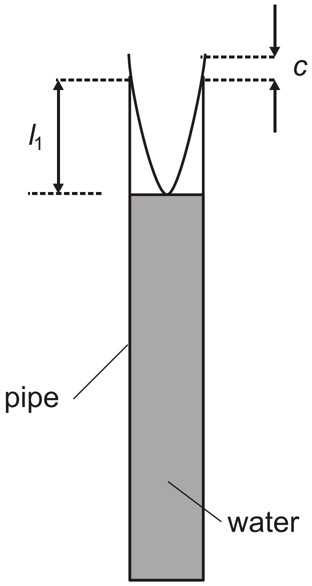


Fig. 1

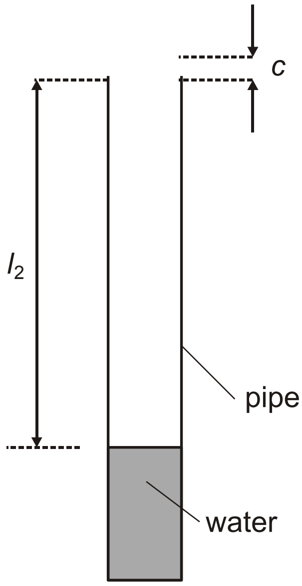


Fig. 2

The air at the open end of of the pipe is free to move and this means that the antinode of the standing wave is actually a small distance *c* beyond the open end. This distance is called the end correction.

A student writes down the following equations relating the two situations shown.

$l_1 + c = \lambda/4$ $\qquad\qquad$ $l_2 + c = 3\lambda/4$

(i) Draw the standing wave in the pipe shown in Fig. 2 which corresponds to the equation $l_2 + c = 3\lambda/4$.

[1]

(ii) On your diagram, label the positions of any displacement nodes and antinodes with the letters N and A respectively.

[1]

(iii) Use the two equations to show that $l_1 - l_2 = \lambda/2$.

[1]

(iv) The following results were obtained in the experiment.

frequency of sound = 500Hz l_1 = 0.170 m l_2 = 0.506 m

Calculate the speed of sound in the pipe.

speed = ... m s^{-1}

[3]

(b) The student repeats the experiment, but sets the frequency of the sound from the speaker at 5000 Hz.

Suggest and explain why these results are likely to give a far less accurate value for the speed of sound than those obtained in the first experiment.

✎ *In your answer, you should make clear the sequence of steps in your argument.*

....

....

....

....

....

....

[4]

[Total 10 marks]

38. Explain what is meant by the principle of superposition of two waves.

....

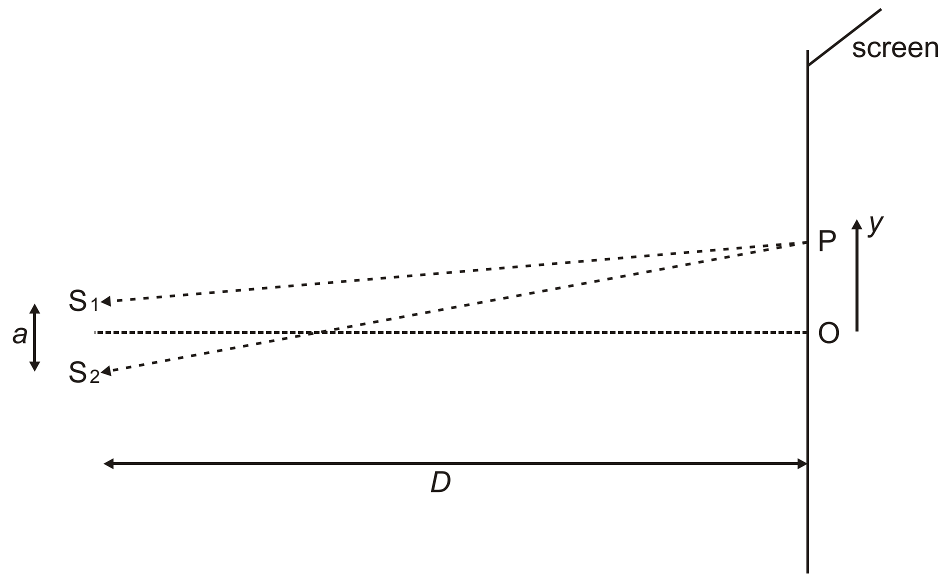
....

....

....

[Total 2 marks]

39. (a) In an experiment to try to produce an observable interference pattern, two monochromatic light sources, S1 and S2, are placed in front of a screen, as shown in the diagram below.



(i) In order to produce a clear interference pattern on the screen, the light sources must be *coherent*. State what is meant by *coherent.*

....

....

....

[2]

(ii) In the diagram, the central point O is a point of maximum intensity. Point P is the position of **minimum** intensity nearest to O. State, in terms of the wavelength λ, the magnitude of the path difference S_1P and S_2P.

....

[1]

(b) In an experiment to try to produce an observable interference pattern, two monochromatic light sources, S1 and S2, are placed in front of a screen, as shown in Fig. 1.

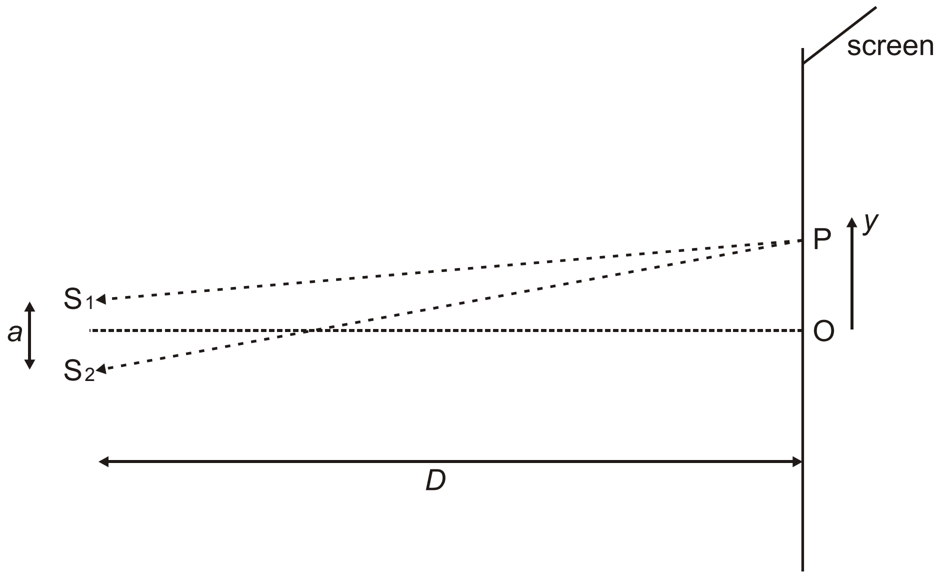


Fig. 1

In another experiment, a beam of laser light of wavelength 6.4×10^{-7} m is incident on a double slit which acts as the two sources in the diagram above.

(i) Calculate the slit separation *a*, given that the distance *D* to the screen is 1.5 m and the distance between P and O is 4.0 mm.

a = ... m

[3]

(ii) Sketch on the axes of Fig. 2 the variation of the intensity of the light on the screen with distance y from O.

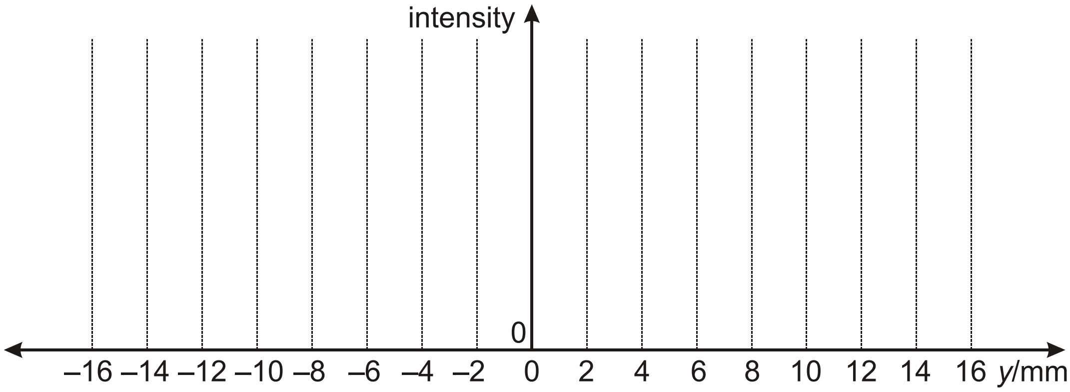


Fig. 2

[2]

[Total 8 marks]

40. (a) The concept of the photon was important in the development of physics throughout the last century. Explain what is meant by a photon.

....

....

[1]

(b) A laser emits a short pulse of ultraviolet radiation. The energy of each photon in the beam is 5.60×10^{-19} J.

(i) Calculate the frequency of an ultraviolet photon of the laser light.

frequency = ... Hz

[2]

(ii) A photon of the laser light strikes the clean surface of a sheet of metal. This causes an electron to be emitted from the metal surface.

1. The work function energy of the metal is 4.80×10^{-19} J. Define the term *work* function energy.

....

....

[1]

2. Show that the maximum kinetic energy of the emitted electron is 8.0×10^{-20} J.

....

....

[1]

(iii) Show that the maximum speed of emission of an electron is about 4×10^5 m s^{-1}.

[2]

(c) (i) State the de Broglie equation. Define any symbols used.

....

....

....

[2]

(ii) Calculate the minimum de Broglie wavelength associated with an electron emitted in (b) above.

wavelength = ... m

[2]

[Total 11 marks]

41. The concept of energy is important in many branches of physics. Energy is usually measured in joules, but sometimes the *kilowatt-hour* (kW h) and the *electron volt* (eV) are more convenient units of energy.

Define the *kilowatt-hour* and the *electron volt* and determine their values in joules.

Suggest why the *kilowatt-hour* and *electron volt* may be more convenient than joules.

✎ *In your answer you should make clear how your suggestions link with the evidence.*

Illustrate your answer by determining the energy dissipated by a 100 W filament lamp left on for 12 hours and the kinetic energy of an electron accelerated through a p.d. of 1.0 MV in a particle accelerator.

[Total 12 marks]

42. State **two** main features that are common to all waves in the electromagnetic spectrum.

....

....

....

[Total 2 marks]

43. Complete the table below, naming the principal electromagnetic radiation with each specified wavelength.

wavelength / m	6×10^{2}	5×10^{-6}	2×10^{-15}
name of principal radiation			

[Total 3 marks]

44. The particle-like behaviour of electromagnetic waves is modelled using the idea of photons. What is a photon?

....

....

[Total 1 mark]

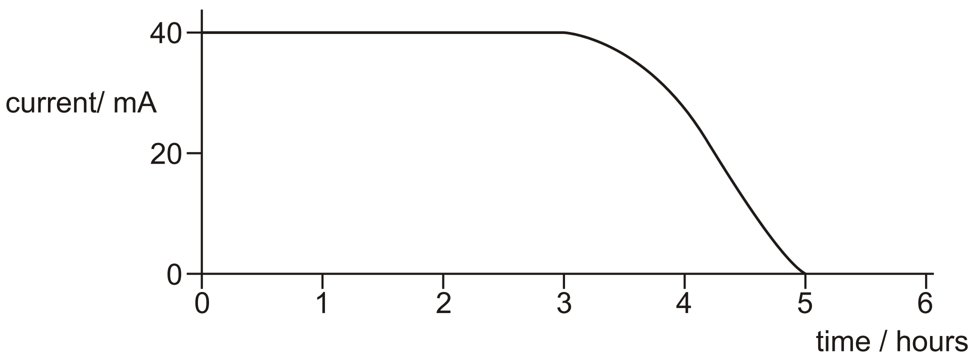
45. A small radio receiver uses a battery that is capable of delivering a constant current of 40 mA for a period of 5.0 hours.

(a) Calculate the total charge delivered by the battery.

charge = ... unit ....

[3]

(b) Below is the graph of current against time for a different battery.



Explain whether the charge delivered by this battery is the same as, greater than or less than your answer to **(a)**.

....

....

[1]

[Total 4 marks]

46. State Ohm's law in words.

....

....

....

[Total 2 marks]

47. The *I/V* characteristic of a filament lamp is shown in Fig. 1.

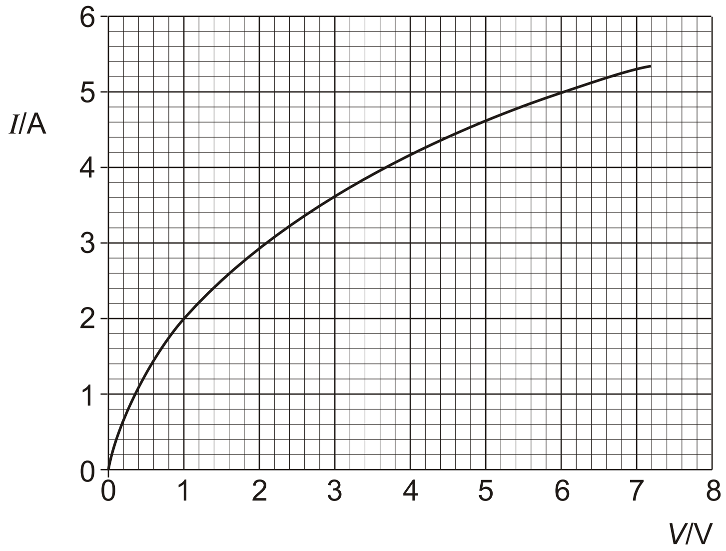


Fig. 1

(i) On Fig. 1, mark a point on the graph, and label it with the letter **M**, where the resistance of the filament lamp is **maximum**.

[1]

(ii) Calculate the power dissipated by the lamp when operating at 6.0 V.

power = ... W

[3]

(iii) Fig. 2 shows the same filament lamp and a resistor of resistance 1.2 Ω connected in series with a battery.

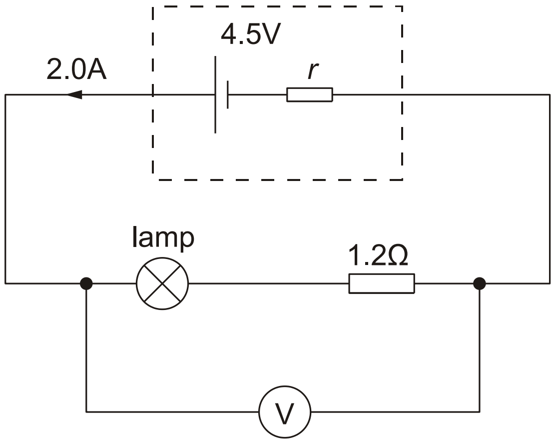


Fig. 2

The battery has e.m.f. 4.5 V and internal resistance *r*. The voltmeter has very high resistance. The current in the circuit is 2.0 A.

1 Show, with the help of Fig. 1, that the voltmeter reading is 3.4 V.

[3]

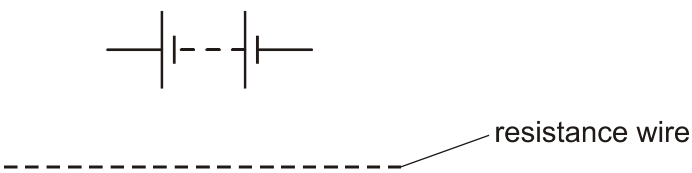
2 Calculate the internal resistance *r* of the battery.

resistance = ... Ω

[2]

[Total 9 marks]

48. The figure below shows an incomplete circuit with a battery and a resistance wire made of a material of resistivity ρ.



(a) Complete the circuit of the figure and show how you would connect suitable meters to determine the current in the resistance wire and the potential difference across the resistance wire.

[2]

(b) In this question, two marks are available for the quality of written communication.

Use your answer to (a) to describe an experiment to determine the resistivity ρ of the material of the resistance wire. Your description should include

- the measurements taken
- the instruments used to take the measurements
- how the measurements are used to determine the resistivity of the material.

....

....

....

....

....

....

....

....

....

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....

....

....

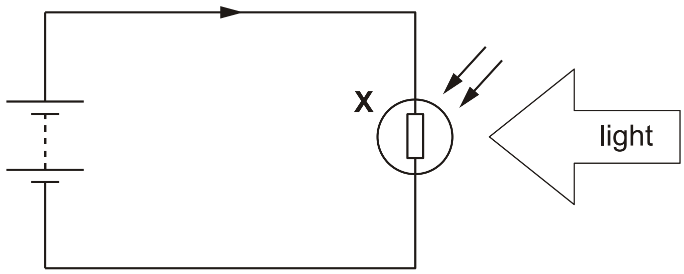
....

[6]

Quality Of Written Communication [2]

[Total 10 marks]

49. The figure below shows an electrical circuit.



The battery has negligible internal resistance.

(i) Name the component **X**.

....

[1]

(ii) Explain what happens to the current in the circuit when the intensity of the light incident on the component **X** is increased.

....

....

....

[2]

(iii) Describe what happens to the current in the circuit when the intensity of the light is kept the same, but a battery of half the e.m.f. is used.

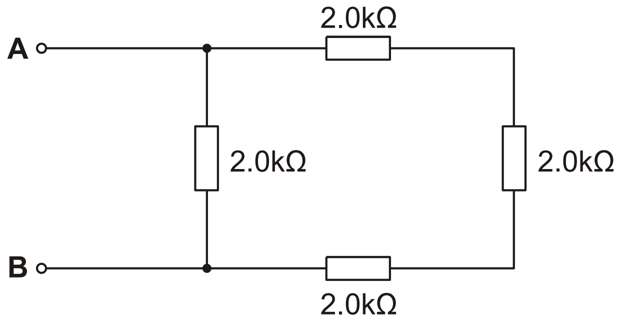
....

....

[1]

[Total 4 marks]

50. The figure below shows a network of identical resistors.

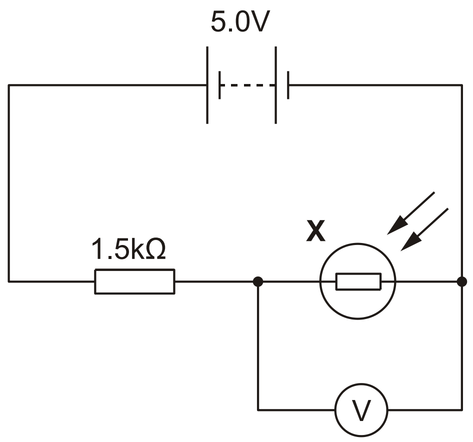


Calculate the total resistance between points **A** and **B**.

resistance = ... kΩ

[Total 3 marks]

51. The circuit shown in the figure below is used to monitor the variation of light intensity in a room.



The battery of e.m.f. 5.0 V has negligible internal resistance. The voltmeter has a very large resistance and it shows a reading of 1.2 V. Calculate

(i) the potential difference across the 1.5 kΩ resistor

potential difference = ... V

[1]

(ii) the resistance *R* of the component **X**.

R = ... Ω

[3]

[Total 4 marks]

52. Write down the de Broglie equation and define the symbols. Explain how this important equation relates to both particle and wave-like properties of the electron.

....

....

....

....

....

....

[Total 4 marks]

53. (i) The surface of a metal is illuminated with electromagnetic radiation. The photons interact with the surface electrons of the metal.

1 Explain what is meant by *threshold frequency*.

....

....

....

[1]

2 Suggest what happens to the **metal** surface when the incident electromagnetic radiation is below the threshold frequency.

....

....

....

[1]

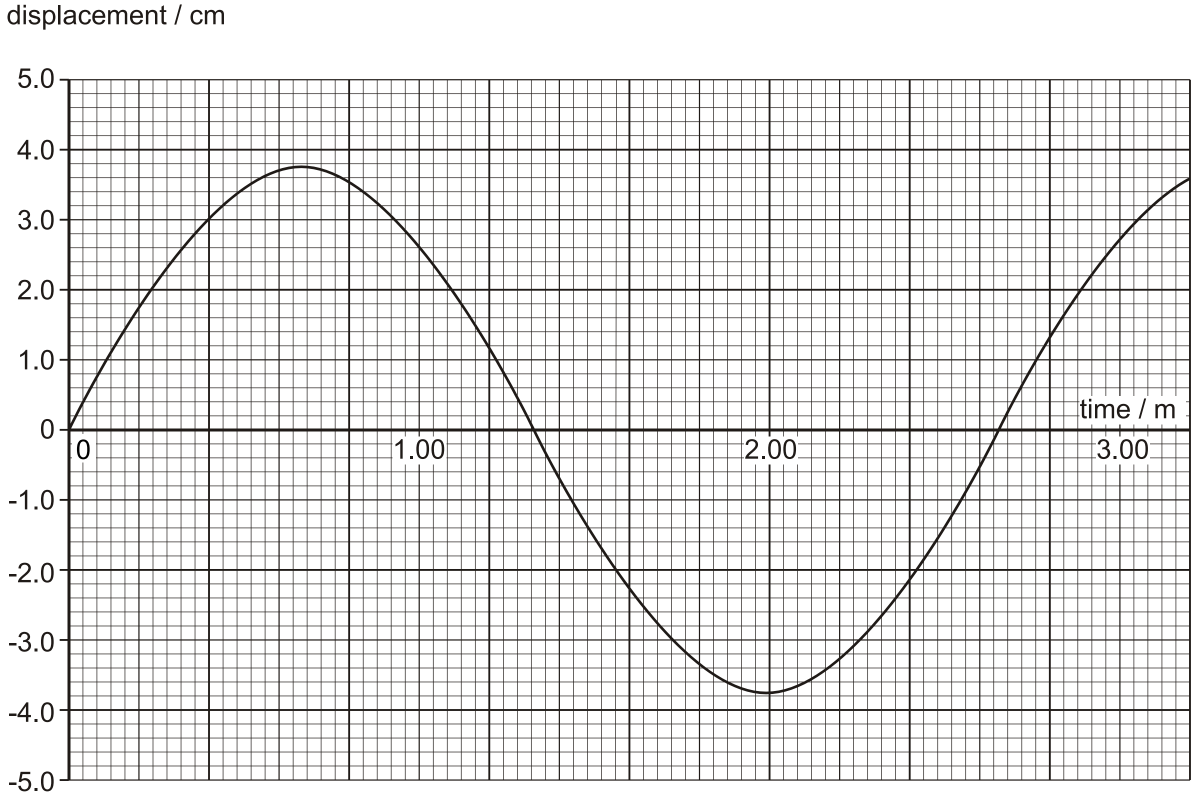
(ii) The work function energy of potassium is 2.2 eV. The surface of potassium is illuminated with electromagnetic radiation of a specific wavelength. Experiments show that the photoelectrons from potassium have kinetic energy in the range zero to 1.9 eV. Determine the wavelength of the incident electromagnetic radiation.

wavelength = ... m

[4]

[Total 6 marks]

54. Below is a displacement-time graph for a wave source.



(a) Use the graph to determine for this wave source

(i) the amplitude

amplitude = …………………… cm

[1]

(ii) the displacement when t = 1.80 ms

displacement = ... cm

[2]

(iii) the period

period = ... ms

[1]

(iv) the frequency.

frequency = ... Hz

[2]

(b) The speed of the waves produced by this wave source is 3.0×10^2 m s^{-1}. Calculate their wavelength.

wavelength = ... m

[2]

[Total 8 marks]

55. (i) State **three** phenomena that apply to all transverse and longitudinal waves.

1. ....

2. ....

3. ....

[2]

(ii) State a wave phenomenon that applies to transverse waves only.

....

[1]

[Total 3 marks]

56. The figure below shows an arrangement that can be used to determine the wavelength of microwaves.

Microwaves leave the transmitter and move in a direction **TP** which is at right angles to the metal plate. A standing (stationary) wave is formed between **T** and **P**.

(i) State what is meant by a *standing wave* and explain how it is formed in this case.

....

....

....

....

....

....

....

[3]

(ii) When a small microwave detector **D** is moved slowly from **T** towards **P** the signal received changes from strong to weak to strong to weak etc. The distance between the positions of neighbouring weak signals is 1.4 cm.

Calculate for these microwaves

1 the wavelength

wavelength = ... cm

[1]

2 the frequency.

frequency = ... Hz

[2]

(iii) Describe how you could test whether the microwaves leaving the transmitter were plane polarised.

....

....

....

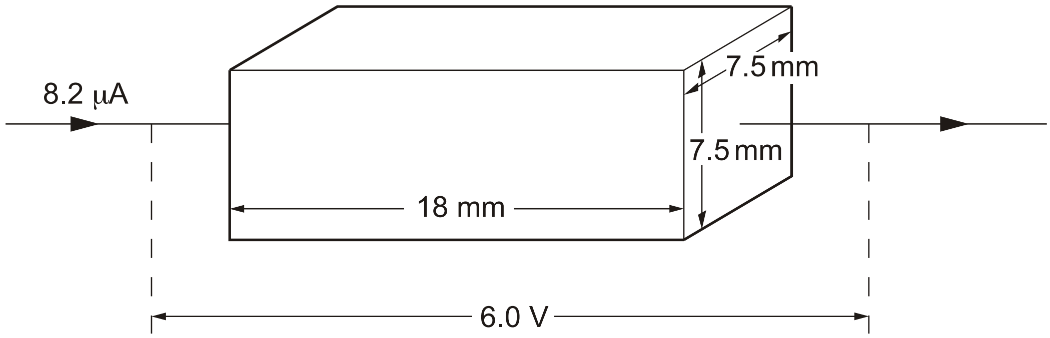
....

....

[2]

[Total 8 marks]

57. A specimen of semiconductor has a square cross-section, as shown in the figure below. The length of the specimen is 18 mm. The side of the square is 7.5 mm. At 25 °C the charge carrier density in the specimen is 2.1×10^{16} m^{-3}. A potential difference of 6.0 V, applied to the ends of the specimen, causes a current of 8.2 μA.



(a) Calculate

(i) the conductivity of the semiconductor

conductivity = ... Ω^{-1} m^{-1}

[4]

(ii) the drift velocity of the charge carriers.

drift velocity = ...m s^{-1}

[2]

(b) The temperature of the specimen in the figure above is now raised to 30 °C.

(i) Explain, using band theory, why the charge carrier density in the specimen increases.

....

....

....

[2]

(ii) The equation relating charge carrier density and **absolute** temperature is

$$\ln\left(\frac{n_2}{n_1}\right) = 1.28 \times 10^4 \left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

where n_1 and n_2 are the charge carrier densities in the specimen at **absolute** temperatures T_1 and T_2 respectively.
Show that the charge carrier density at 30 °C is about 4.3×10^{16} m^{-3}.

[3]

(iii) Calculate the potential difference needed to give a current of 8.2 μA through the specimen at 30 °C. Assume that the change from 25 °C to 30 °C causes negligible change in the mean drift velocity.

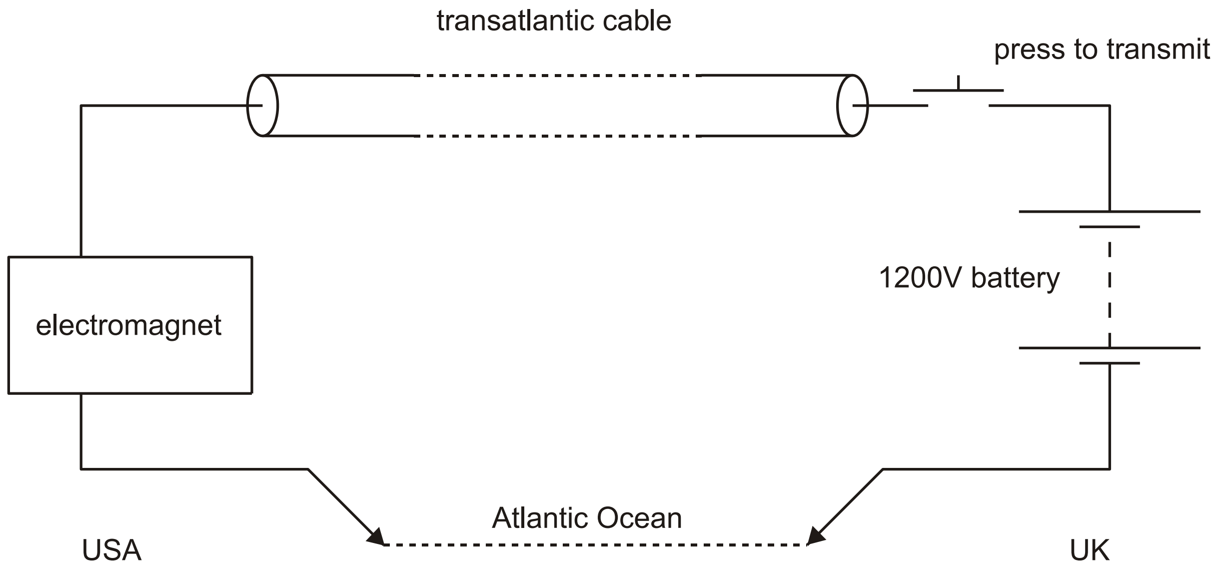
potential difference = ... V

[2]

[Total 13 marks]

58. The first successful transatlantic telegraph cable was laid in 1866. This cable was effectively a continuous length of insulated copper wire lying on the sea bed. There were no amplifiers in the cable because these had not yet been invented. The cable was used to transmit simple on/off currents from the UK to the USA.

The figure below shows the basic arrangement where a key pressed at one end caused an electromagnet to operate at the other. Only a single copper conductor was laid with the current returning through the ocean.



(a) The electromagnet has a resistance of 48 Ω and is energised by a current of 200 mA. Show that the required p.d. across the electromagnet, when the key is pressed, is less than 1% of the 1200 V battery voltage.

[2]

(b) The resistance of the ocean is negligible compared with the resistance of the cable.

Show that the cable resistance is about 6 kΩ.

[1]

(c) The length of the cable is 3000 km. The resistivity of copper is 1.7×10^{-8} Ω m. Show that the diameter of the copper conductor in the cable is about 3.5 mm.

[4]

(d) The density of copper is 8930 kg m^{-3}. Calculate the mass of copper used in the cable.

mass of copper = ... kg

[2]

[Total 9 marks]

59. (a) A rechargeable battery is put on charge for 4.0 hours with a constant current of 50 mA from a 6.0 V supply. Calculate

(i) the charge which flows through the battery in this time

charge = ... C

[3]

(ii) the energy which has been provided from the supply.

energy = ... J

[2]

(b) In what form does a battery store energy?

.... energy

[1]

(c) The charged battery has an e.m.f of 4.5 V and is connected to a 48 Ω resistor. The potential difference across the resistor is found to be 4.0 V. The current is constant during the 45 minutes the battery discharges. Calculate

(i) the internal resistance of the battery when in use

internal resistance = ... Ω

[2]

(ii) the energy supplied to the 48 Ω resistor in this time

energy = ... J

[3]

(iii) the fraction of the initial energy (a)(ii) which the energy in (c)(ii) represents.

fraction = ...

[1]

(d) Explain why the value of the internal resistance calculated in (c)(i) is only reliable to 1 significant figure.

....

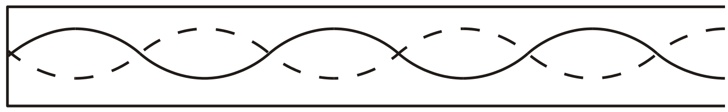
[1]

[Total 13 marks]

60. This question gives a statement which can lead to misconceptions in physics. The statement is correct.

A standing wave set up in air in a pipe is often illustrated by a diagram such as the one below.

How can this be possible as sound is a longitudinal wave?



....

....

....

....

....

[Total 2 marks]

61. This question gives a statement which can lead to misconceptions in physics. The statement is correct.

A battery of e.m.f. E and internal resistance r gives zero output power when on open circuit or when its terminals are shorted together.

Why is this?

....

....

....

....

[Total 2 marks]

62. All electromagnetic radiation, as its name implies, has an electric field and a magnetic field. These fields are always at right angles to one another and oscillate in the transmitted wave. The waves at one instant are represented in Fig. 1, which is drawn full size.

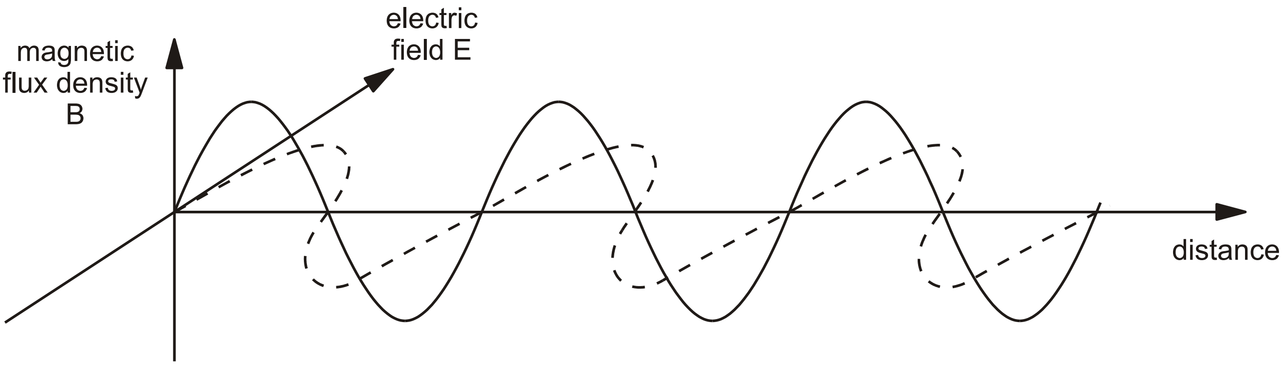


Fig. 1

(a) What is the speed of travel of electromagnetic waves in a vacuum?

speed = ... m s^{-1}

[1]

(b) (i) Measure the wavelength of the electromagnetic wave in Fig. 1.

wavelength = ... m

[1]

(ii) Calculate the frequency of this wave and give its unit.

frequency = ... unit ....

[2]

(iii) What type of electromagnetic wave does this wavelength correspond to in the electromagnetic spectrum?

type of electromagnetic wave ....

[1]

(c) Waves of this type are used in radar systems where they are passed along tubes called waveguides. One part of the system can be a double tube as shown in Fig. 2, where the lengths of the wave paths in the tube are 18 cm and 31 cm as shown. The wavelength of the radar waves in the waveguide is 4.0 cm.

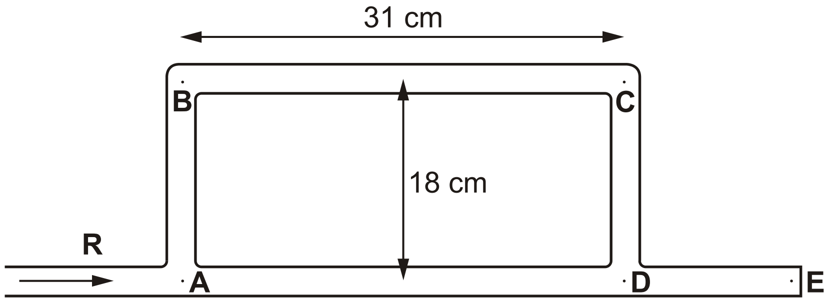


Fig. 2

(i) A wave ***R*** arriving at **A** can divide at **A** and reach **C** either by path **ABC** or path **ADC**.
What is the length of each of these paths?

path length **ABC** = ... cm

path length **ADC** = ... cm

[1]

(ii) State the phase difference between the two waves arriving at **C** and comment on the amplitude of the resultant wave.

....

....

....

[2]

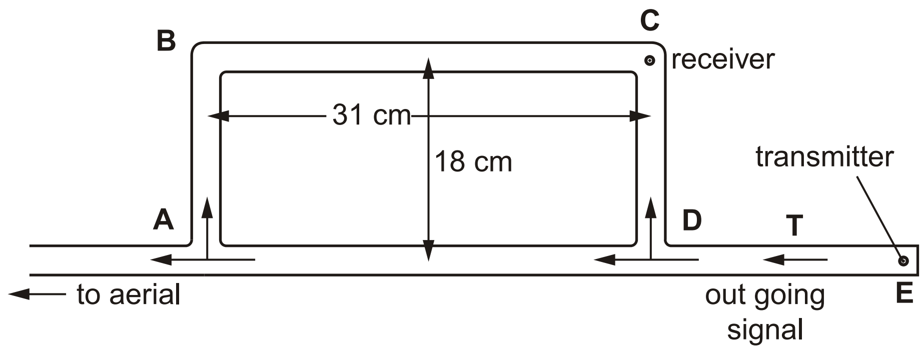


Fig. 3

(iii) Another wave ***T*** travelling from **E** in the opposite direction is shown in Fig. 3. It reaches **C** by paths **DABC** or **DC**.

What is the path length of each of these paths?

path length **DC** = ... cm

path length **DABC** = ... cm

[1]

(iv) Calculate the phase difference between these two waves arriving at **C** and comment on the amplitude of the resultant wave at **C**.

....

....

....

[3]

(v) In practice in a radar system a powerful transmitter is placed at **E** while a receiver of weak incoming signals is placed at **C**. Suggest why this arrangement of waveguides is necessary.

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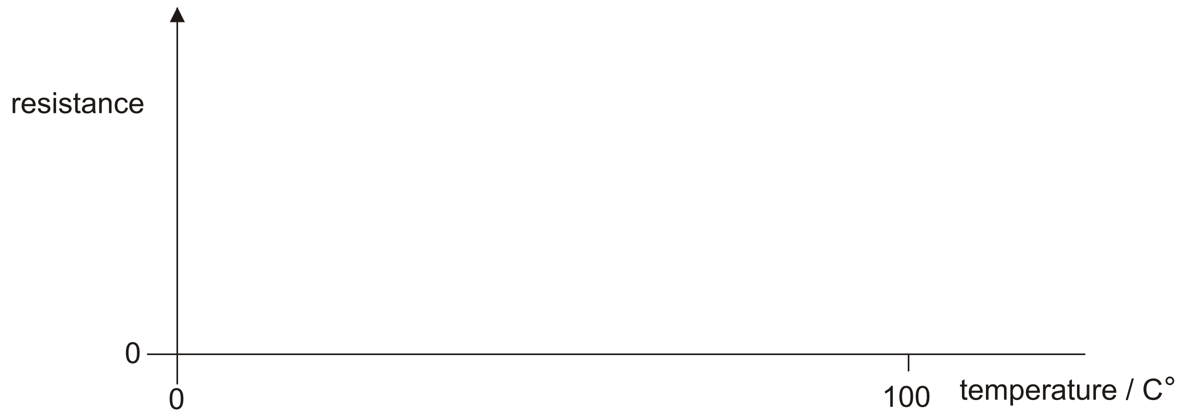
....

....

[3]

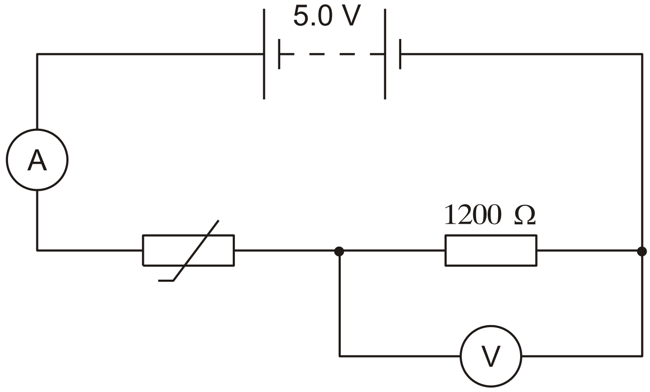
[Total 15 marks]

63. On the figure below, sketch the variation with temperature of the resistance of a pure metallic conductor.



[Total 2 marks]

64. The figure below shows a circuit used to monitor the changes in the temperature of a room.



The thermistor is connected in series with a resistor of fixed value 1200 Ω. The battery has e.m.f. 5.0 V and negligible internal resistance. Assume that the ammeter has negligible resistance and the voltmeter has very high resistance.

(i) The thermistor is a negative temperature coefficient (NTC) thermistor. State and explain the changes in the ammeter and voltmeter readings as the temperature of the thermistor is increased.

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[4]

(ii) At a particular temperature, the reading on the voltmeter is 3.6 V. Calculate the resistance of the thermistor at this temperature.

resistance = ... Ω

[3]

[Total 7 marks]

65. Fig. 1 shows the *I-V* characteristic of a particular electrical component.

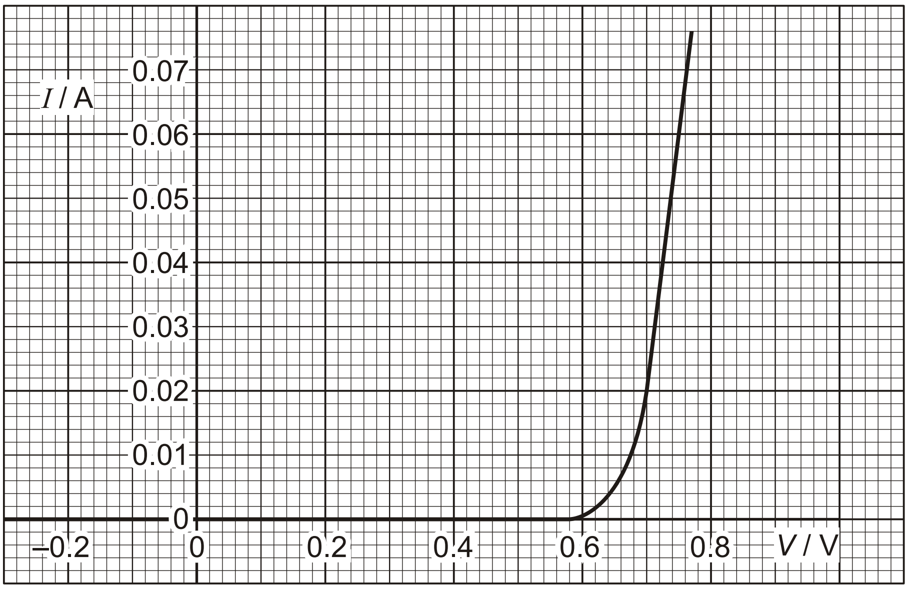


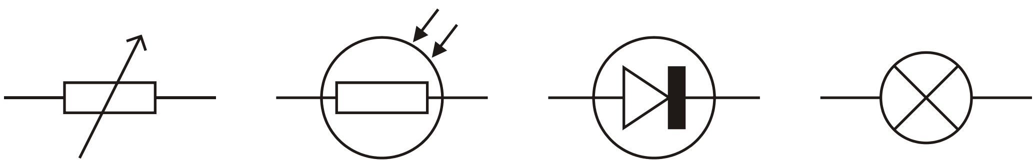
Fig. 1

(a) Name the component.

....

[1]

(b) Circle the correct circuit symbol for the component.



[1]

(c) Use Fig. 1 to calculate the resistance of the component at 0.20 V and 0.70 V.

resistance at 0.20 V = ... Ω

resistance at 0.70 V = ... Ω

[3]

(d) Fig. 2 shows the component with the *I-V* characteristic shown in Fig. 1 connected in series with a resistor of resistance *R* and a supply of e.m.f. 4.5 V.

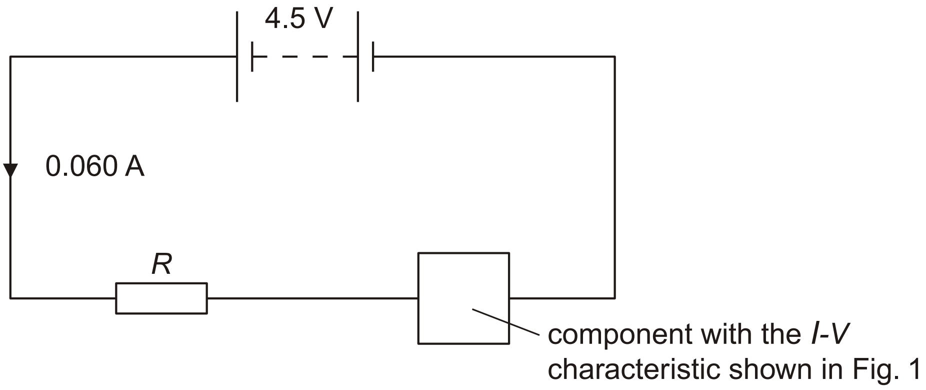


Fig. 2

The supply has negligible internal resistance. The current in the resistor is 0.060 A.

Use Fig. 1 to determine the resistance *R* of the resistor.

R = ... Ω

[3]

(e) On the axes of Fig. 1, draw the *I-V* characteristic of a metallic conductor kept at a constant temperature and having the same resistance as your answer to **(d)**. Label your line **M**.

[2]

[Total 10 marks]

66. Name a quantity that has the same unit as potential difference or voltage.

....

[Total 1 mark]

67. State the electrical unit defined as ‘a potential difference of 1 volt per ampere’.

....

[Total 1 mark]

68. State the SI unit for electrical charge.

....

[Total 1 mark]

69. State Kirchhoff’s first law.

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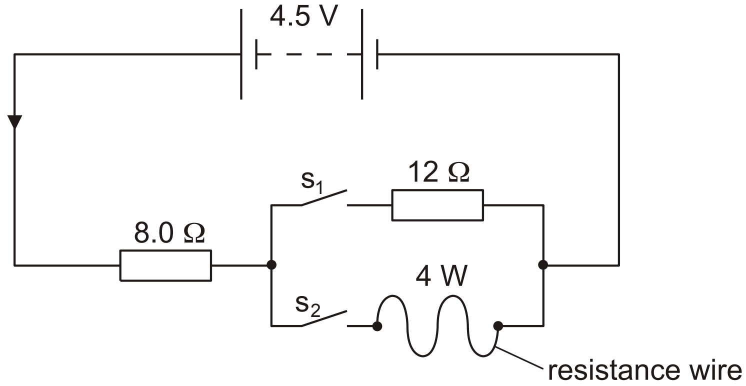
....

[Total 2 marks]

70. The figure below shows an electrical circuit.



The battery has e.m.f. 4.5 V and has negligible internal resistance. The resistance wire has resistance 4.0 Ω, length 15 cm and cross-sectional area 2.3×10^{-8} m^2.

(i) Suggest how you can arrange switches $\mathbf{S_1}$ and $\mathbf{S_2}$ (e.g. opened or closed) so that the circuit has a total resistance of 12 Ω.

....

....

[1]

(ii) Calculate the resistivity of the material of the resistance wire.

resistivity = ... unit …………

[4]

(iii) When both switches are **closed**, calculate

1 the **total** resistance of the circuit

resistance = ... Ω

[3]

2 the **total** electrical power delivered by the battery

power = ... W

[3]

3 the ratio

$$\frac{\text{current in the } 12\Omega \text{ resistor}}{\text{current in the resistance wire}}$$

ratio = ...

[1]

[Total 12 marks]

71. Two of the most important equations from quantum physics are listed below.

equation 1 $E = hf$

equation 2 $\lambda = \dfrac{h}{mv}$

Complete the following sentences:

(i) Equation 1 describes the …………… behaviour of electromagnetic waves.

[1]

(ii) Equation 2 describes the …………… behaviour of a particle such as an electron.

[1]

[Total 2 marks]

72. In this question two marks are available for the quality of written communication.

A negatively charged metal plate is illuminated by light. Electrons escape from the metal when blue light of weak intensity is used. No electrons are released when weak or intense red light is used. Use the ideas of the photoelectric effect to explain these observations.

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[6]

Quality of Written Communication [2]

[Total 8 marks]

73. In a laser beam, each photon has energy 2.0 eV.

(i) Show that the wavelength of the electromagnetic waves emitted by the laser is about 6×10^{-7} m.

[2]

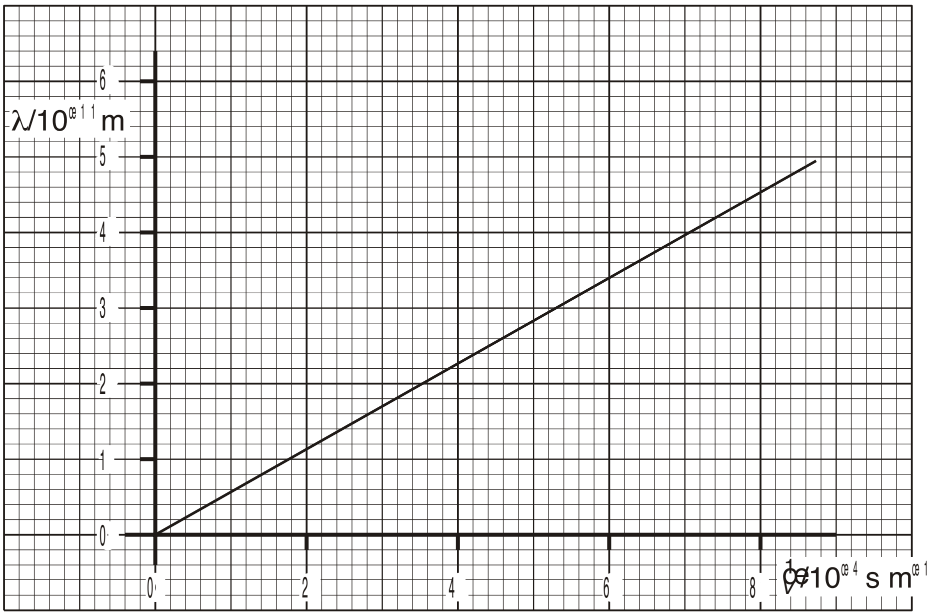
(ii) Identify the region of the electromagnetic spectrum to which the waves emitted by the laser belong.

....

[1]

[Total 3 marks]

74. Lithium ions are accelerated to a speed v. Below is a graph of the de Broglie wavelength λ of the ions against 1 $\frac{1}{v}$



Determine the gradient of the graph and hence calculate the mass *m* of a single ion of lithium.

m = ... kg

[Total 3 marks]

75. (a) Define the following terms associated with waves.

(i) frequency *f*

....

....

[1]

(ii) wavelength λ

....

....

[1]

(b) Use the definitions in **(a)** to deduce an equation for the speed *v* of a wave in terms of λ and *f*.

[2]

[Total 4 marks]

76. State two differences, other than their speeds, between sound and light waves.

....

....

....

[Total 2 marks]

77. A detector is moved in front of two identical coherent wave sources and detects regions of constructive and destructive interference. Explain the terms

(i) *coherence*

....

....

[1]

(ii) *path difference.*

....

....

[1]

[Total 2 marks]

78. The figure below shows two identical monochromatic light sources **S_1** and **S_2** placed in front of a screen. The sources emit light in phase with each other.

(i) State, in terms of the path difference of the waves, the conditions necessary to produce

1 constructive interference at point **P** on the screen

....

....

[1]

2 destructive interference at point **Q** on the screen.

....

....

[1]

(ii) The light sources **S_1** and **S_2** are 0.50 mm apart. They each emit light of wavelength 4.86×10^{-7} m. An interference pattern is produced on the screen placed 2.00 m from the sources. Calculate the distance between two neighbouring bright fringes on the screen.

distance = ... m

[3]

(iii) Suggest how the appearance of the interference pattern would change if coherent **white** light sources were used instead of the monochromatic sources.

....

....

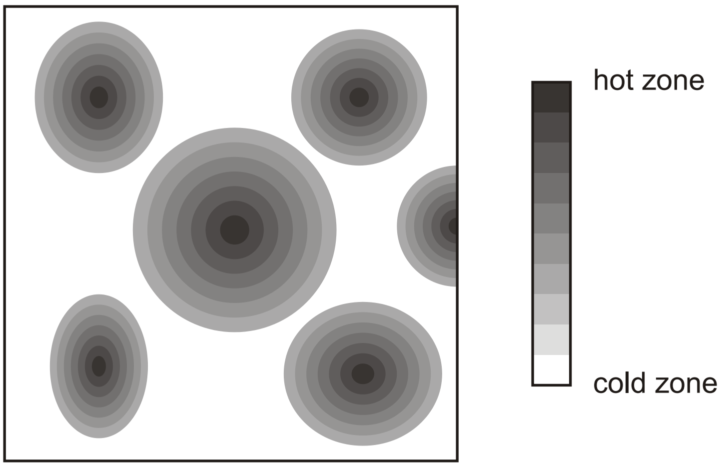
....

[2]

[Total 7 marks]

79. A phenomenon associated with microwave ovens is the uneven heating of food. An internet website gives the following explanation and the illustration shown in the figure below.

> 'Microwaves of a fixed frequency are emitted in all directions from a source within the oven. The waves reflect off the metal walls so that the microwave radiation reaching any particular point arrives both directly and by reflection. The waves interfere and set up standing waves. This produces the pattern of hot and cold zones observed in food heated in the oven.'



(a) State how the reflected microwaves set up standing (stationary) waves in the oven.

....

....

....

....

[2]

(b) Mark on the figure the positions of two antinodes – label these as **A**.

[1]

(c) The frequency of the microwaves is 2.45×10^9 Hz. Calculate the wavelength of the microwaves.

wavelength = ... m

[3]

[Total 6 marks]

80. In order for a light sensitive cell in the retina to be stimulated, a minimum of 10 photons per second must reach the cell. 3 cells need to be stimulated to trigger a single nerve fibre. 85% of the photons incident on the eye reach the retina.

At low light intensity, 5000 nerve fibres must be triggered each second in order to just form a recognisable image.

(i) Calculate the minimum number of photons incident each second on the **cornea** needed to just form an image.

number = ...

[3]

(ii) If the average wavelength of the incident light is 4.0×10^{-7} m, calculate the minimum power of light needed to just form an image.

power = ... W

[3]

[Total 6 marks]

81. Describe the motion of the free electrons in a metal when there is an electric current in it. In your answer, distinguish between the root-mean-square (r.m.s.) speed and the drift velocity of these electrons.

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....

[Total 4 marks]

82. Movement of energy supplies from source to consumer is essential in the modern world. For example, oil from the Middle East is transported to Europe where it is refined and used. Back in the 16th century the same principle applied to shipping coal from Newcastle to London. Today a great deal of energy is transmitted, using the National Grid, from coal (and gas) power stations in the Midlands to the South, where there are fewer power stations. It would be more efficient to have the power stations near to people's homes and factories but people do not like living near power stations.

(a) Suggest why power stations are near coalfields, even though many coal mines have now ceased production.

....

....

....

[2]

(b) State and explain **two** reasons why people do not like living near power stations.

1 ....

....

2 ....

....

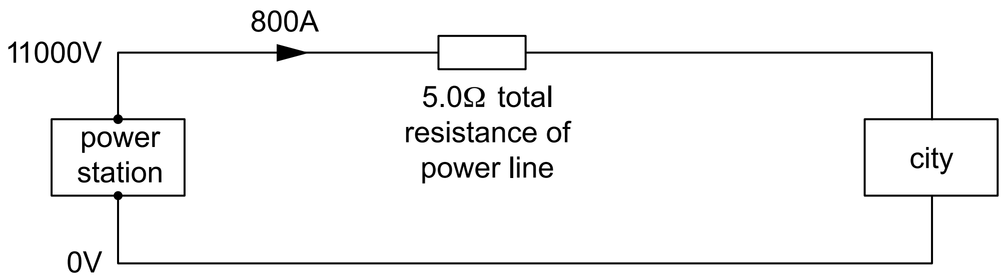
[4]

(c) Nuclear power stations are sited on the coast. Apart from keeping them some distance from centres of population, what reason is there for this?

....

[1]

(d) In order to transmit electrical energy from a power station to a city, a distance of 100 km away, a power line of total resistance 5.0 Ω is used. The power is generated at 11 000 V and the current supplied is 800 A, as shown in the diagram below.



Calculate

(i) the power supplied by the power station

power = ... W

[2]

(ii) the voltage drop across the power line

voltage drop = ... V

[2]

(iii) the voltage supplied to the city

voltage supplied = ... V

[1]

(iv) the power supplied to the city

power = ... W

[2]

(v) the efficiency, which is the percentage of the power generated by the power station that reaches the city.

efficiency = ... %

[2]

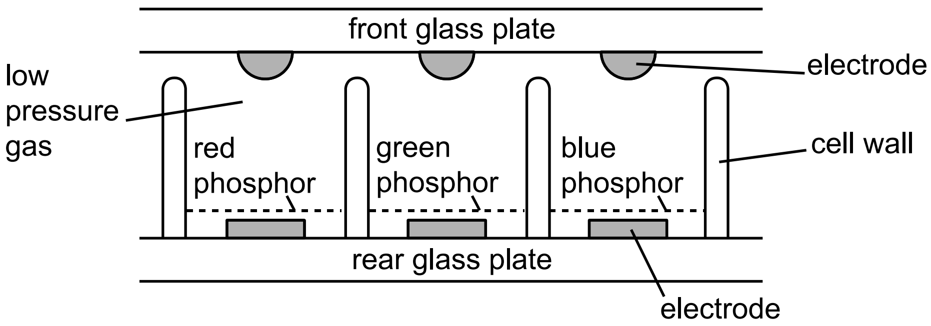
(e) The figures used in (d) are impractical. The total power delivered is too small to be really useful and the efficiency is too low. An alternative power station has an output of 100 MW and 98% of this power is to be supplied to the city. The same power line has to be used. Calculate the output voltage required at the power station.

voltage = ... V

[5]

[Total 21 marks]

83. Many televisions are now produced with flat panel screens. One type of flat panel screen is the plasma screen. In a plasma screen millions of tiny cells are sandwiched between two glass plates which enclose low pressure gas. In order to make a cell emit light a voltage is applied across the cell between two electrodes. This ionises the gas and ultra-violet radiation is emitted. This radiation falls on a phosphor which then emits light. One third of all the phosphors emit red light, one third emit green light and one third emit blue light. Three of the cells, one for each colour, are shown in the figure below.



(a) Explain the meaning of the word *ionise.*

....

....

[1]

(b) Calculate the photon energy of ultra-violet radiation of wavelength 238 nm.

energy = ... J

[3]

(c) Explain why it is possible to use ultra-violet photons to create photons of visible light in a phosphor, but it would **not** be possible to create ultra-violet photons from any photons of visible light.

....

....

....

....

[2]

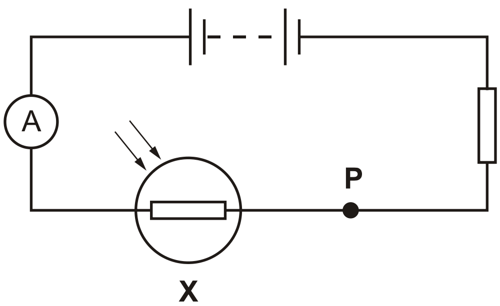
(d) A cell will emit light when a voltage of +15 V is applied to its positive electrode and a voltage of −15 V to its negative electrode. The electrode separation is 0.20 mm. Calculate the value of the uniform electric field causing the ionisation. State the SI unit for electric field.

electric field = ... unit ……….

[3]

[Total 9 marks]

84. The figure below shows an electrical circuit.



(a) On the figure, show how a voltmeter may be connected to measure the potential difference (voltage) across the component **X**.

[1]

(b) State the effect, if any, on the ammeter reading when the ammeter is moved from the position shown to position **P** in the circuit.

....

....

[1]

(c) The resistance of component **X** is affected by the intensity of visible light falling on it.

(i) Name the component **X.**

....

[1]

(ii) State how the resistance of **X** changes as the intensity of visible light is **increased**.

....

[1]

(iii) State the range of the wavelength of visible light.

....m to ....m

[1]

(d) The current measured by the ammeter is 4.8×10^{-3} A when the p.d. across the component **X** is 1.8 V.

(i) Calculate the resistance of component **X**

resistance = ... Ω

[2]

(ii) For a time interval of 30 s, calculate

1 the charge passing through the ammeter

charge = ... C

[3]

2 the electrical energy transformed by the component **X.**

energy = ... unit ....

[3]

[Total 13 marks]

85. The statements below are either laws of physics or definitions of physical quantities or units. In the space provided, name the law, quantity or unit being stated.

(a) The sum of the e.m.f.s in a loop of an electrical circuit is equal to the sum of the p.d.s in that loop

This is a statement of .... law.

[1]

(b) The current in a metallic conductor kept at a constant temperature is directly proportional to the potential difference across its ends.

This is a statement of .... law.

[1]

(c) The potential difference divided by the current.

This is the definition for ....

[1]

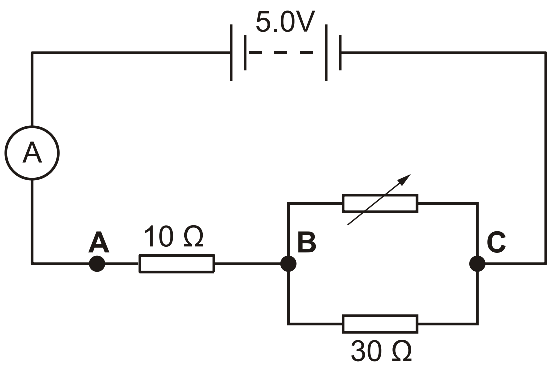
(d) The energy transformed by an electron travelling through a potential difference of one volt.

This is the definition for the ....

[1]

[Total 4 marks]

86. The figure below shows an electrical circuit including three resistors.



(a) The variable resistor is set on its maximum resistance of 20 Ω. Calculate the resistance between points

(i) **B** and **C**

resistance = ... Ω

[2]

(ii) **A** and **C.**

resistance = ... Ω

[1]

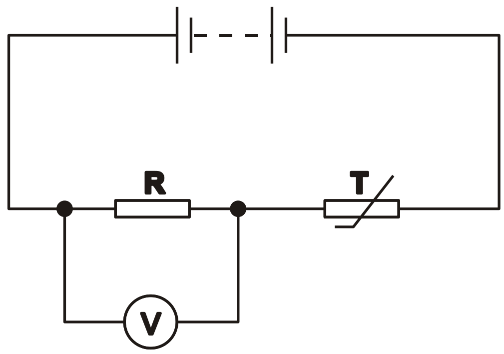
(b) In the circuit shown in the figure above, the battery has negligible internal resistance and an e.m.f. 5.0 V. The variable resistor is now set on its lowest resistance of 0 Ω. Calculate the ammeter reading.

reading = ... A

[2]

[Total 5 marks]

87. The figure below shows a potential divider circuit used to monitor the temperature of a greenhouse.



The thermistor **T** is a negative temperature coefficient type. The voltmeter is placed across the resistor **R.** Describe and explain how the voltmeter reading changes as the temperature of the greenhouse **increases**.

....

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....

[Total 4 marks]

88. (a) A wire has length *L*, cross-sectional area *A* and is made of material of resistivity ρ. Write an equation for the electrical resistance *R* of the wire in terms of *L, A* and ρ.

[1]

(b) A second wire is made of the same material as the wire in **(a)**, has the same length but twice the diameter. State how the resistance of this wire compares with the resistance of the wire in **(a)**.

....

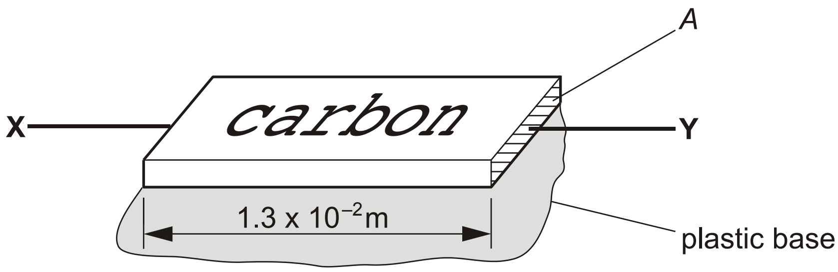
....

....

[2]

[Total 3 marks]

89. The figure below shows a resistor made by depositing a thin layer of carbon onto a plastic base.



The resistance of the carbon layer between **X** and **Y** is 2200 Ω. The length of the carbon layer is 1.3×10^{-2} m. The resistivity of carbon is 3.5×10^{-5} Ω m.

(i) Show that the cross-sectional area *A* of the carbon layer is about $2 \times 10^{-10} m^2$.

[2]

(ii) The maximum power that can be safely dissipated by the resistor is 0.50 W. Calculate the current in the resistor for this power.

current = ... A

[3]

[Total 5 marks]

90. In this question, two marks are available for the quality of written communication.

The Planck constant *h* is a very important fundamental constant in the study of wave-particle duality.

- With the aid of equations, discuss how this constant is used to describe the behaviour of electromagnetic waves and moving electrons.
- Describe the experimental evidence for the wave behaviour of the electron.

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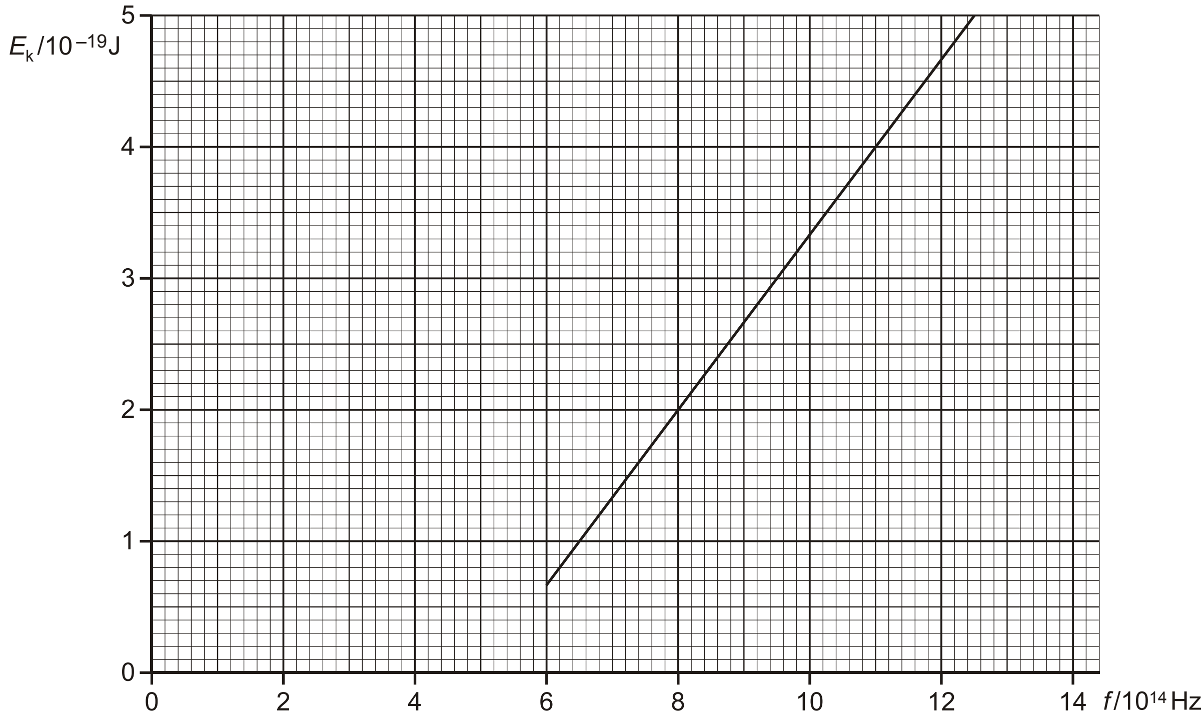
[6]

Quality of Written Communication [2]

[Total 8 marks]

91. A negatively charged metal plate is exposed to electromagnetic radiation of frequency *f*. The figure below shows the variation with *f* of the maximum kinetic energy E_k of the photoelectrons emitted from the surface of the metal.



(i) Define the *threshold frequency* of a metal.

....

....

[1]

(ii) 1 Explain how the graph shows that the threshold frequency of this metal is 5.0×10^{14} Hz.

....

....

[1]

2 Calculate the work function energy of this metal in joules.

work function energy = ... J

[2]

(iii) Electromagnetic radiation falls on the surface of a metal having work function energy greater than your answer in **(ii).**

1 State and explain the change, if any, to the gradient of the line shown in the figure above.

....

....

....

[2]

2 State and explain the change, if any, to the position of the line shown in the figure.

....

....

....

[2]

[Total 8 marks]

92. When waves from two coherent sources meet, they interfere. The principle of superposition of waves helps to explain this interference.
State what is meant by

(i) *coherent sources*

....

....

....

[2]

(ii) *principle of superposition of waves*

....

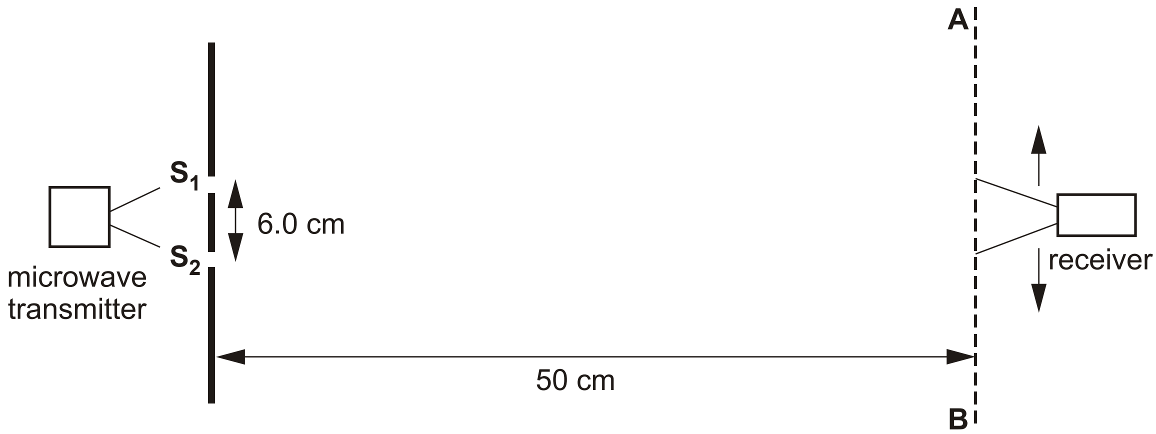
....

....

[1]

[Total 3 marks]

93. The figure below shows an arrangement to demonstrate interference effects with microwaves. A transmitter, producing microwaves of wavelength 3.0 cm, is placed behind two slits 6.0 cm apart. A receiver is placed 50 cm in front of the slits and is used to detect the intensity of the resultant wave as it moves along the line **AB**.



(i) Explain, in terms of the **path difference** between the waves emerging from the slits $\mathbf{S_1}$ and $\mathbf{S_2}$, why a series of interference maxima and minima are produced along the line **AB**.

....

....

....

....

....

[3]

(ii) Assuming that the interference of the microwaves is similar to double slit interference using light, calculate the distance between neighbouring maxima along the line **AB.**

distance = ... cm

[3]

(iii) The microwaves from the transmitter are *plane polarised*. State what this means and suggest what would happen if the receiver were slowly rotated through 90° while still facing the slits.

....

....

....

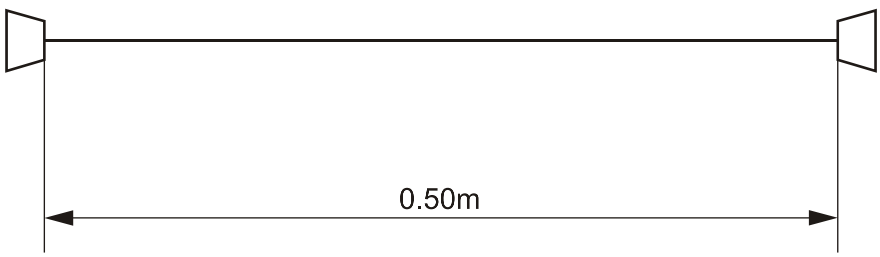
....

....

[2]

[Total 8 marks]

94. The figure below shows a stretched wire held horizontally between supports 0.50m apart.



When the wire is plucked at its centre, a standing wave is formed and the wire vibrates in its fundamental mode (lowest frequency).

(a) Explain how the standing wave is formed.

....

....

....

....

....

[2]

(b) On the figure above, draw the fundamental mode of vibration. Label the position of any nodes with the letter **N** and any antinodes with the letter **A**.

[2]

(c) What is the wavelength of this standing wave?

wavelength = ...m

[1]

[Total 5 marks]

95. State what is meant by *diffraction.*

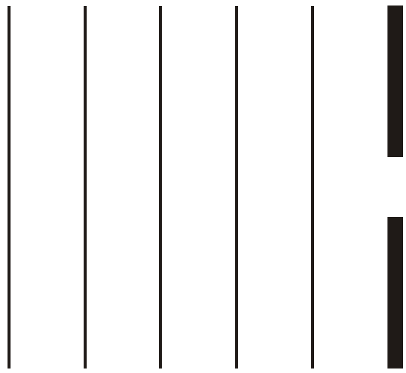
....

....

....

[Total 2 marks]

96. The figure below shows plane water waves in a ripple tank approaching a narrow gap the size of which is approximately the same as the wavelength of the waves.



(i) On the figure, draw the pattern of the wavefronts emerging from the gap.

[2]

(ii) Describe how the pattern of wavefronts emerging from the gap would change if the size of the gap were significantly increased.

....

....

....

....

[2]

(iii) Describe and explain the difference in the amount of diffraction for sound waves and light waves passing through an open door.

....

....

....

....

....

[3]

[Total 7 marks]

97. The radioactive nickel nuclide $^{63}_{28}Ni$ decays by beta-particle emission with a half-life of 120 years.

(a) A copper nucleus is produced as the result of this decay. State the number of nucleons in the copper nucleus which are

protons ....

neutrons ....

[2]

(b) Show that the decay constant of the nickel nuclide is 1.8×10^{-10} s^{-1}.

1 year = 3.2×10^{7} s

[1]

(c) A student designs an electronic clock, powered by the decay of nuclei of $^{63}_{28}Ni$. One plate of a capacitor of capacitance 1.2×10^{-12} F is to be coated with this isotope. As a result of this decay, the capacitor becomes charged. The capacitor is connected across the terminals of a small neon lamp. See Fig. 1. When the capacitor is charged to 90 V, the neon gas inside the lamp becomes conducting, causing it to emit a brief flash of light and discharging the capacitor. The charging starts again. Fig. 2 is a graph showing how the voltage *V* across the capacitor varies with time.

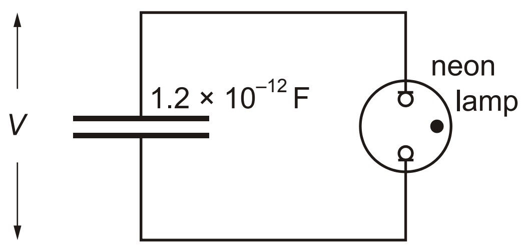


Fig. 1

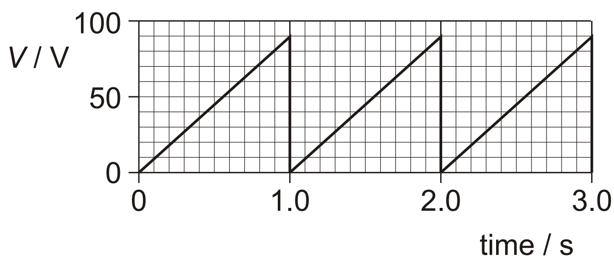


Fig. 2

(i) Show that the maximum charge stored on the capacitor is 1.1×10^{-10} C.

[2]

(ii) When a nickel atom emits a beta-particle, a positive charge of 1.6×10^{-19} C is added to the capacitor plate. Show that the number of nickel nuclei that must decay to produce 1.1×10^{-10} C is about 7×10^{8}.

[2]

(iii) The neon lamp is to flash once every 1.0 s. Using your answer to (b), calculate the number of nickel atoms needed in the coating on the plate.

number = ...

[3]

(iv) State, giving a reason, whether or not you would expect the clock to be accurate to within 1% one year after manufacture.

....

....

....

[1]

[Total 11 marks]

98. This question is about the design and use of Christmas tree lights.

Design of bulbs

An engineer intends to design light bulbs for use in a set of Christmas tree lights to be powered by a 240 V mains supply.

Each bulb, when operating normally, will use 0.50 W and will have a filament 6.0 mm long, made of tungsten.

resistivity of tungsten at normal working temperature = $1.1 \times 10^{-6}\ \Omega\ \text{m}$

(a) State **one** advantage of connecting these bulbs in parallel, rather than in series.

....

....

....

[1]

(b) Suppose the bulbs are connected in **parallel**. Calculate

(i) the current through each bulb

current = ... A

[2]

(ii) the resistance of each bulb filament

resistance = ... Ω

[2]

(iii) the radius of each bulb filament.

radius = ... m

[3]

(iv) Hence suggest why these bulbs are impractical.

....

....

....

[1]

Use of bulbs

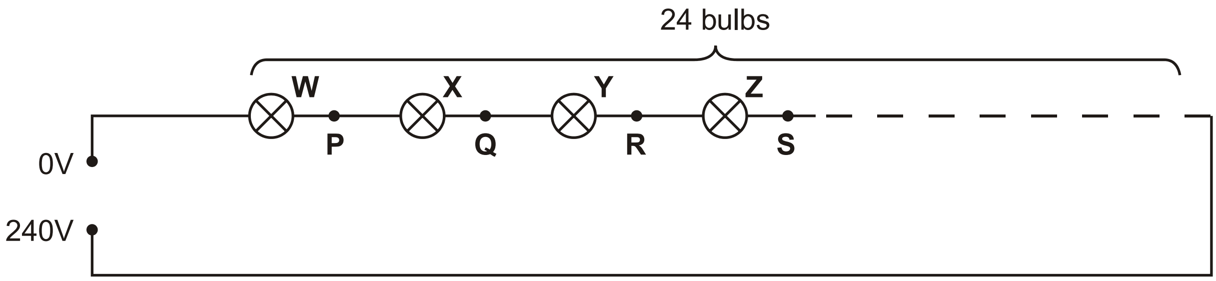
A householder has two sets of Christmas tree lights.

Set A consists of 24 bulbs, each of resistance 200 Ω, connected in series.

Set B consists of 48 bulbs, each of resistance 50 Ω, connected in series.

All bulbs fail when their power dissipation reaches 0.75 W.

(c) **Set A** is connected to a 240 V mains supply. The diagram below shows the wiring of four of these bulbs.



During use, the filament of bulb **Y** fails and its resistance becomes infinite. In order to find which bulb has failed, the householder connects one terminal of a voltmeter to the 0 V terminal of the mains and notes the voltmeter reading when its other terminal is connected successively to points **P**, **Q**, **R** and **S**.
Enter in the table the voltmeter reading for each connection.
Explain your answer.

connection	reading / V
P	
Q	
R	
S	

....

....

....

....

....

....

[4]

(d) (i) The householder has no correct replacement bulbs for **Set A**. Each time a **Set A** bulb fails, it is replaced by a **Set B** bulb.
Explain why this is unsatisfactory and what will happen as more bulbs are replaced in this way.

....

....

....

....

....

....

[3]

(ii) Calculate how many bulbs from **Set A** can be replaced by **Set B** bulbs before the system fails altogether.
Assume that the resistance of each bulb is independent of the current.

number = ...

[4]

[Total 20 marks]

99. (a) A light-dependent resistor (LDR) has a resistance in daylight of less than 1 kΩ, and in the dark about 1MΩ. Explain in terms of band theory why the resistance changes with light intensity.

....

....

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....

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....

....

[4]

(b) An experiment is to be carried out to investigate how the resistance of the LDR in (a) varies with the intensity of light incident upon it. An ohmmeter is **not** available.

(i) Sketch a suitable electric circuit.

[2]

(ii) Describe the procedure to be carried out, including the following aspects

- suggestions about the control and measurement of the light intensity
- suitable ranges for the meters used in the circuit
- the readings and calculations to be carried out.

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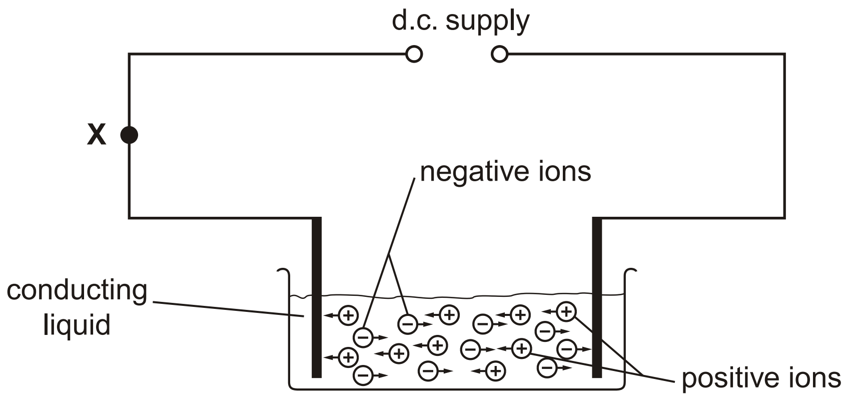
[8]

[Total 14 marks]

100. The figure below shows an electrical circuit.



(i) The directions of flow of ions in the liquid are shown. On the figure, draw an arrow at X to show the direction of the electron flow in the wire

[1]

(ii) State what is meant by *conventional current*.

....

....

[1]

(iii) A charge of 0.76 C flows past point X in a time of 5.0 minutes. Calculate the current in the wire.

current = ...A

[3]

[Total 5 marks]

101. State **three** main features common to all types of radiations in the electromagnetic spectrum. Name **three** principal radiations in the electromagnetic spectrum other than visible light. For **one** of these radiations, give a useful application.

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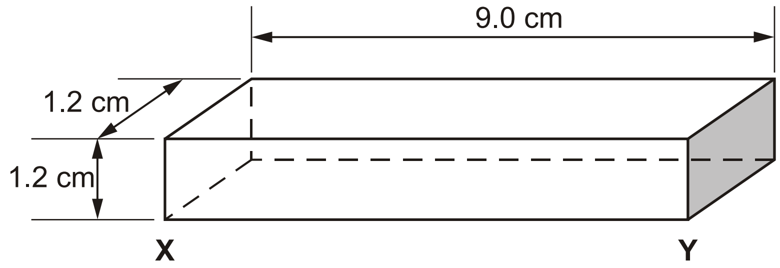
[Total 7 marks]

102. The figure below shows a rectangular block of electrically conducting material.



(a) The conducting block obeys Ohm's law. State Ohm's law, in words.

....

....

....

[2]

(b) When the ends **X** and **Y** of the block are connected to a 0.15 V d.c. supply of negligible internal resistance, the current drawn is 4.3 A.

(i) Show that the block has a resistance of $3.5 \times 10^{-2}\ \Omega$.

[1]

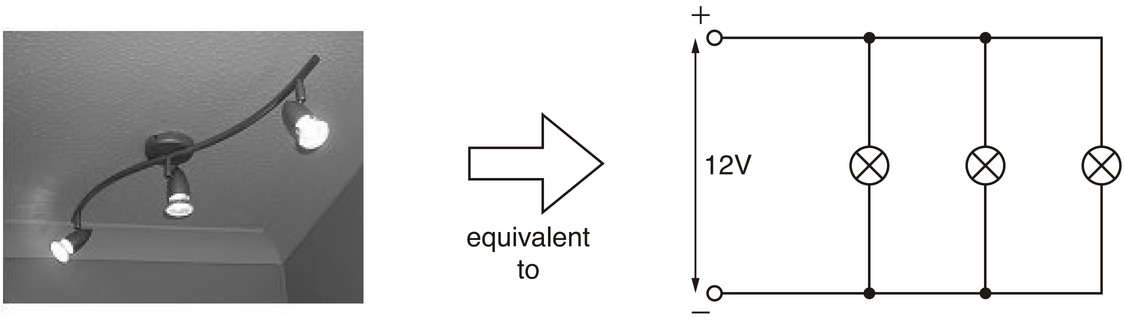
(ii) Calculate the resistivity of the material.

resistivity = ... unit ....

[4]

[Total 7 marks]

103. The figure below shows an arrangement of three – filament lamps used to illuminate a room.



(a) Name the arrangement in which the three lamps are connected.

....

[1]

(b) Each lamp has resistance 8.0 Ω when operating at 12 V.

Calculate

(i) the current drawn by **each** lamp

current = ... A

[2]

(ii) the power dissipated by **each** lamp

power = ... W

[3]

(iii) the **total** resistance of the lamps as connected in the picture above.

resistence = ... Ω

[3]

(iv) the **total** energy transformed by the three lamps in kilowatt hour when operated for 12 hours.

energy = ... kW h

[2]

(c) One of the lamps is replaced by another lamp that also operates at 12 V but has a smaller resistance than 8.0 Ω. State and explain how its brightness will compare with one of the other two remaining lamps.

....

....

....

....

[2]

[Total 13 marks]

104. Complete the following sentence for a statement of Kirchhoff's first law.

The sum of the .... into a point in a circuit is equal to the sum of

the .... out from that point.

[Total 1 mark]

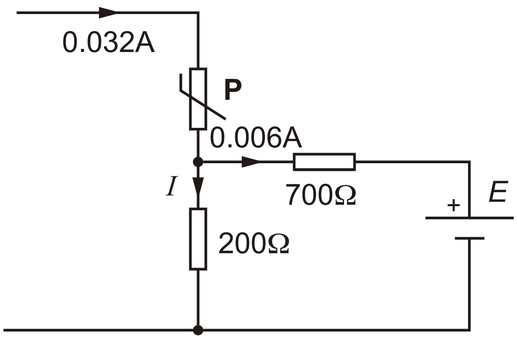
105. Complete the following statement about Kirchhoff's second law.

In an electrical circuit, the sum of the e.m.f.s around a closed loop is equal to the sum of the p.d.s around the same loop. This is a consequence of conservation of

....

[Total 1 mark]

106. The figure below shows a part of an electrical circuit.



(i) Name the component **P.**

....

[1]

(ii) State how the resistance of component **P** is affected by a change in its temperature.

....

....

[1]

(iii) At a particular temperature, the currents are as shown in the figure. Use Kirchhoff's laws to determine

1 the current *I* in the 200 Ω resistor

I = ... A

[1]

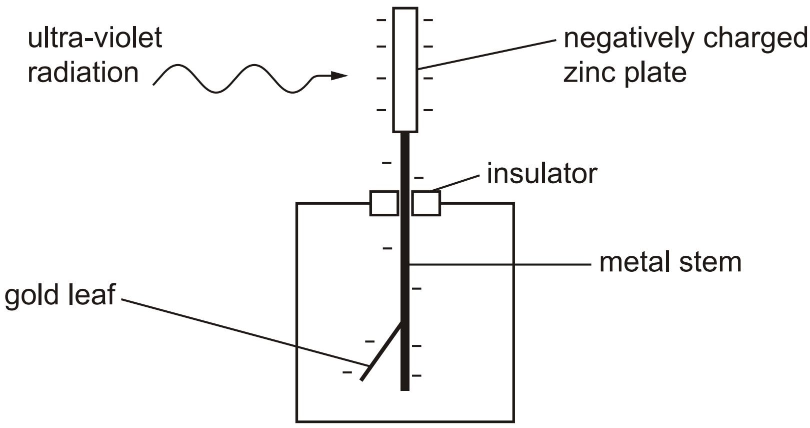
2 the e.m.f. *E* of the cell.

E = ... V

[3]

[Total 6 marks]

107. The following figure shows a zinc plate attached to a charged gold-leaf electroscope. The arrangement is used to demonstrate the photoelectric effect.



The zinc plate, metal stem and gold leaf have an excess of electrons. This causes the leaf to deflect away from the stem.

(a) When the zinc plate is exposed to high frequency ultra-violet radiation, it loses electrons from its surface and consequently the gold leaf falls rapidly. If the demonstration is repeated with visible light, the leaf does not fall.
Use the photoelectric effect to describe how the ultra-violet radiation interacts with the surface electrons of the zinc plate. Explain why visible light, no matter how intense, does no release electrons from the zinc plate.

In this question, two marks are available for the quality of written communication.

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[5]

Quality of Written Communication [2]

[Total 7 marks]

108. Ultra-violet radiation of wavelength 3.9×10^{-7} m is incident on the surface of a metal plate. The maximum kinetic energy of an emitted photoelectron is 1.5 eV.

Calculate

(i) the maximum kinetic energy of a photoelectron in joules

kinetic energy = ... J

[2]

(ii) the work function energy of the metal in joules.

work function energy = ... J

[3]

[Total 5 marks]

109. The table below shows four statements that may or may not be true about the wave-nature of the electron. Place a tick (✓) next to the statement if it is correct and a cross (✗) if it is incorrect.

	Place a ✓ or a ✗ here
Electrons can be diffracted by matter. This confirms their wave nature.	
The wavelength of the electron is given by the de Broglie equation.	
The wave associated with a moving electron is an electromagnetic wave.	
The kinetic energy of the electron is given by the equation $E = hf$.	

[Total 3 marks]

110. Calculate the speed of a carbon atom of mass 2.0×10^{-26} kg travelling in space with a de Broglie wavelength of 6.8×10^{-11} m.

speed = ... m s^{-1}

[Total 3 marks]

111. The table below shows part of a student's revision notes about 'Waves'. The notes contain several errors of physics.

WAVES
1. Longitudinal waves are caused by vibrations perpendicular to the direction of the waves.
2. No waves can travel through a vacuum, there must be a medium to carry them.
3. Waves carry the medium from one place to another.
4. Speed v is the distance travelled by the wave per unit time.
5. Frequency f is the number of waves produced in unit time.
6. Wavelength λ is the distance from a crest to a trough.

Identify 4 incorrect statements of physics and state how each could be corrected.

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[Total 6 marks]

112. Draw a labelled diagram to show the arrangement that you would use to produce, on a screen, a double-slit interference pattern for light.

[1]

In order to see the interference pattern clearly in a darkened room, suggest suitable values for

(i) the distance from the double-slit to the screen

distance = ...

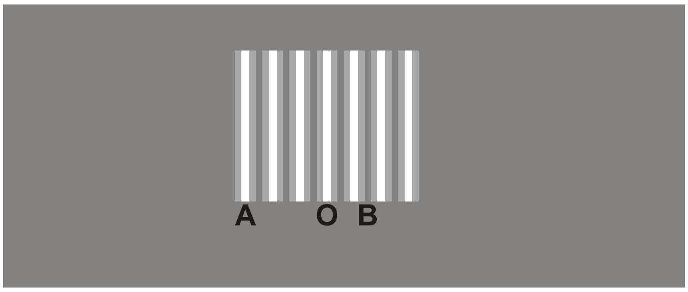
(ii) the distance between the centres of the slits in the double-slit.

distance= ....

[2]

[Total 3 marks]

113. (a) The following figure shows the light and dark fringes in a typical double-slit interference pattern. The diagram is drawn to full scale.



(i) By taking measurements directly from the figure, determine the fringe separation *x*.

x = ... mm

[2]

(ii) Fringe **O** is the bright fringe at the centre of the pattern, **A** is a bright fringe and **B** is a dark fringe. For each of these fringes, state in terms of the wavelength λ, the value of the path difference for light coming from each slit.

fringe **O** path difference = ...

fringe **A** path difference = ...

fringe **B** path difference = ...

[3]

(b) Use the formula for double-slit interference to explain how the fringe separation would change if blue light were used instead of red light.

....

....

....

[2]

[Total 7 marks]

114. State **two** differences between sound and light waves.

1. ....

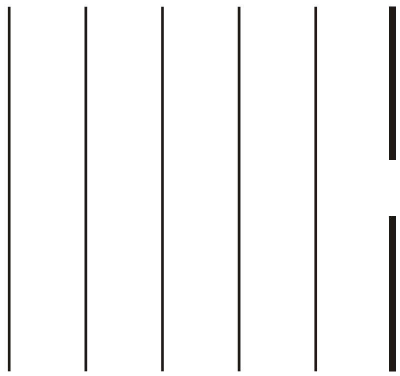
....

2. ....

....

[Total 2 marks]

115. The figure below shows plane water waves in a ripple tank approaching a narrow gap. On the diagram, draw the pattern of the wavefronts emerging from the gap.



[Total 2 marks]

116. Explain why the diffraction of sound waves is much more likely to be noticeable than the diffraction of light.

....

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[Total 2 marks]

117. A nitrogen atom is initially stationary at point **P** in Fig. 1, midway between two large horizontal parallel plates in an evacuated chamber. The nitrogen atom becomes charged.
There is an electric field between the plates. Ignore any effects of gravity.

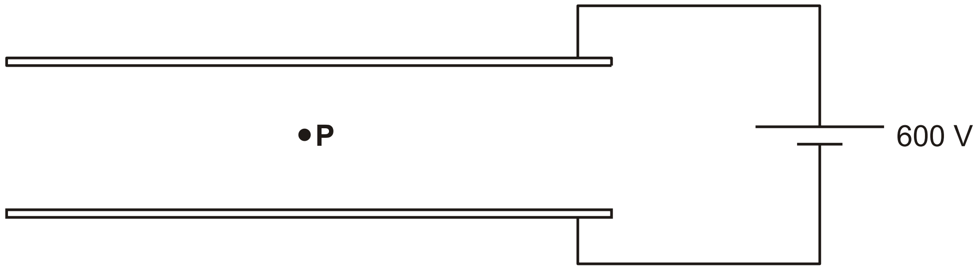

Fig. 1

(a) The direction of the electric force on the nitrogen ion is vertically downwards. State with a reason the sign of the charge on the ion.

....

....

....

[1]

(b) The voltage between the plates is 600 V. At the instant that the ion, charge 1.6×10^{-19} C and mass 2.3×10^{-26} kg, reaches the lower plate, show that

(i) the kinetic energy of the ion is 4.8×10^{-17} J

[2]

(ii) the speed of the ion is 6.5×10^4 m s^{-1}.

[2]

(c) The electric field strength between the plates is 4.0×10^4 N C^{-1}. Calculate the separation of the plates.

separation = ... m

[2]

(d) The ion passes through a hole in the lower plate at a speed of 6.5×10^4 m s^{-1}. It enters a region of uniform magnetic field of flux density 0.17 T perpendicularly into the plane of Fig. 2.

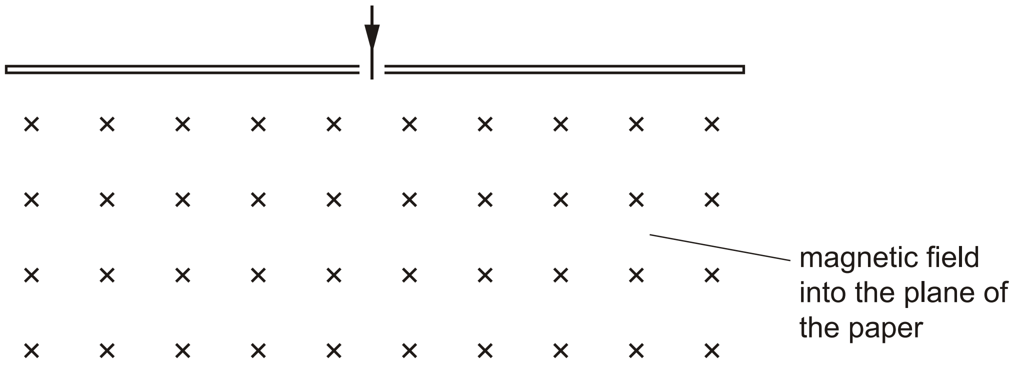

Fig. 2

(i) Sketch on Fig. 2 the semicircular path taken by the ion.

[1]

(ii) Calculate how far from the hole the ion will collide with the plate. Use data from **(b)**.

distance = ... m

[5]

[Total 13 marks]

118. Most man-made objects launched into space are satellites placed in a particular orbit around the Earth to function as TV transmitters, telephone relays or weather stations. Some spacecraft have been launched, however, to travel into much deeper space to explore the outer planets of our solar system. All spacecraft, whether satellites or deep space probes, must communicate with Earth by transmitting a radio signal. The circuits producing the signal require battery power and batteries require recharging from an energy source.

Most satellites in orbit around the Earth derive their power from a panel of solar cells which convert sunlight into electrical energy. One such telecommunications satellite transmits a continuous 360 W signal powered from its battery for 24 hours per day. The battery is recharged from a solar panel which has an efficiency of 16% while in direct sunlight of light intensity 1.5 kW m^{-2}.

(a) Suggest what happens to the 84% of light energy which reaches the solar panel but is not converted to electrical energy.

....

....

[1]

(b) (i) Calculate the minimum surface area of solar panel required to produce the 360 W for the transmitter.

surface area = ... m^2

[2]

(ii) Give two reasons why the surface area would have to be much greater than your answer above.

1 ....

....

2 ....

....

[2]

[Total 5 marks]

119. For a spacecraft launched into the outer regions of the solar system, it is not practical to have its battery recharged by solar panels. Such spacecraft use a Radioisotope Thermoelectric Generator (RTG). This generator has no moving parts and contains two different metals joined to form a closed electric circuit. When the two junctions between these metals are kept at different temperatures, an electric current is produced. One junction is cooled by space while the other is heated by the decay from a radioactive isotope. RTGs are very reliable sources of power.

Nowadays, RTGs use plutonium-238 which is an alpha emitter with a half-life of 88 years.
Each alpha particle is emitted with a kinetic energy of 5.0MeV.

(a) State **one** reason why solar panels are not practical in deep space.

....

....

[1]

(b) Suppose such a spacecraft transmits for 120 minutes each day from a 12 V circuit which draws a current of 5.0 A while transmitting back to Earth. During the rest of the day, the transmitting circuit is shut down. The battery charging, however, carries on continuously.

(i) Show that the energy required per day for transmission is about 0.4 MJ.

[2]

(ii) The overall efficiency in the RTG battery charging system is 25%. Show that the steady power output required from the RTG is about 20 W.

[2]

(iii) Calculate the minimum activity of the source (i.e. the number of 5 MeV alpha particles emitted per second) required to generate this power.

activity = ... Bq

[2]

(c) (i) Show that the decay constant λ of Pu-238 is 2.5×10^{-10} s^{-1}.

[2]

(ii) Calculate the number N of nuclei of Pu-238 required to generate the activity calculated in (b)(iii).

N = ...

[2]

(iii) Calculate the mass of Pu-238 corresponding to this number of nuclei.

mass = ... kg

[2]

(d) Plutonium is one of the most dangerous chemical poisons known, as well as being a radioactive hazard. It has been estimated that 1 kg of this substance, suitably distributed, would be enough to kill everyone on Earth. Comment on the risks involved in using plutonium as a fuel for spacecraft.

....

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[2]

[Total 15 marks]

120. Show that the wavelength of a photon of energy 3.9 eV is 320 nm.

[Total 2 marks]

121. Describe in detail the motion of free electrons in a copper wire

- when there is no current in the wire
- when there is a current in the wire.

Your answer should include the meanings of root-mean-square speed and drift velocity and the factors that determine them.

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[Total 7 marks]

122. A current of 0.75 A is carried in a copper wire of cross-sectional area 4.0×10^{-7} m^2. The drift velocity of free electrons in the wire is 1.4×10^{-4} m s^{-1}.

(i) Calculate n, the number of free electrons per unit volume in copper.

n = ... m^{-3}

[2]

(ii) Calculate the new drift velocity when

1 the current is changed to 0.25 A in the same wire

drift velocity = ... m s^{-1}

[1]

2 a current of 0.75 A is carried in a copper wire of twice the diameter.

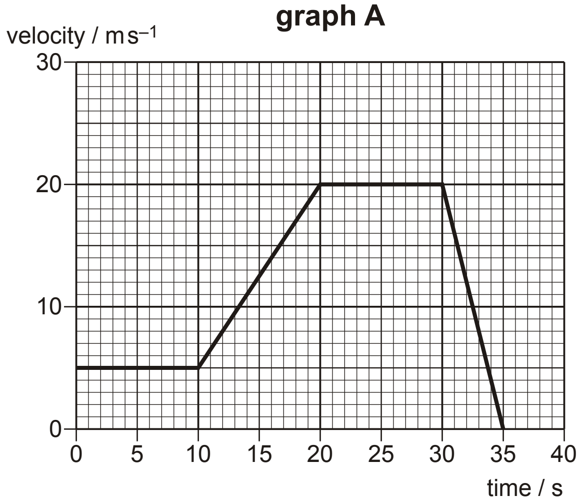
drift velocity = ... m s^{-1}

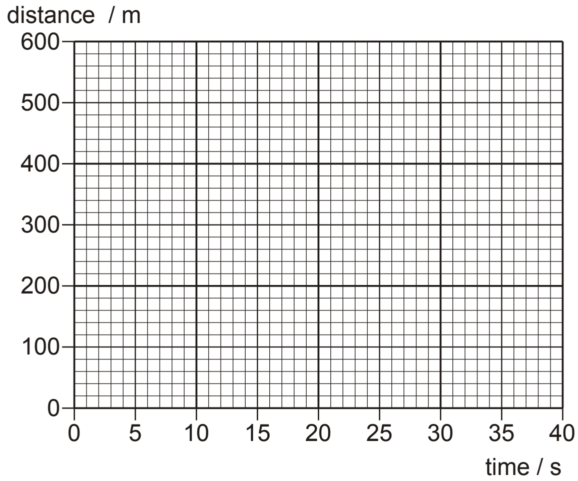
[1]

[Total 4 marks]

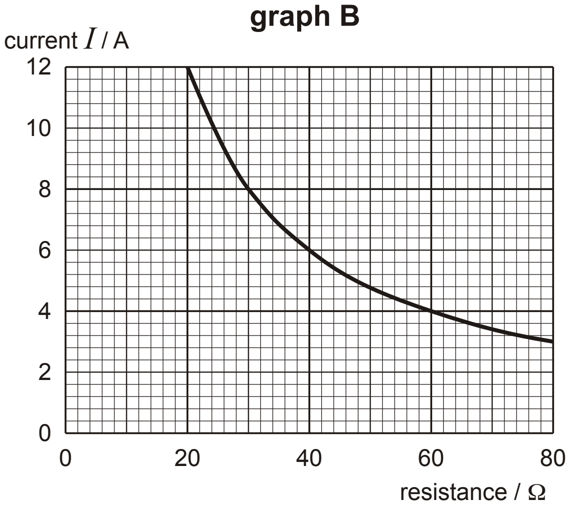
123. Data can be displayed in graphical form in many different ways. Sometimes it is necessary to change from one way of displaying data to another. Four graphs are drawn below.

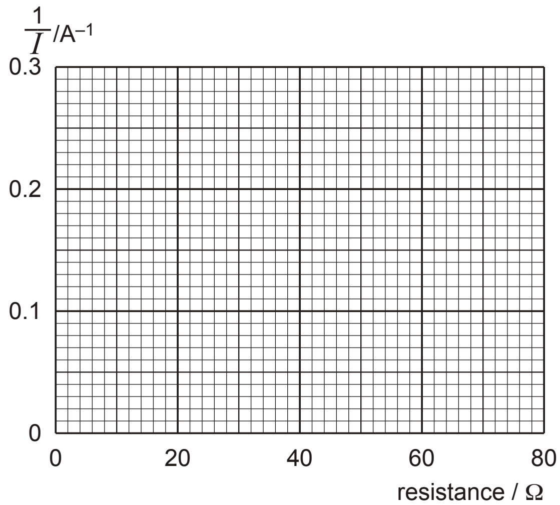
graph A



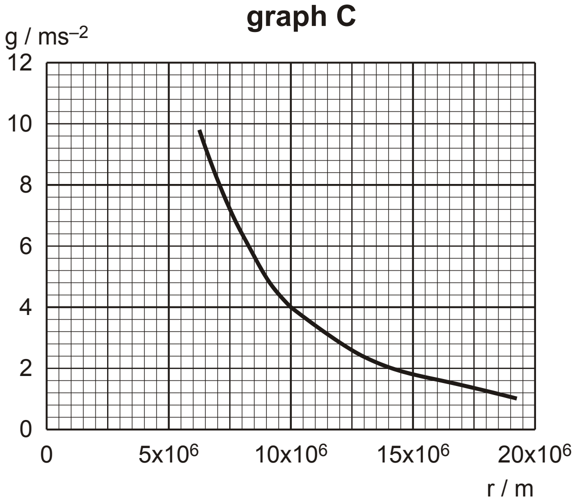


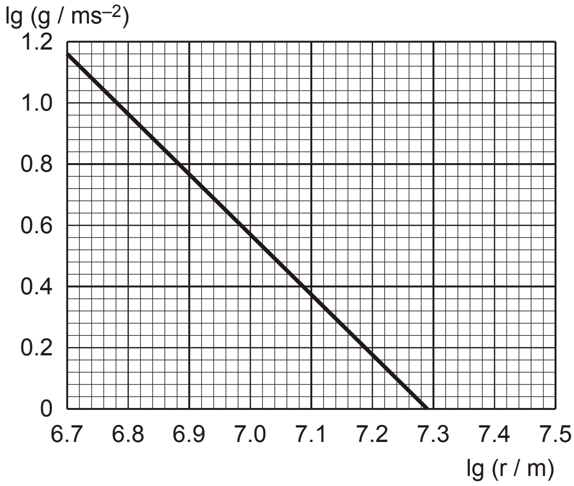
graph B





graph C





(a) (i) Calculate the total distance travelled from the velocity-time **graph A**.

distance = ... m

[3]

(ii) Using **graph A**, draw the corresponding distance-time graph.

[3]

(b) **Graph B** shows how the current I in a circuit varies with the total circuit resistance R when the e.m.f. of the supply is kept constant.

(i) Draw the corresponding graph of $1/I$ against R.

[2]

(ii) What is the e.m.f. of the supply?

e.m.f. = ... V

[1]

(iii) How is the gradient of the graph you have drawn related to your answer to (b)(ii)?

....

....

[1]

(c) **Graph C** shows how *g*, the acceleration due to gravity, varies with *r*, the distance from the centre of the Earth. A log-log graph showing the same data has been drawn on new axes.

(i) Calculate the gradient of the log-log graph.

gradient = ...

[2]

(ii) What can be deduced from the value of the gradient?

....

....

[2]

[Total 14 marks]

124. State the difference between the directions of conventional current and electron flow.

....

....

[Total 1 mark]

125. In the space provided below, draw the symbol for a light-dependent resistor (LDR) and state how its resistance is affected by the intensity of light falling on it.

....

....

....

....

[Total 2 marks]

126. State Ohm's law.

....

....

....

[Total 2 marks]

127. Current against voltage (*I*/*V*) characteristics are shown in Fig. 1a for a metallic conductor at a constant temperature and in Fig. 1b for a particular thermistor.

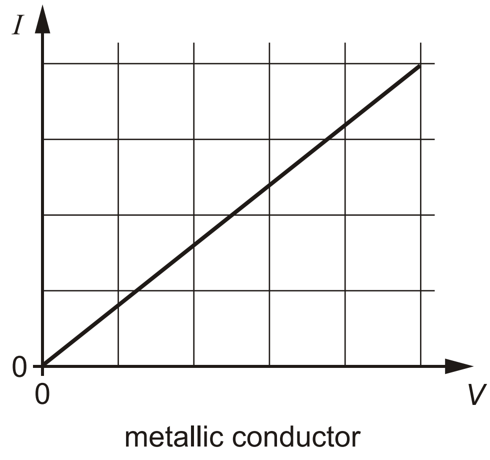


Fig. 1a

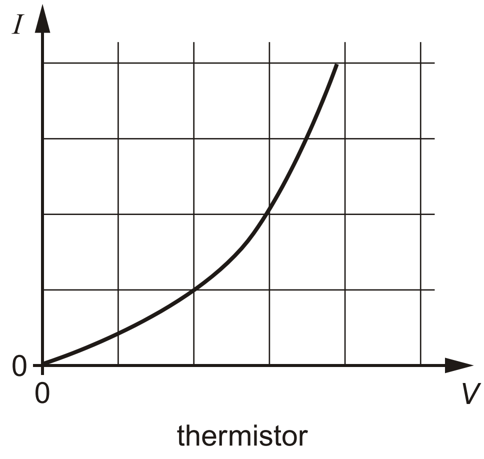


Fig. 1b

(i) Sketch the variation of resistance *R* with voltage *V* for

1. the metallic conductor at constant temperature (draw this on Fig. 2a)
2. the thermistor (draw this on Fig. 2b).

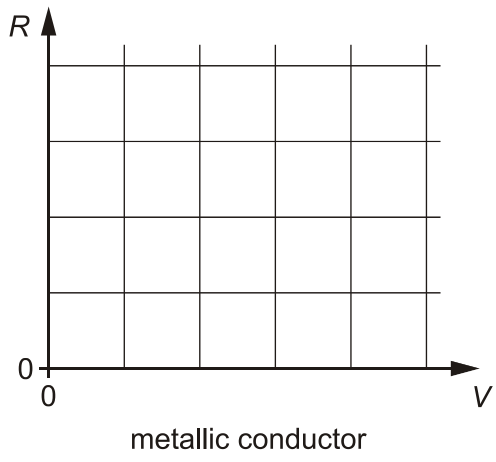


Fig. 2a

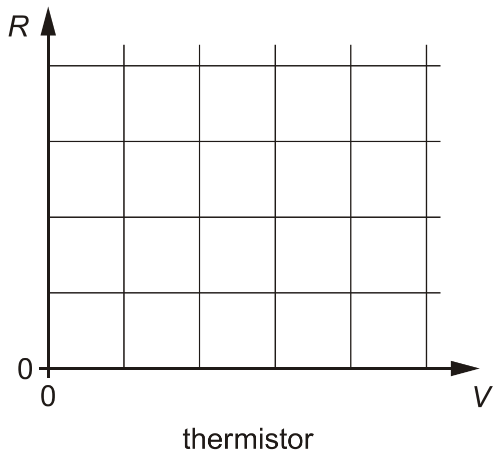


Fig. 2b

[3]

(ii) State and explain the change, if any, to the graph of resistance against voltage for the metallic conductor

1. when the temperature of the metallic conductor is kept constant at a **higher** temperature

....

....

....

2. when the length of the conductor is doubled but the material, temperature and the cross-sectional area of the conductor remain the same.

....

....

....

[4]

[Total 7 marks]

128. Define the *kilowatt-hour* (kW h).

....

....

[Total 1 mark]

129. On average, a student uses a computer of power rating 110 W for 4.0 hours every day. The computer draws a current of 0.48 A and its screen emits visible light of average wavelength 5.5×10^{-7}m.

(i) For a period of **one** week, calculate

1. the number of kilowatt-hours supplied to the computer

number of kW h = ...

[2]

2. the cost of operating the computer.
(The cost of each kW h is 7.5p)

cost = ... p

[1]

(ii) Calculate the electric charge drawn by the computer for a period of **one** week.

charge = ... C

[3]

(iii) 1. Calculate the energy of each photon of wavelength 5.5×10^{-7} m emitted from the computer screen.

energy = ... J

[3]

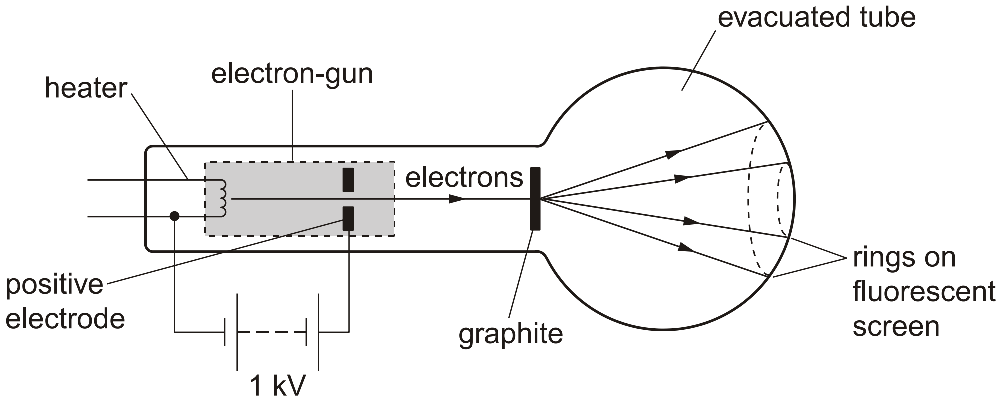
2. The power of the light emitted from the computer screen is 8.0 W. Calculate the total number of photons emitted per second from the computer screen.

number = ... s^{-1}

[2]

[Total 11 marks]

130. Wave-particle duality suggests that an electron can exhibit both particle-like and wave-like properties. The figure below shows the key features of an experiment to demonstrate the wave-like behaviour of electrons.



The electrons are accelerated to high speeds by the electron-gun. These high speed electrons pass through a thin layer of graphite (carbon atoms) and emerge to produce rings on the fluorescent screen.

(a) In this question, two marks are available for the quality of written communication.

Use the ideas developed by de Broglie to explain how this experiment demonstrates the wave-like nature of electrons. Suggest what happens to the appearance of the rings when the speed of the electrons is increased.

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[5]

Quality of Written Communication [2]

(b) Suggest how, within the electron-gun, this experiment provides evidence for the particle-like property of the electrons.

....

....

[1]

[Total 8 marks]

131. Both electromotive force (e.m.f.) and potential difference (p.d.) may be defined as 'energy per unit charge'. With reference to energy transfers, state **one** major difference between e.m.f. and potential difference.

....

....

[Total 1 mark]

132. State Kirchhoff's first law.

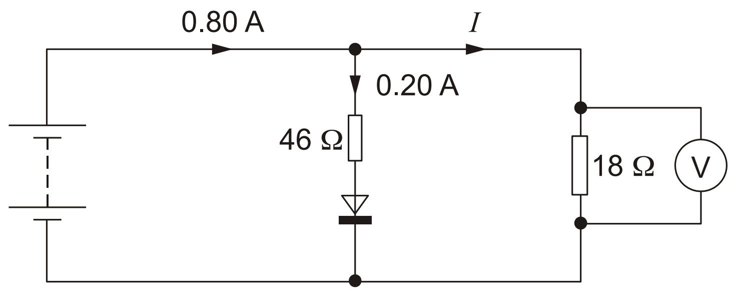
....

....

....

[Total 2 marks]

133. The figure below shows an electrical circuit in which the voltmeter has an infinite resistance.



Calculate

(i) the current *I* in the 18 Ω resistor

I = ... A

[1]

(ii) the voltmeter reading

reading = ... V

[2]

(iii) the resistance of the diode

resistance = ... Ω

[3]

(iv) the power dissipated by the diode.

power = ... W

[2]

[Total 8 marks]

134. Electrons are emitted from the surface of zinc when it is exposed to ultraviolet radiation.

(i) Name this phenomenon.

....

[1]

(ii) State a typical value for the wavelength of ultraviolet radiation in metres.

....

[1]

[Total 2 marks]

135. Electromagnetic radiation incident on a metal plate releases energetic electrons from its surface. The metal plate is placed in an evacuated chamber. The energy of each photon is 2.8 eV. The metal has a work function energy of 1.1 eV.

(i) Explain what is meant by the *work function energy* of the metal.

....

....

[1]

(ii) State the speed of the photons.

....

[1]

(iii) For an electron emitted from the surface of the metal, calculate

1. its maximum kinetic energy in joules

energy = ... J

[3]

2. its maximum speed.

speed = ... m s^{-1}

[2]

(iv) State the change, if any, to your answer for the maximum speed of an electron emitted from the surface of the metal when the intensity of the incident electromagnetic radiation is doubled.

....

....

[1]

[Total 8 marks]

136. State an example of

(i) *a transverse wave*

....

[1]

(ii) *a longitudinal wave*.

....

[1]

[Total 2 marks]

137. By referring to the nature of the vibrations involved, describe what is meant by

(i) a transverse wave

....

....

[1]

(ii) a longitudinal wave.

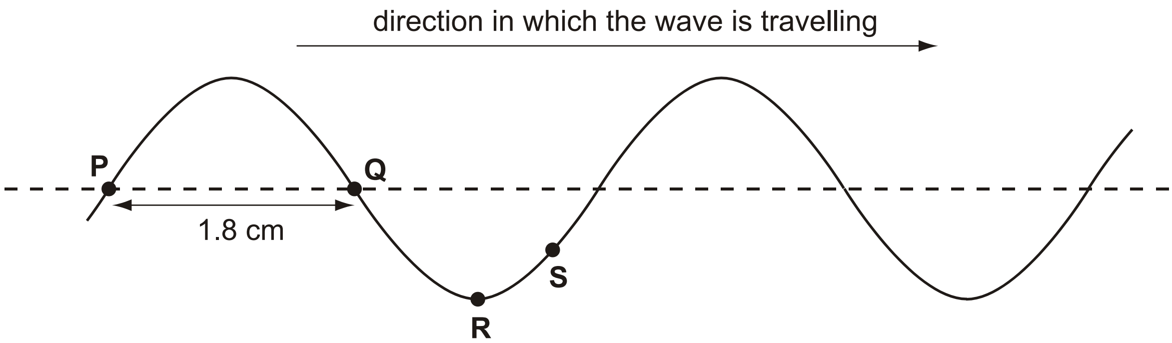
....

....

[1]

[Total 2 marks]

138. The figure below shows, at a given instant, the surface of the water in a ripple tank when plane water waves are travelling from left to right.



(a) Show on the figure

(i) the amplitude of the wave – label this **A**

[1]

(ii) the wavelength – label this λ.

[1]

(b) On the figure above

(i) draw the position of the wave a short time, about one-tenth of a period, later

[2]

(ii) draw arrows to show the directions in which the particles at **Q** and **S** are moving during this short time.

[2]

(c) State the phase difference between the movement of particles at **P** and **Q**.

phase difference = ... °

[1]

(d) The frequency of the wave is 25 Hz and the distance between **P** and **Q** is 1.8 cm. Calculate

(i) the period of the wave

period = ...s

[2]

(ii) the speed of the wave.

speed = ...m s^{-1}

[3]

(e) (i) Suggest how the speed of the waves in the ripple tank could be changed.

....

....

[1]

(ii) The frequency of the wave source is kept constant and the wave speed is halved. State what change occurs to the wavelength.

....

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[2]

[Total 15 marks]

139. State the term used to describe two wave sources that have a constant phase difference.

....

[Total 1 mark]

140. Using suitable diagrams, state and explain what is meant by

- constructive interference
- destructive interference.

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[Total 4 marks]

141. Describe an experiment to determine the wavelength of monochromatic light (i.e. light of one wavelength) using a double-slit of known slit separation. Include in your answer

- a labelled diagram showing how the apparatus is arranged
- a list of the measurements required to determine the wavelength λ of the light
- the formula, with all symbols identified, that could be used to determine λ.

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....

[Total 6 marks]

142. In this question, two marks are available for the quality of written communication.

A beam of low-energy electrons, incident on an atomic crystal or lattice, enables the spacing of the atoms to be determined. Explain the principles of such an experiment and how the atomic spacing is found.
How does the energy of the electrons in the beam determine the size of the particles that can be investigated?
A space has been left for you to draw suitable diagram(s), if you wish to illustrate your answer.

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[5]

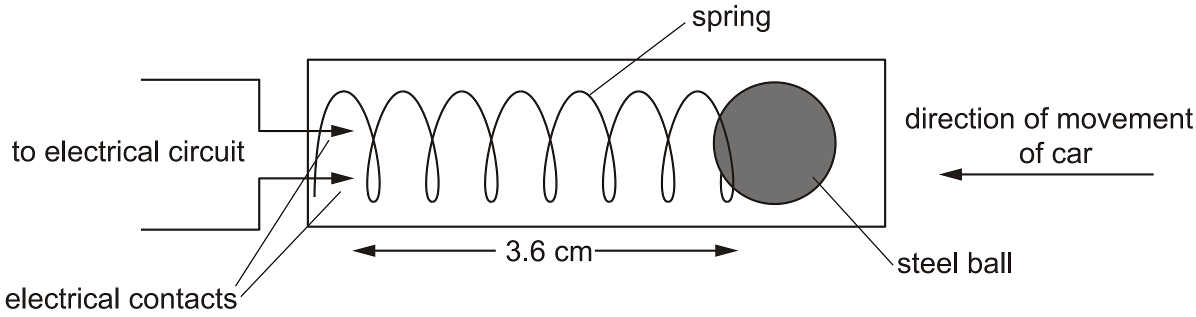
Quality of Written Communication [2]

[Total 7 marks]

143. Although the idea for the airbag was first suggested more than fifty years ago, it has only been a compulsory safety feature in the modern motor car since 1998. When a car experiences a serious head-on collision, the seat belt is designed to restrain the driver's body. However, without the cushioning effect of an airbag, the inertia in the driver's head will cause it to carry on moving at the speed of the car until it is stopped by the steering wheel or the windscreen. When activated, the airbag must be fully inflated before the driver's head reaches it so that the head hits a soft target.

One early system stored the gas for the airbag in a cylinder under the driver's seat. When the deceleration of the car was sufficiently large, a sensor caused an electrical circuit to operate and open a valve so that the compressed gas could rush into the airbag on the steering wheel.

The sensor used a steel ball and spring in a cylinder as shown below.



When the car was being driven normally, the spring kept the steel ball apart from the two electrical contacts inside the cylinder. But if the deceleration became large enough, the inertia of the free ball compressed the spring and the ball touched the two contacts, thus activating the electrical circuit.

The method of storing compressed gas in a cylinder was not very reliable because some cylinders slowly leaked gas and so all had to be checked regularly.

The modern method of inflating an airbag is to generate the gas chemically by activating an electrical heater or detonator in an explosive chemical mixture. The heating starts a very rapid chemical reaction which produces nitrogen for the airbag. This means that the folded airbag along with chemicals and heater can all be located together in a compact container and positioned anywhere inside the car.

Consider the following data for a car running head-on into an immovable object.

initial velocity of car	= 54 km hr^{-1}
final velocity of car	= 0
car front crumple distance	= 1.25m
distance from head to windscreen	= 0.96m

(a) Show that the car's speed in m s^{-1} just before hitting the object is 15 m s^{-1}.

[2]

(b) Calculate

(i) the deceleration of the car during the collision (assumed to be constant)

deceleration = ... m s^{-2}

[2]

(ii) the time taken for the car to crumple to rest.

time = ... s

[2]

(c) The data for a ball and spring sensor is given below.

mass of ball	= 0.12 kg
spring constant	= 30 N m^{-1}
distance to be compressed	= 3.6 cm

Calculate

(i) the force necessary to compress the spring by 3.6 cm

force = ... N

[2]

(ii) the deceleration which the force in (c)(i) would cause in a mass of 0.12 kg.

deceleration = ... m s^{-2}

[1]

(d) When the airbag was fully inflated from a storage cylinder, the bag had a volume of 0.060 m^3, with the gas inside at a pressure of 250 kPa. If the storage cylinder had a volume of 3.0×10^{-4} m^3, calculate the stored gas pressure, assuming the gas was ideal and at constant temperature.

pressure = ... Pa

[2]

(e) Suppose that the pressure inside the cylinder dropped by 20% over a period of 4 weeks.
Assuming the mean temperature of the cylinder is 17 °C, calculate the average number of gas molecules leaving per second during this time.

number leaving per second = ...

[4]

(f) The data for a modern airbag is given below.

energy required for reaction to start	= 0.96 J
heater wire cross sectional area	= 2.75×10^{-8} m^2
heater wire length	= 2.2 cm
resistivity of heater wire	= 1.5×10^{-6} Ωm
battery voltage	= 12V

(i) Show that the resistance of the heater filament is 1.2Ω.

[2]

(ii) Hence calculate the time taken for the heater to start the chemical reaction.

time to start = ... s

[3]

[Total 20 marks]

144. A thermistor made of semiconducting material is connected to a voltage source using copper wire. The current in the circuit is 2.5 mA.

(i) The free electron concentration in copper is 8.5×10^{28} m^{-3}. The cross-sectional area of the wire is 1.1×10^{-7} m^2. Calculate the drift velocity of free electrons in the wire.

drift velocity = ... $m\ s^{-1}$

[2]

(ii) The cross-sectional areas of the thermistor and wire are similar. Suggest why the drift velocity of free electrons in the thermistor is greater than the drift velocity in the wire.

....

[1]

[Total 3 marks]

145. Flow occurs in many different aspects of physics. For example, flow of electrons is an electric current, heat flow takes place as a result of a temperature gradient and flow of water or gas along a pipe is a common experience. The dimensions of the material through which flow occurs, together with the properties of the material and the cause of flow, determine the amount of flow which takes place.

(a) Why is one pipe necessary for the supply of gas to a house but two cables are necessary for the supply of electricity?

....

....

....

....

[3]

(b) The amount of heat energy flowing per unit time through the wall of a room is given by

$$\frac{Q}{t} = kA\left(\frac{\theta_2 - \theta_1}{d}\right)$$

where Q is the quantity of heat energy which flows in time t,
k is called the thermal conductivity,
A is the surface area of the wall,
d is the thickness of the wall
and θ_2 and θ_1 are the inside and outside temperatures respectively.

(i) Deduce the SI unit of k, the thermal conductivity.

unit of k ....

[3]

(ii) Calculate the rate at which heat energy is lost through the wall of the room under the following conditions.

k = 0.35 in SI units
A = 12.0 m^2
θ_2 = 22.0 °C
θ_1 = 8.0 °C
d = 0.10 m

rate at which heat energy is lost $\left(\frac{Q}{t}\right)$ = ... W

[2]

(c) (i) Write a corresponding equation to that in (b) for charge flow per unit time, $\frac{Q}{t}$ through a wire, in terms of

the potential difference across the wire V
the resistivity of the material of which the wire is made ρ
and the length l and area of cross-section A of the wire.

[2]

(ii) Compare the equations in (c)(i) and (b).

1 State which thermal property corresponds with V in the electrical case.

....

[1]

2 State which thermal property corresponds with ρ in the electrical case.

....

[1]

(d) (i) Flow of gas through a pipe follows the same pattern as for electron flow and heat flow. Suggest an equation for gas flow. State the meaning of any symbols you introduce.

[3]

(ii) 160 cm^3 of gas flow per second through a pipe of internal diameter 15 mm. How much gas will flow per second through a pipe of internal diameter 22 mm under the same conditions?

volume per second = ... $cm^3\ s^{-1}$

[2]

[Total 17 marks]

146. The electromagnetic spectrum covers a very wide range of wavelengths, frequencies and photon energies.

(i) State the names and wavelengths for the shortest and longest electromagnetic waves.

shortest: name .... wavelength ....m

longest: name .... wavelength ....m

[4]

(ii) Calculate the ratio

$$\frac{\text{longest wavelength}}{\text{shortest wavelength}}$$

ratio = ...

[1]

(iii) Two notes in sound which are an octave apart have a wavelength ratio of 2. When the notes are **three** octaves apart, the wavelength ratio is 8 since $8 = 2^3$. By how many octaves does your answer to (ii) correspond?

number of octaves ....

[2]

(iv) Calculate the maximum energy of a photon in the electromagnetic spectrum, using a value of wavelength which you have given in (i).

photon energy .... J

[2]

[Total 9 marks]

147. State **two** properties of electromagnetic waves which **do not** change across the whole of the spectrum.

Discuss **two** features of electromagnetic waves, other than just wavelength and frequency, which **do** change across the spectrum.

(Allow one lined page).

[Total 6 marks]

148. All electromagnetic waves travel at the same speed in free space.
State this speed in m s^{-1}.

....

[Total 1 mark]

149. A television remote control has a battery of electromotive force (e.m.f.) 3.0 V. When the remote control is operated, the battery delivers a current of 1.4×10^{-3} A and infra-red radiation of wavelength 8.8×10^{-7} m is emitted.

(i) Calculate the frequency of the infra-red radiation.

frequency = ... Hz

[2]

(ii) State what is meant by *electromotive force*.

....

....

[1]

(iii) In a time interval Δt, an amount of charge ΔQ flows through the battery. Write an equation for the magnitude of the electric current I in terms of Δt and ΔQ.

[1]

(iv) Calculate the charge flowing through the battery when the remote control is operated for a time interval of 0.20 s.

charge = ... C

[2]

(v) Calculate the chemical energy transformed into electrical energy by the charge calculated in (iv) flowing through the battery.

energy = ... J

[2]

[Total 8 marks]

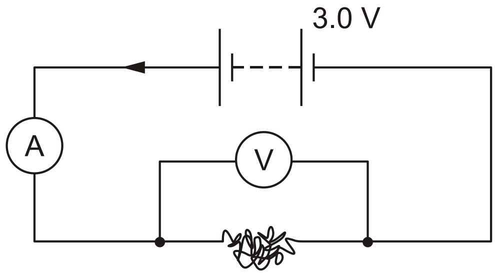
150. The electrical resistance of a wire depends on its temperature and on the resistivity of the material. List **two** other factors that affect the resistance of a wire.

1. ....

2. ....

[Total 2 marks]

151. The figure below shows an electrical circuit that contains a thin insulated copper wire formed as a bundle.



The ammeter and the battery have negligible resistance and the voltmeter has an infinite resistance.

The copper wire has length 1.8 m and diameter 0.27 mm. The resistance of the wire is 0.54 Ω.

(i) Calculate the resistivity of copper.

resistivity = ... unit ....

[4]

(ii) In this question, one mark is available for the quality of written communication.

State and explain the effect on the ammeter reading and the voltmeter reading when the temperature of the copper wire bundle is increased.

....

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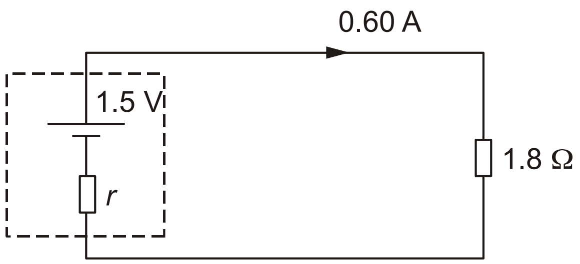
[4]

Quality of Written Communication [1]

[Total 9 marks]

152. The figure below shows an electrical circuit.

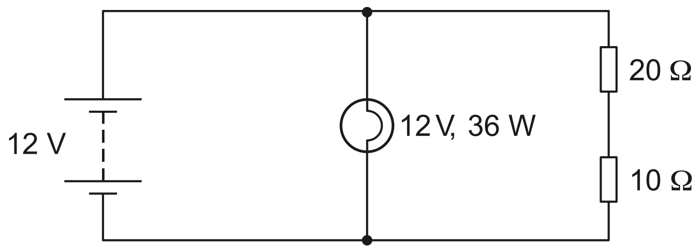


The cell has e.m.f. 1.5 V and internal resistance *r*. The current drawn from the cell is 0.60 A. Calculate the internal resistance of the cell.

r = ... Ω

[Total 3 marks]

153. The figure below shows a filament lamp and two resistors connected to a d.c. supply.



The d.c. supply has negligible internal resistance.

(i) The filament lamp is rated as '12 V, 36 W'. Calculate the resistance of the filament lamp when used in this circuit.

resistance = ... Ω

[2]

(ii) Calculate the total resistance of this circuit.

resistance = ... Ω

[3]

(iii) Calculate the ratio

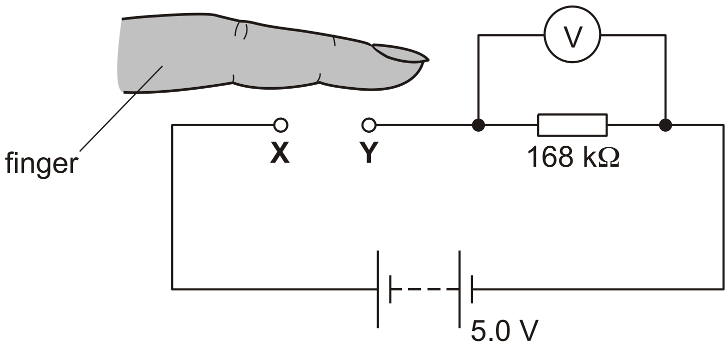
$$\frac{\text{current in the filament lamp}}{\text{current in the } 20\,\Omega \text{ resistor}}.$$

ratio = ...

[2]

[Total 7 marks]

154. The following figure shows a potential divider circuit designed as a touch-sensor.



The battery has negligible internal resistance and the voltmeter has infinite resistance.

(a) Explain why the voltmeter reading is zero when there is nothing connected between the contacts **X** and **Y**.

....

....

[1]

(b) When the finger makes contact between **X** and **Y**, the voltmeter reading changes from 0 V to 3.4 V because of the electrical resistance of the skin. Use this information to calculate the electrical resistance of the skin between the two contacts.

resistance = ... kΩ

[3]

[Total 4 marks]

155. The table below shows four statements that may or may not be true about a photon. Place a tick (✓) next to each statement if it is correct and a cross (✗) if it is incorrect.

place ✓ or ✗ here

A photon has a negative charge.	
A photon travels at the speed of 3.0×10^{8} m s^{-1} in a vacuum.	
A photon is a quantum of electromagnetic radiation.	
An X-ray photon has less energy than a photon of radio waves.	

[Total 2 marks]

156. In this question, one mark is available for the quality of written communication.

Describe and explain the photoelectric effect in terms of photons interacting with the surface of a metal.

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[6]

Quality of Written Communication [1]

[Total 7 marks]

157. An X-ray machine in a hospital emits X-rays of wavelength 4.0×10^{-10} m and of power 1.4 W.

(i) Calculate the energy of each X-ray photon

1. in joules

energy = ... J

2. in electronvolts (eV).

energy = ... eV

[4]

(ii) Calculate the number of photons emitted per second from the X-ray machine.

number = ... s^{-1}

[3]

[Total 7 marks]

158. Describe the differences between transverse and longitudinal waves.

....

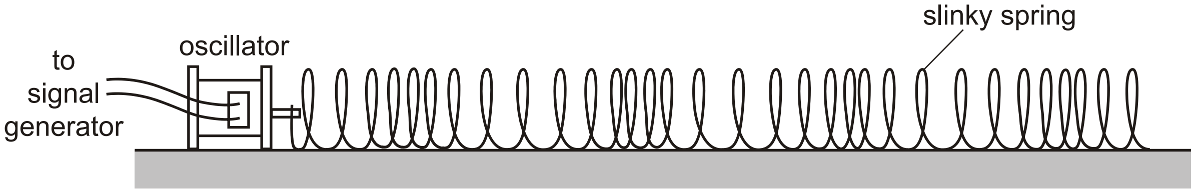
....

....

....

[Total 2 marks]

159. The figure below shows a **progressive** longitudinal wave formed in a slinky spring by an oscillator connected to a signal generator.



On the figure,

(a) (i) draw arrows to show the direction of the vibrations produced by the oscillator – label these **V**

[1]

(ii) label with a **C** the centre of a compression on the slinky

[1]

(iii) show the wavelength of the wave and label this λ.

[1]

(b) State and explain the effect on the wavelength of increasing the frequency of the oscillator.

....

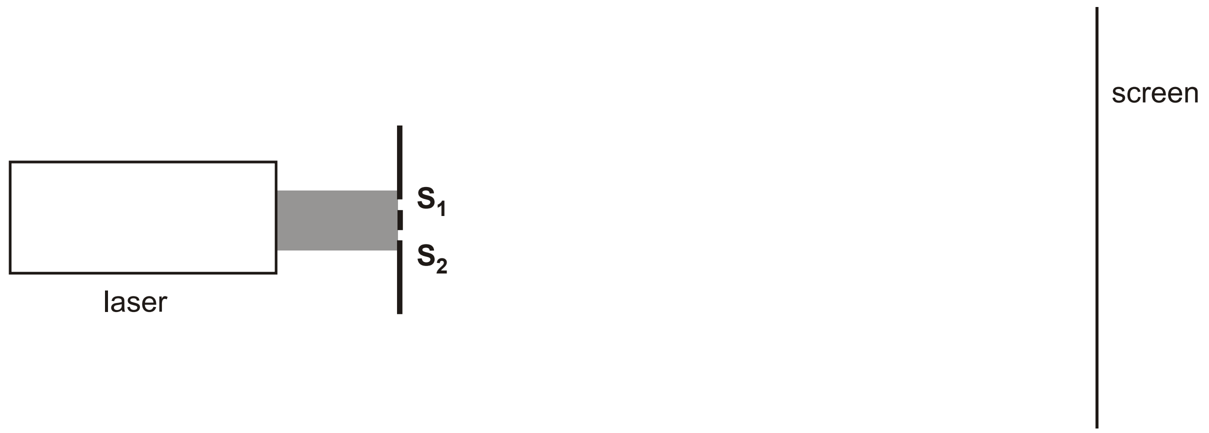
....

....

[2]

[Total 5 marks]

160. The following figure shows an arrangement to demonstrate the interference of light. A double-slit, consisting of two very narrow slits very close together, is placed in the path of a laser beam.



(a) Light spreads out as it passes through each slit. State the term used to describe this.

....

[1]

(b) The slits S_1 and S_2 can be regarded as coherent light sources. State what is meant by *coherent*.

....

....

[1]

(c) Light emerging from $\mathbf{S_1}$ and $\mathbf{S_2}$ produces an interference pattern consisting of bright and dark lines on the screen. Explain **in terms of the path difference** why bright and dark lines are formed on the screen.

....

....

....

....

....

....

[4]

(d) The wavelength of the laser light is 6.5×10^{-7} m and the separation between $\mathbf{S_1}$ and $\mathbf{S_2}$ is 0.25 mm. Calculate the distance between neighbouring dark lines on the screen when the screen is placed 1.5 m from the double-slit.

distance = ... m

[3]

[Total 9 marks]

161. In standing waves, there are *nodes* and *antinodes*. Explain what is meant by

(i) a *node*

....

....

[1]

(ii) an *antinode*.

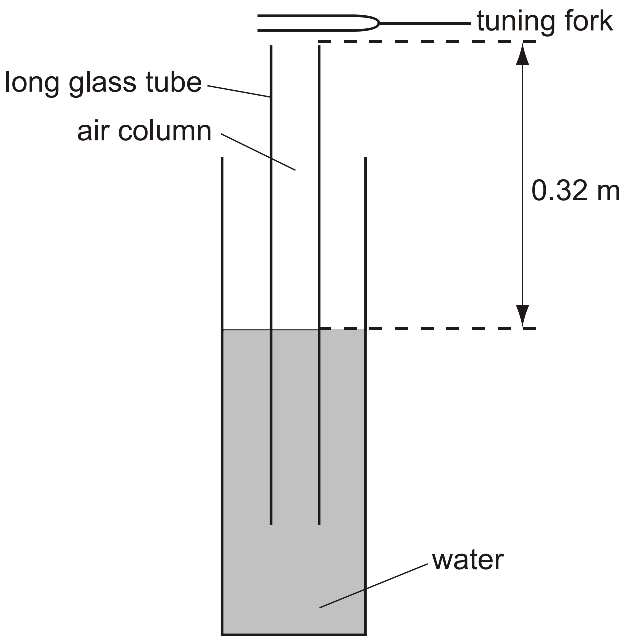
....

....

[1]

[Total 2 marks]

162. The figure below shows a long glass tube within which standing waves can be set up.



A vibrating tuning fork is placed above the glass tube and the length of the air column is adjusted, by raising or lowering the tube in the water, until a loud sound is heard.

(i) The standing wave formed in the air column is the fundamental (the lowest frequency). Show on the figure the position of a node – label as **N**, and an antinode – label as **A**.

[2]

(ii) When the fundamental wave is heard, the length of the air column is 0.32 m. Determine the wavelength of the standing wave formed.

wavelength = ... m

[1]

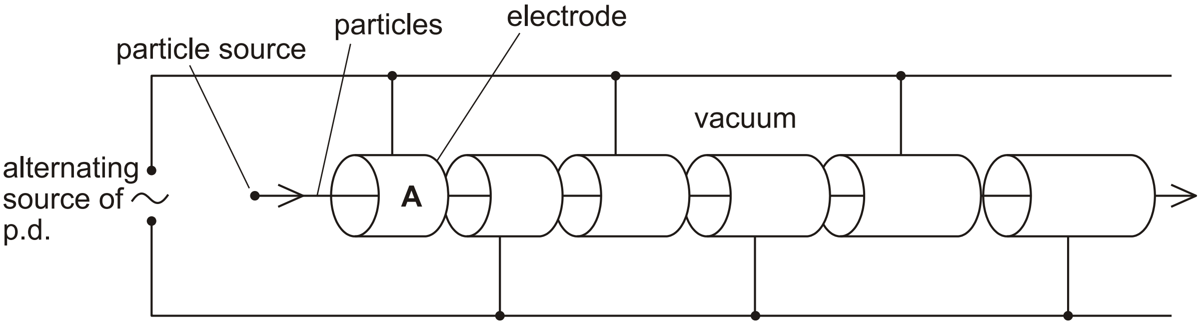
(iii) The speed of sound in air is 330 m s^{-1}. Calculate the frequency of the tuning fork.

frequency = ...Hz

[3]

[Total 6 marks]

163. The linear accelerator or linac may be used for accelerating **protons** or **positrons**. A particular linac consists of a source of charged particles and a series of cylindrical electrodes. These electrodes are attached alternately to the terminals of an alternating source of potential difference. The particles accelerate each time they cross the gap between two electrodes when the p.d. is 50 kV.



The diagram above shows the first part of such a linac.

(a) **Protons** from the particle source enter electrode **A** with 30 keV of energy.

(i) State the energy of one of these protons after being accelerated 10 times.

energy = ... keV

[1]

(ii) Calculate the speed of this proton.

speed = ... m s^{-1}

[3]

(b) A 0.65 MeV positron collides with a stationary electron. The two particles are annihilated and two γ-photons are produced. Calculate the frequency of one of these photons.

frequency = ... Hz

[4]

[Total 8 marks]

164. Explain the physics of why X-rays do **not** seem to be diffracted by a narrow slit of width about 0.1mm

....

....

....

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....

....

....

....

[Total 3 marks]

165. Explain the physics of why it is **not** possible to polarise sound waves in air

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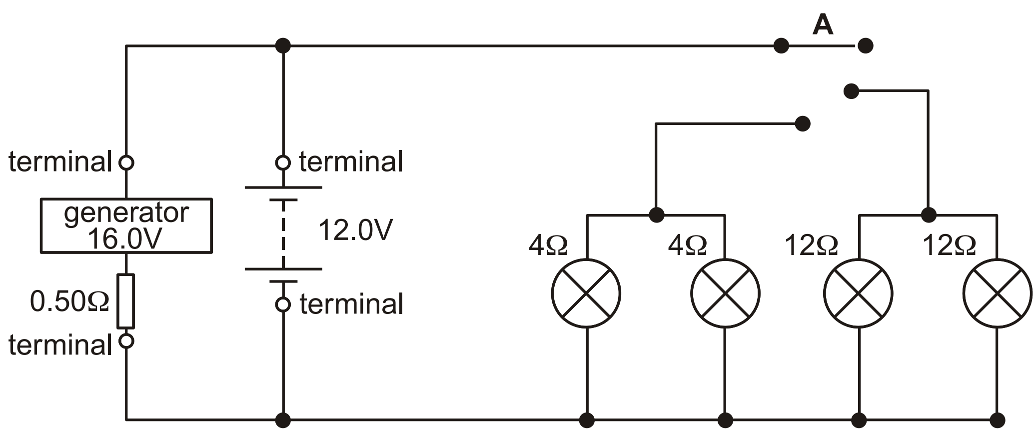
....

....

[Total 2 marks]

166. The electrical supply in most cars uses a 12.0 V battery and a 16.0 V generator connected in parallel with it. Fig. 3.1 shows part of the arrangement in a particular car. The battery has a very low internal resistance, which may be neglected, and the generator has an internal resistance of 0.50 Ω. The part of the car circuit shown is that for two bright headlamps and two side lamps, together with their switch. Sidelights and headlights cannot both be on at the same time.



(a) Explain why headlamps have a lower resistance than side lamps.

....

....

[2]

(b) Explain the function of the three-way switch **A**.

....

....

....

....

....

[3]

(c) The p.d. across the terminals of the generator must be 12.0 V, the same as the terminal p.d. of the battery. Calculate the current through the generator.

current = ... A

[2]

(d) When the headlamps are switched on, calculate

(i) the current to each headlamp

current = ... A

[2]

(ii) the total power supplied to the two headlamps. Give the correct unit.

power = ... unit ....

[3]

(e) For the situation in (d)(i) and assuming that no other current is being required by other car components, deduce the current through the battery.
State what is happening to the battery.

current = ... A

....

[3]

(f) What advantage is gained by

(i) using a battery with a very low internal resistance

....

....

....

[2]

(ii) having the e.m.f. of the generator higher than the e.m.f. of the battery?

....

....

....

[2]

[Total 19 marks]

167. (a) Explain what is meant by *electric current*.

....

[1]

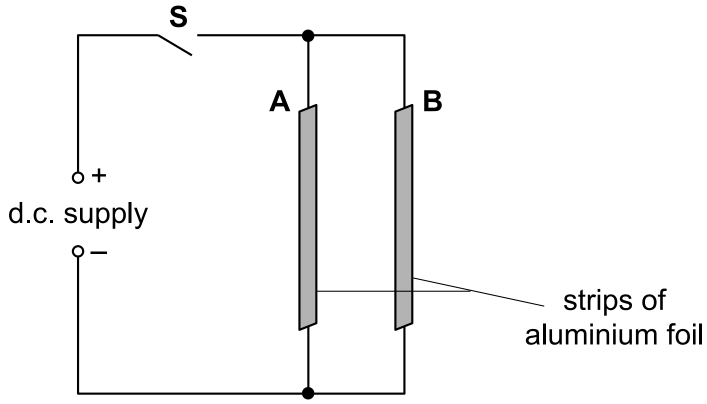
(b) The SI unit of electric charge is the coulomb. Define the *coulomb*.

....

....

[1]

(c) The diagram below shows two strips of aluminium foil connected to a d.c. supply.



The switch **S** is closed.

(i) The charge flow past a particular point in one of the aluminium strips is 340 C in a time of 50 s. Calculate the current in this aluminium strip.

current = ... A

[2]

(ii) **1** There is a force between the two aluminium strips when the switch is closed.
State why each of the aluminium strips experiences a force.

....

....

2 Name the rule that may be used to determine the direction of the force on a current-carrying wire in an electric motor.

....

3 State the direction of the force experienced by the aluminium strip **B**.

....

[3]

[Total 7 marks]

168. State Ohm's law.

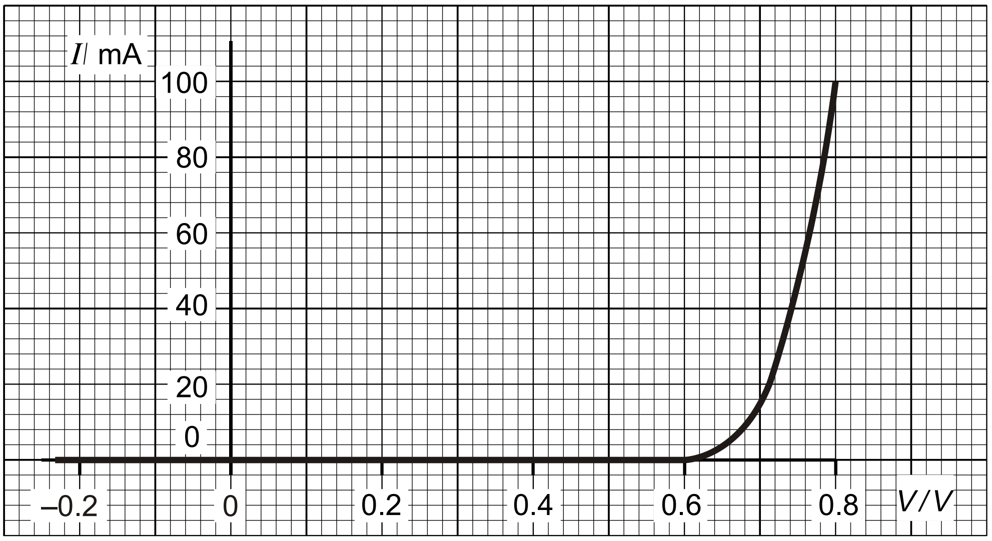
....

....

....

[Total 2 marks]

169. The *I*/*V* characteristic for a particular component is shown in the diagram below.



(i) Name the component with the *I*/*V* characteristic shown in the diagram above.

....

[1]

(ii) In this question, one mark is available for the quality of written communication.

Describe, making reference to the diagram above, how the resistance of the component depends on the potential difference V across it. You are advised to show any calculations.

....

....

....

....

....

....

....

....

....

[5]

Quality of Written Communication [1]

[Total 7 marks]

170. State Kirchhoff's first law.

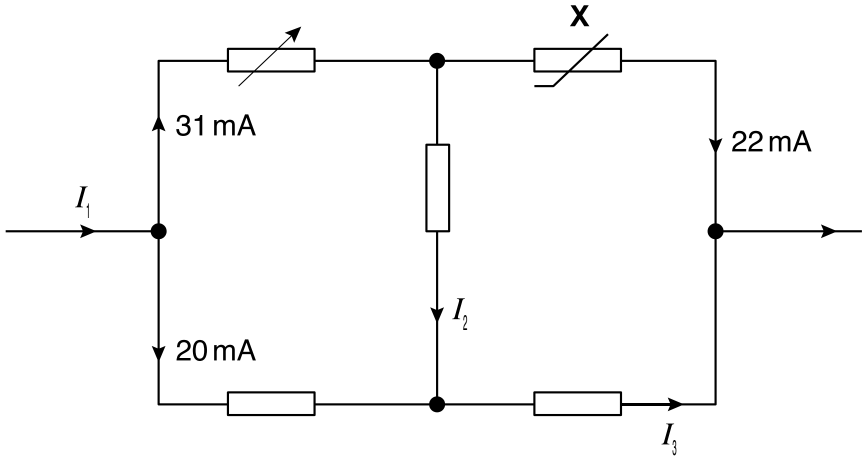
....

....

....

[Total 2 marks]

171. The diagram below shows part of an electrical circuit.



(i) Name the component marked **X**.

....

[1]

(ii) Determine the magnitude of the currents I_1, I_2 and I_3.

I_1 = ... mA

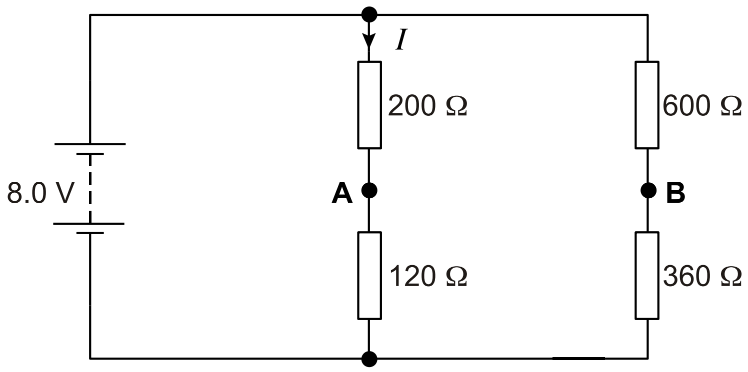
I_2 = ... mA

I_3 = ... mA

[3]

[Total 4 marks]

172. The diagram below shows an electrical circuit.



The battery has negligible internal resistance.

(a) Show that the current I is 25 mA.

[2]

(b) Calculate the potential difference (p.d.) across the resistor of resistance 120 Ω.

p.d. = ... V

[1]

(c) Explain why a voltmeter connected between points **A** and **B** will read 0 V.

....

....

....

[2]

[Total 5 marks]

173. Fig. 1 shows a plan view of an electrical circuit that includes a flat circular coil.

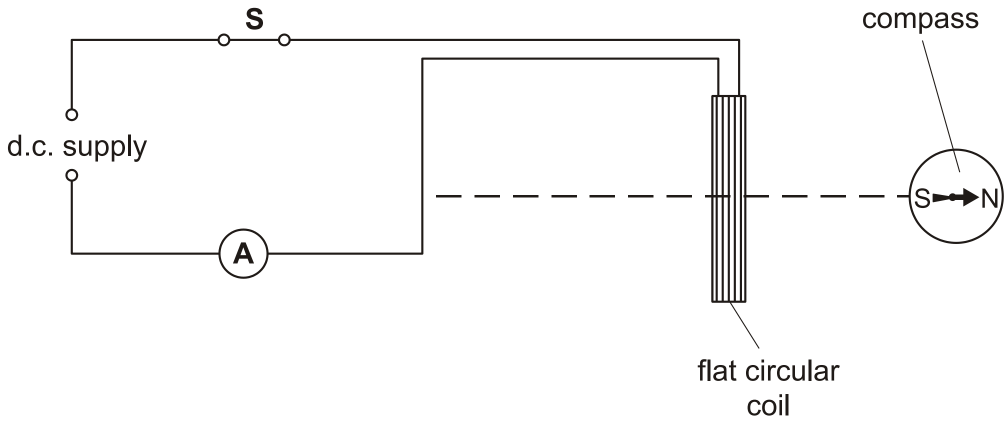


Fig. 1

(a) The coil is made from insulated wire of cross-sectional area 8.4×10^{-7} m^2. At room temperature, the material of the wire has resistivity 4.9×10^{-7} Ω m. The coil consists of 20 turns and has a mean radius 2.8 cm.

(i) Show that the total length of the wire is 3.5 m.

[1]

(ii) Calculate the resistance of the coil.

resistance = ... Ω

[3]

(b) Fig. 2 shows the variation with time *t* of the current *I* in the circuit after the switch **S** has been closed.

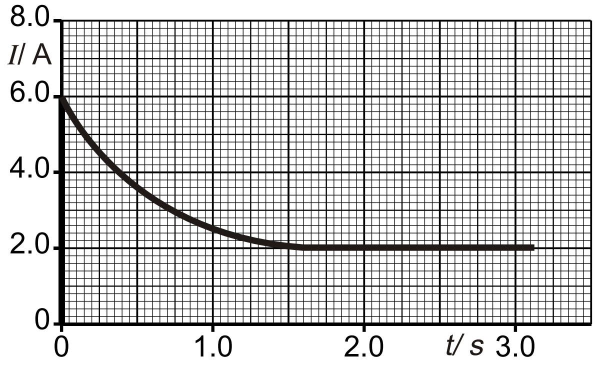


Fig. 2

(i) Calculate the potential difference (p.d.) across the coil immediately after the switch **S** is closed.

p.d. = ... V

[2]

(ii) Calculate the power dissipated by the coil immediately after the switch **S** is closed.

power = ... unit ....

[3]

(iii) In this question, one mark is available for the quality of written communication.

Explain why the current changes as shown in Fig. 2.

....

....

....

....

....

....

....

....

....

....

[4]

Quality of Written Communication [1]

[Total 14 marks]

174. State what property of electromagnetic radiation is demonstrated by the photoelectric effect.

....

[Total 1 mark]

175. Define each of the following terms

(i) photon

....

....

[1]

(ii) threshold frequency.

....

....

[1]

[Total 2 marks]

176. An argon-laser emits electromagnetic radiation of wavelength 5.1×10^{-7} m. The radiation is directed onto the surface of a caesium plate. The work function energy for caesium is 1.9 eV.

(i) Name the region of the electromagnetic radiation emitted by the laser.

....

[1]

(ii) Show that the work function energy of caesium is 3.0×10^{-19} J.

[1]

(iii) Calculate

1 the energy of a single photon

energy = ... J

[2]

2 the maximum kinetic energy of an electron emitted from the surface of caesium.

kinetic energy = ... J

[3]

(iv) State and explain what change, if any, occurs to the maximum kinetic energy of an emitted electron if the intensity of the laser light is reduced.

....

....

....

....

[2]

(v) The power of the laser beam is 80 mW. Calculate the number of electrons emitted per second from the caesium plate assuming that only 7.0% of the incident photons interact with the surface electrons.

number = ... s^{-1}

[2]

[Total 11 marks]

177. An argon-laser emits electromagnetic radiation of wavelength 5.1×10^{-7} m. The radiation is directed onto the surface of a caesium plate. The work function energy for caesium is 1.9 eV.

Moving electrons have a wave-like property. Calculate the speed *v* of an electron having a de Broglie wavelength equal to the wavelength of the laser above.

v = ... m s^{-1}

[Total 3 marks]

178. (i) State **three** phenomena that are associated with **all** waves.

1 ....

2 ....

3 ....

[3]

(ii) State a phenomenon that is only associated with transverse waves.

....

[1]

[Total 4 marks]

179. (a) Define the following wave characteristics.

(i) frequency f

....

....

(ii) wavelength λ

....

....

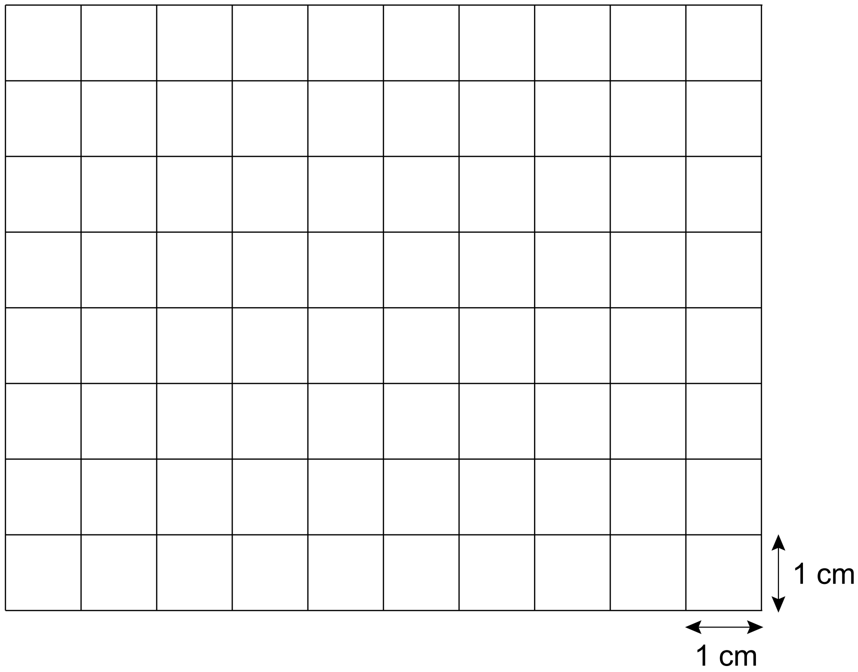
[2]

(b) Use the definitions of f and λ to deduce the relationship between f, λ and the speed v of a wave. Explain each stage of your deduction.

[2]

[Total 4 marks]

180. The diagram below represents the screen of a cathode ray oscilloscope (c.r.o.).



The time-base setting is 0.50 ms cm^{-1} and the voltage (y-gain) setting is 2.0 mV cm^{-1}. A microphone connected to the c.r.o. detects a pure (sinusoidal) sound wave note of frequency 500 Hz.

(i) Calculate the period of the note.

period = ... s

[1]

(ii) The amplitude of the signal from the microphone produced by the note is 6.0 mV.

Draw on the diagram above the trace produced on the c.r.o. screen when the microphone detects the sound wave. Draw at least two full cycles of the wave on the diagram.

[3]

(iii) The speed of sound in air is 330 m s^{-1}. Calculate the wavelength of the sound received by the microphone.

wavelength = ... m

[2]

[Total 6 marks]

181. State **one** similarity and **one** difference between progressive waves and standing waves.

similarity

....

....

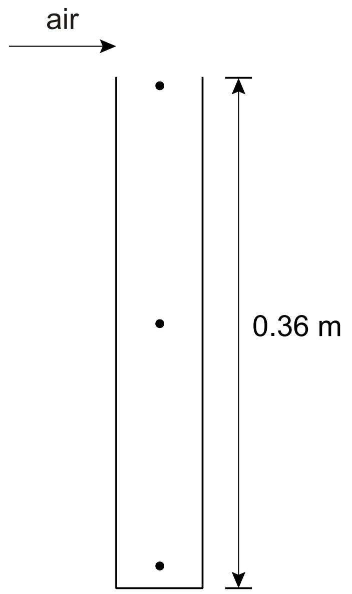
difference

....

....

[Total 2 marks]

182. A standing sound wave can be produced in an air column by blowing across the open end of a tube as shown in the diagram below.



The length of the tube is 0.36 m. The air column in the tube is sounding its lowest (fundamental) frequency note.

(i) Add **arrowed** lines to the dots in the diagram above to show the direction of movement and relative amplitudes of the air at these positions.

[3]

(ii) Calculate the wavelength of the sound produced.

wavelength = ... m

[1]

(iii) The speed of sound in air is 330 m s^{-1}. Determine the frequency of this standing wave.

frequency = ... Hz

[2]

(iv) Determine the value of the lowest frequency of the note produced in a tube of this length but open at **both** ends. Show your reasoning.

lowest frequency = ... Hz

[3]

[Total 9 marks]

183. (i) State what is meant by a *progressive* wave.

....

....

[1]

(ii) Describe in terms of the motions involved, the essential difference between longitudinal and transverse progressive waves.

....

....

....

[2]

[Total 3 marks]

184. Mobile phones use electromagnetic radiation in the form of microwaves.

State a typical value for the wavelength of microwaves.

wavelength = ... m

[Total 1 mark]

185. Mobile phones use electromagnetic radiation in the form of microwaves.

State **one** property of microwaves.

....

[Total 1 mark]

186. Mobile phones use electromagnetic radiation in the form of microwaves.

A particular mobile phone battery transforms 78 J of chemical energy into electrical energy for every 24 C of charge. Calculate the electromotive force (e.m.f.) of the battery.

e.m.f. = ... V

[Total 2 marks]

187. A convenient unit of energy is the kilowatt hour (kW h).

(a) Define the *kilowatt hour*.

....

....

[1]

(b) A 120 W filament lamp transforms 5.8 kW h. Calculate the time in seconds for which the lamp is operated.

time = ... s

[2]

[Total 3 marks]

188. Fig. 1 shows a cell of e.m.f. E and internal resistance r connected to a variable resistor.

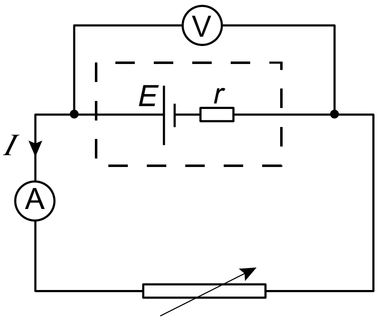


Fig. 1

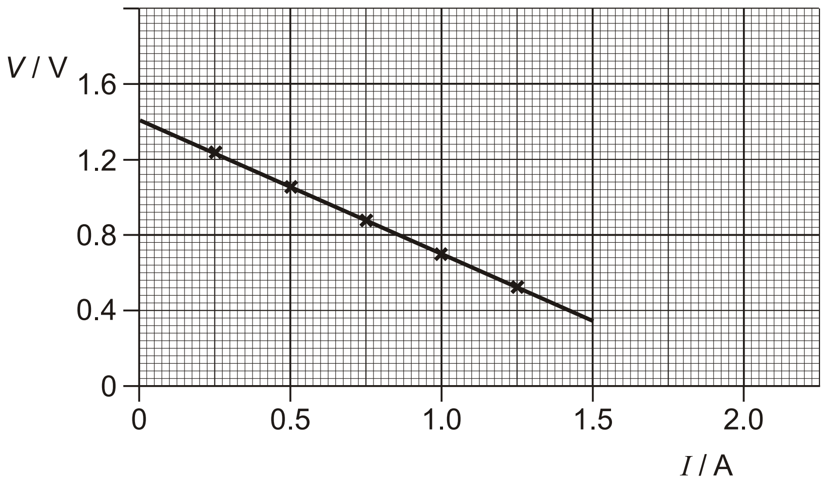


Fig. 2

Fig. 2 shows the variation of the p.d. V across the terminals of the cell with the current I drawn from the cell.

(a) Explain how Fig. 2 shows that the e.m.f. E is 1.4 V.

....

....

[1]

(b) (i) Use Fig. 2 to determine the maximum possible current that can be drawn from the cell.

current = ... A

[1]

(ii) Calculate the internal resistance r of the cell.

r = ... Ω

[2]

(iii) Suggest why it may not be advisable to maintain the current determined in (b)(i) for a long time.

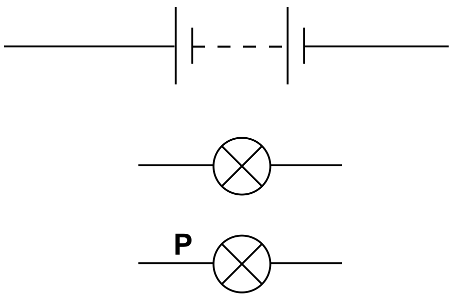
....

....

[1]

[Total 5 marks]

189. The diagram below shows components of an incomplete electrical circuit.



Complete the circuit of the diagram to show how both lamps, connected in parallel, may be lit using the battery. Include an ammeter to measure the current in the lamp **P**.

[Total 2 marks]

190. Fig. 1 shows a circuit designed to monitor the speed of rotation of a small fan.

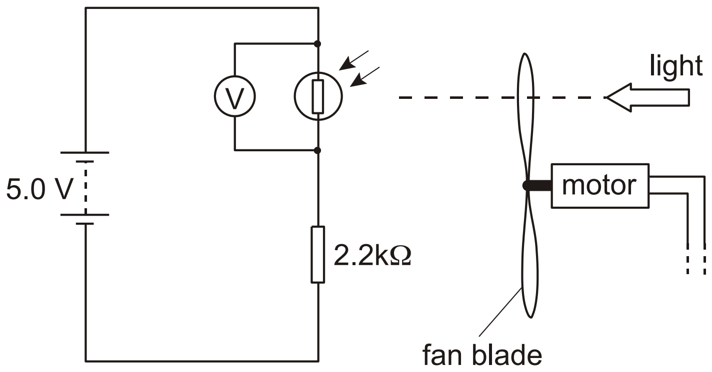


Fig. 1

The battery has negligible internal resistance. The output voltage *V* from the circuit is equal to the potential difference across the LDR. Fig. 2 shows the variation of the output voltage *V* with time *t*.

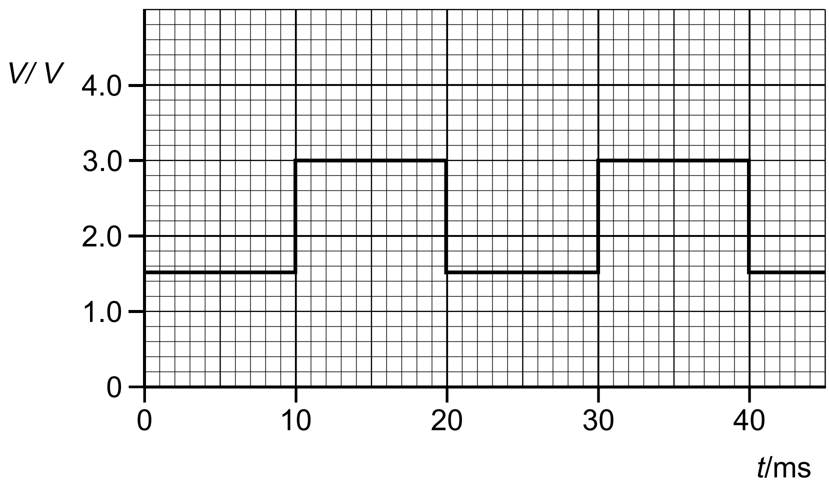


Fig. 2

(i) Explain why the graph of Fig. 2 shows two levels of output voltage.

....

....

....

....

....

....

....

[3]

(ii) For the **maximum** value for the output voltage *V*, calculate

1. the potential difference across the 2.2 kΩ resistor

potential difference = ... V

[1]

2. the resistance of the LDR.

resistance = ... Ω

[2]

[Total 6 marks]

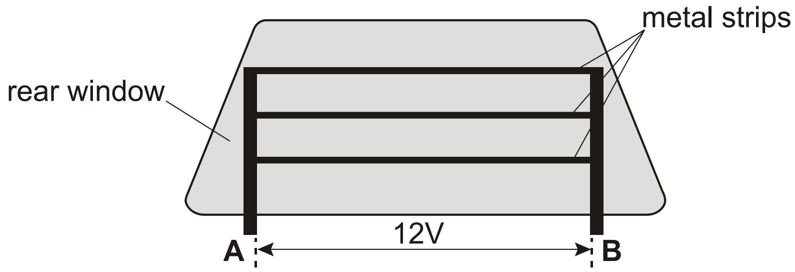
191. Define *electrical resistance*.

....

....

[Total 2 marks]

192. The diagram below shows a method of demisting the rear window of a car. Three identical metal strips attached to the glass are connected to a 12 V supply.



(i) State whether the strips are connected in series or in parallel.

....

[1]

(ii) Each strip has length 85 cm and resistance 18 Ω. The material of the metal strip has resistivity 6.9×10^{-6} Ω m. Calculate

1. the resistance of the three strips between **A** and **B**

resistance = ... Ω

[2]

2. the total power dissipated by the three strips

power = ... W

[2]

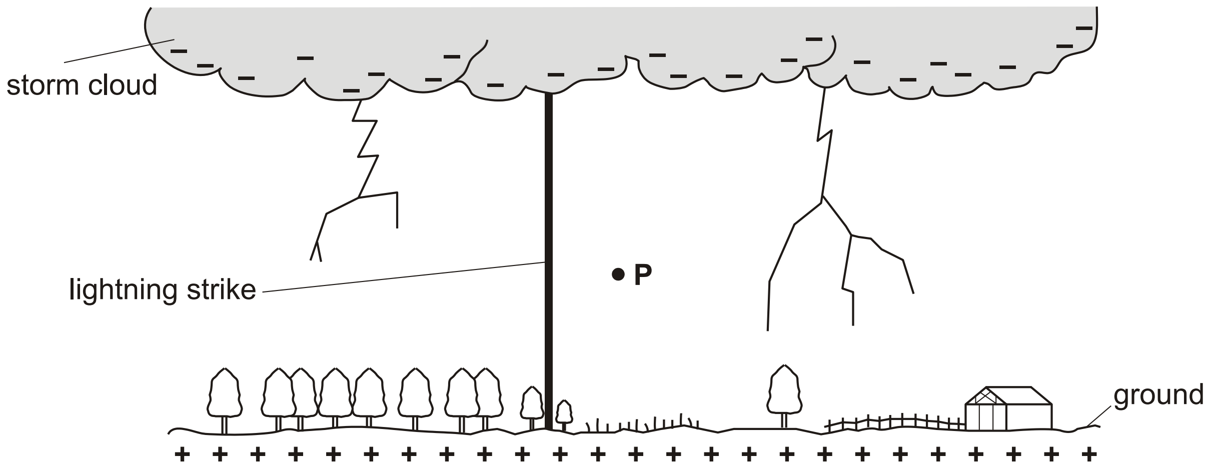
3. the cross-sectional area of **each** strip.

cross-sectional area = ... m^2

[3]

[Total 8 marks]

193. The diagram below shows a lightning strike between a storm cloud and the ground.



(a) State the direction of the magnetic field at point **P** due only to the lightning strike.

....

[1]

(b) The current in the lightning strike is 7800 A. The strike lasts for a time of 230 ms.

Calculate

1. the charge flowing between the cloud and the ground

charge = ... C

[3]

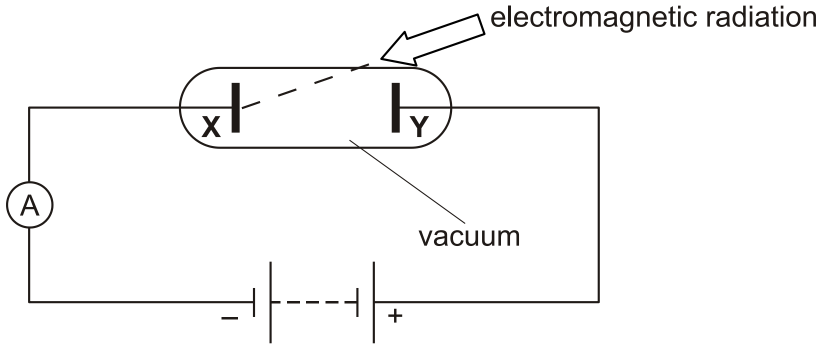
2. the number of electrons transferred to the ground.

number = ...

[2]

[Total 6 marks]

194. The diagram below shows an electrical circuit including a photocell.



The photocell contains a metal plate **X** that is exposed to electromagnetic radiation. Photoelectrons emitted from the surface of the metal are accelerated towards the positive electrode **Y**. A sensitive ammeter measures the current in the circuit due to the photoelectrons emitted by the metal plate **X**.

(a) In this question, one mark is available for the quality of written communication.

Name and describe the process by which the photoelectrons are released from the metal plate **X** by the electromagnetic radiation.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

[5]

Quality of Written Communication [1]

(b) The metal of plate **X** has work function energy of 2.2 eV. The maximum kinetic energy of an emitted photoelectron from this plate is 0.3 eV. Calculate

(i) the energy of a single photon in

1. electronvolts (eV)

energy = ... eV

[1]

2. joules

energy = ... J

[2]

(ii) the frequency of the incident electromagnetic radiation.

frequency = ... Hz

[2]

(c) Deduce the effect on the current if the radiation has the same intensity but the frequency of the electromagnetic radiation is greater than (b)(ii).

....

....

....

[2]

[Total 13 marks]

195. State what is meant by the *diffraction of waves*.

....

....

[Total 1 mark]

196. Draw diagrams, in the spaces below, to illustrate how plane water waves are diffracted when they pass through a gap

(i) about 2 wavelengths wide

[1]

(ii) about 10 wavelengths wide.

[3]

[Total 4 marks]

197. Suggest why the diffraction of light waves cannot usually be observed except under laboratory conditions.

....

....

....

[Total 2 marks]

198. Fig. 1 shows the displacement-time graph for a particle in a medium as a progressive wave passes through the medium.

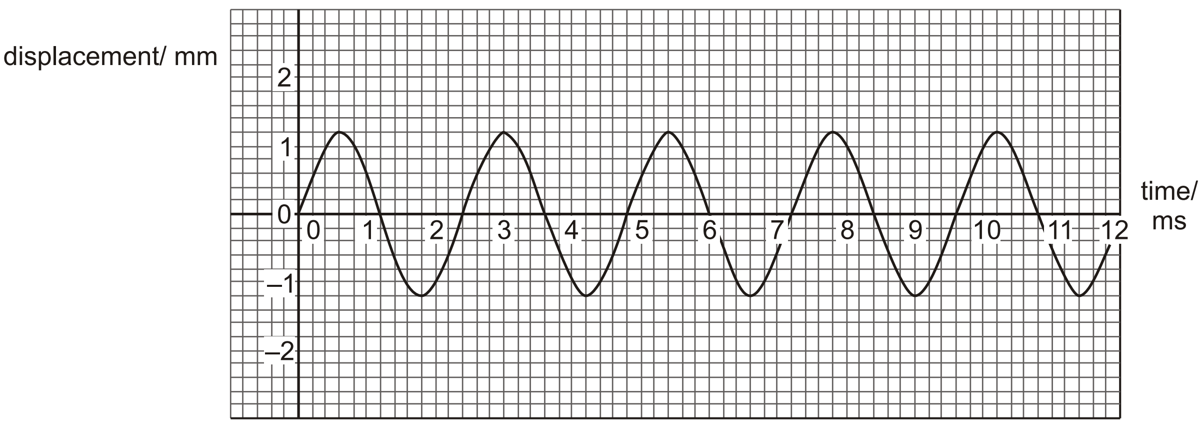


Fig. 1

(a) Determine from the graph

(i) the amplitude of the wave

amplitude = ... mm

[1]

(ii) the period of the wave.

period = ... ms

[1]

(b) (i) What is the frequency of the wave?

frequency = ... Hz

[2]

(ii) The speed of the wave is 1500 m s^{-1}. Calculate its wavelength.

wavelength = ... m

[2]

(iii) Use the grid in Fig. 2 to sketch a displacement-position graph for the wave at a particular instant. Mark the scale on the position axis and draw at least two full cycles.

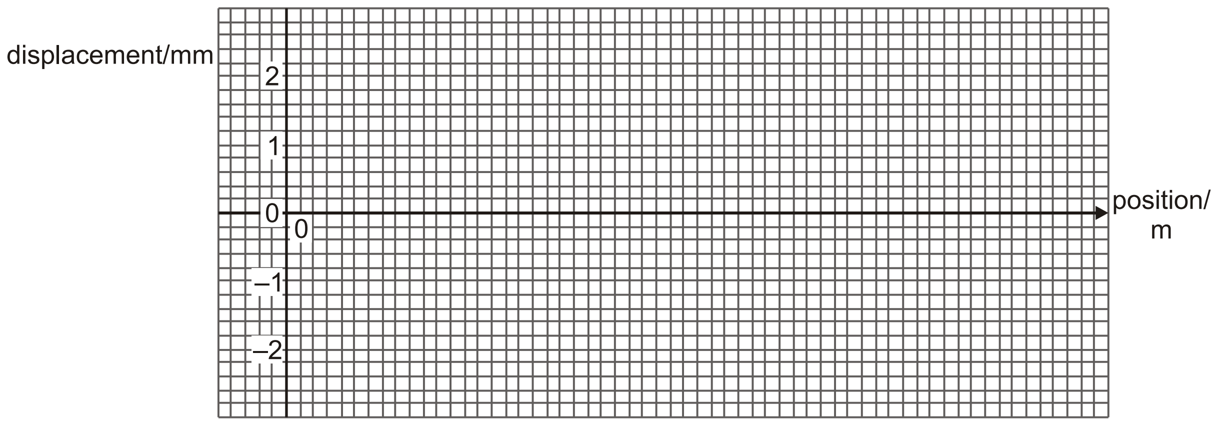
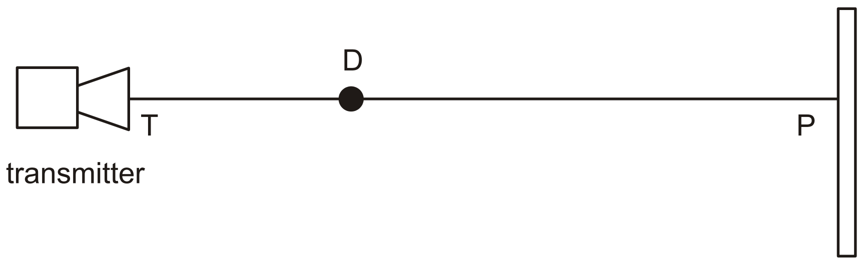


Fig. 2

[3]

[Total 9 marks]

199. The diagram below shows an arrangement where microwaves leave a transmitter **T** and move in a direction **TP** which is perpendicular to a metal plate **P**.



(a) When a microwave detector **D** is slowly moved from **T** towards **P** the pattern of the signal strength received by **D** is high, low, high, low … etc.

Explain

- why these maxima and minima of intensity occur
- how you would measure the wavelength of the microwaves
- how you would determine their frequency.

....

....

....

....

....

....

....

....

....

[6]

(b) Describe how you could test whether the microwaves leaving the transmitter are plane polarised.

....

....

....

....

[2]

[Total 8 marks]

200. Explain what is meant by the *principle of superposition* of two waves.

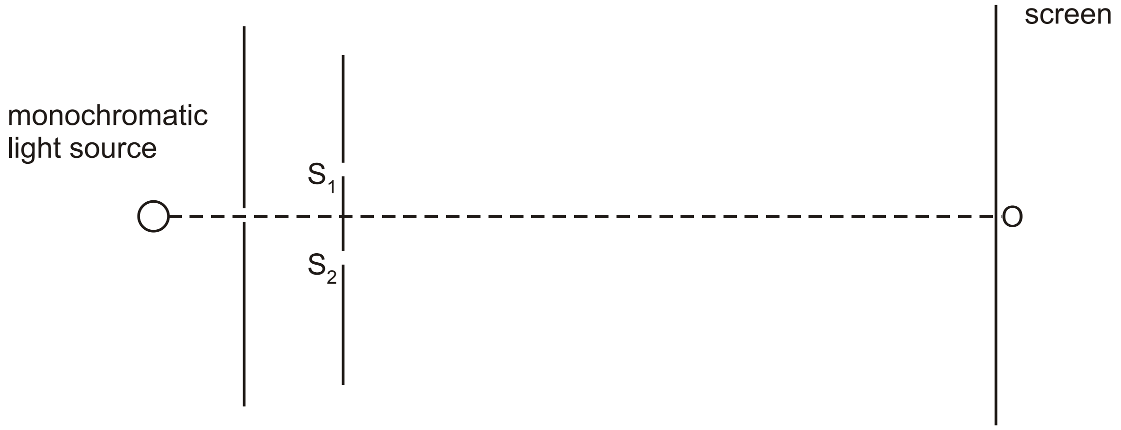
....

....

....

[Total 2 marks]

201. The diagram below shows the arrangement for viewing a visible interference pattern on a screen.



In a darkened room, a double slit (**S_1S_2**) is placed in front of a narrow single slit situated in front of a monochromatic (one frequency only) light source.

(i) In order to produce a clear interference pattern on the screen, the wave sources must be *coherent*. State what is meant by *coherent*.

....

....

[1]

(ii) Explain how the arrangement shown ensures that the slits **S_1** and **S_2** act as coherent light sources.

....

....

....

[2]

(iii) The point **O** on the screen is directly opposite the centre of the double slit. State and explain the nature of the interference that occurs at **O**.

....

....

....

[2]

(iv) The distance between slits $\mathbf{S_1}$ and $\mathbf{S_2}$ is 0.6 mm. When the screen is placed 1.8 m from the slits, the distance between neighbouring minima in the interference pattern formed on the screen is 2.0 mm. Calculate the wavelength of the light.

wavelength = ... m

[3]

(v) State and explain how the interference pattern changes when light of a shorter wavelength is used in the experiment.

....

....

....

[2]

[Total 10 marks]