Physics A

Unit: G482: Electrons, Waves and Photons

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

[2]

Candidate style answer	Examiners commentary
Electrons are the charged particles in a metal. Cations and anions are the charge carriers in an electrolyte	

(b)(i) Define electrical *resistivity*.

[2]

Candidate style answer	Examiners commentary
The electrical resistivity of a substance is given by the formula $\rho = RA/l$ where A is the area of cross-section and l the length of the resistor of resistance R.	

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

[1]

Candidate style answer	Examiners commentary
The resistivity does not depend on the geometry of a resistor. It is the same for all resistors of the same material.	

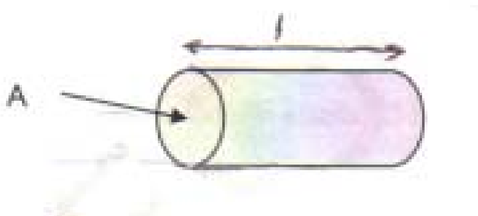


Fig. 1.1

(c) Fig. 1.1. shows a copper rod of length *l* = 0.080m, having a cross-sectional area *A* = 3.0×10^{-4} m^2.

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

(i) Calculate the resistance between the ends of the copper rod.

[2]

Candidate style answer	Examiners commentary
$R = \rho l/A$ $= 1.7 \times 10^{-8} \times 0.08/3.0 \times 10^{-4} = 4.53 \times 10^{-6}$	

Resistance = ...4.53 x 10 -6... Ω	

(ii) 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** **[2]**	
Candidate style answer	*Examiners commentary*
I = Q/t *= 650/5* *current = ...130..............A*	

2 the total number of electrons passing any point in the rod per second. **[2]** **[Total:11]**	
Candidate style answer	*Examiners commentary*
$n = I/e = 130/1.6 \times 10^{-19} = 8.13 \times 10^{20}$ *number = ... 8.13×10^{20}.....*	

Comments: The candidate gained full marks for this first question as a strong candidate should as all of the marks are targeted at the level of middle or weak grade candidates. The question is typical of an opening question to help candidates settle into the examination. It relies on recall of basic facts and definitions and simple calculations. The answers are clear. There is no ambiguity anywhere as the candidate has shown full working at all stages in the calculations.

2(a) (i) Use energy considerations to distinguish between potential difference (p.d.) and electromotive force (e.m.f.). **[2]**	
Candidate style answer	*Examiners commentary*
The term potential difference is used when energy is transferred in a resistor from electrical form into heat. The term e.m.f. is used when energy is transferred from mechanical or chemical form into electricity in a dynamo or battery	In part (a) (i) the examiner is looking for *the energy transformed per unit charge* or equivalent.

(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]**	
Candidate style answer	*Examiners commentary*
J C -1.	Although the candidate has part (a) (ii) correct. There is no mention of *per unit charge* so the candidate loses both marks.

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

[2]

Candidate style answer	*Examiners commentary*
The sum of the e.m.f.s and potential differences across all of the components in a circuit is zero *Energy is the conserved quantity.*	In part (b) the statement of Kirchhoff's second law is considered to be adequate – it should really be *a closed loop* rather than *a circuit*. The conserved quantity is correct so both marks are awarded.

(c) A battery is being tested. Fig. 2.1 shows the battery connected to a variable resistor R and two meters.

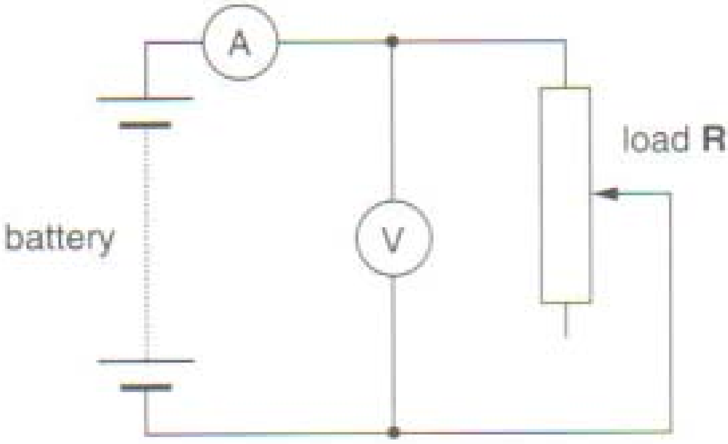
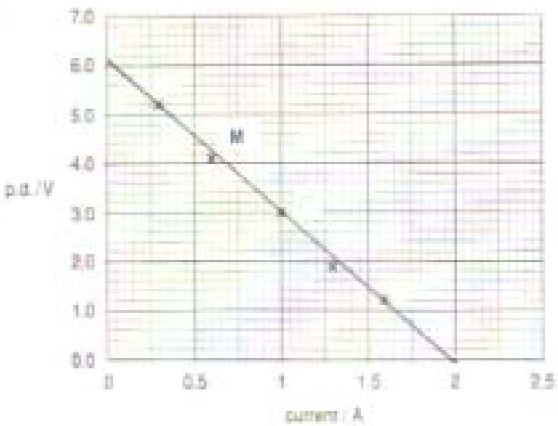


Fig. 2.1

The graph of Fig.2.2 shows the variation of the p.d. *V* across the battery with the current *I* as R is varied.

(i) Draw the line of best fit on Fig. 2.2.

[1]

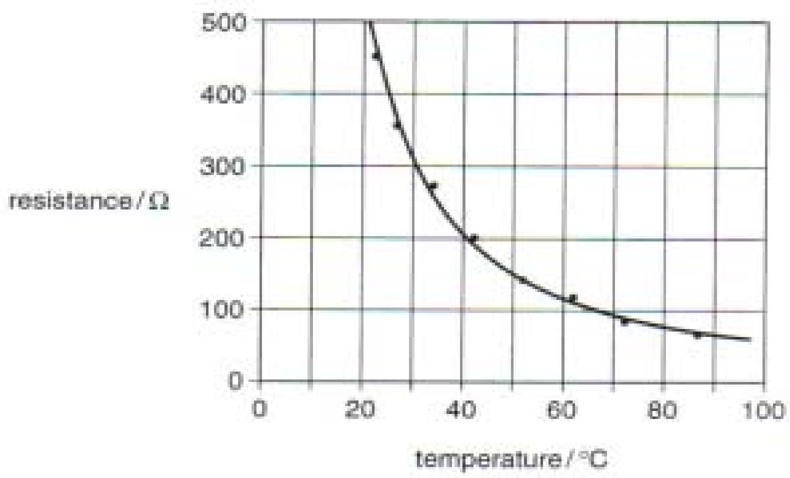
Candidate style answer	*Examiners commentary*
 **Fig. 2.2**	In part (c) the straight line is adequate and the intercept with the y-axis is 6.1 rather than 6.0. The method for finding the internal resistance is given and the correct calculation using the chosen value of e.m.f is made so only one mark is lost, i.e. for misreading the y-intercept.

(ii) Use your line of best fit to determine **the e.m.f. $\mathcal{E}$ of the battery** **the internal resistance *r* of the battery. Show your working clearly.** **[3]**	
Candidate style answer	*Examiners commentary*
ε = ……6.0…….. V the internal resistance is equal to the slope of the line r. = (6.0 - 0)/2.0 r = …..3.0 …….Ω	

(d) The variable resistor R is adjusted to give the values at point M on Fig. 2.2. Calculate **(i) the resistance of R at this point** **[3]**	
Candidate style answer	*Examiners commentary*
At point M, I = 0.6 A and V = 4.3 V R = V/I = 4.3/0.6 = 7.16 R = …..7.16……Ω	In part (d) the candidate takes the value of the p.d. on the line rather than at M so loses one mark but the remainder of the question is correct. As above in part (c) with *error carried forward* applied the candidate just loses one mark.

(ii) the power dissipated in R. **[2]** **[Total: 15]**	
Candidate style answer	*Examiners commentary*
P = IV= 0.6 x 4.3 = 2.58 power =….. 2.58… W	

Comments: The candidate scores 11/15 for this question.

3 Fig. 3.1 shows how the resistance of a thermistor varies with temperature.  **Fig. 3.1** **(a) (i) Describe qualitatively how the resistance of the thermistor changes as the temperature rises.** **[1]**	
Candidate style answer	*Examiners commentary*
As the temperature rises the resistance is reduced.	There is enough in part (a) to gain all of the marks.

(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]**	
Candidate style answer	*Examiners commentary*
100 Ω.	

(iii) Describe, giving a reason, how the sensitivity of temperature measurement using this circuit changes over the range of temperatures shown on Fig. 3.1. **[2]**	
Candidate style answer	*Examiners commentary*
The sensitivity is greater at low temperatures because the change in resistance is larger from 30 °C and 40 °C than it is from 80 °C and 90 °C	

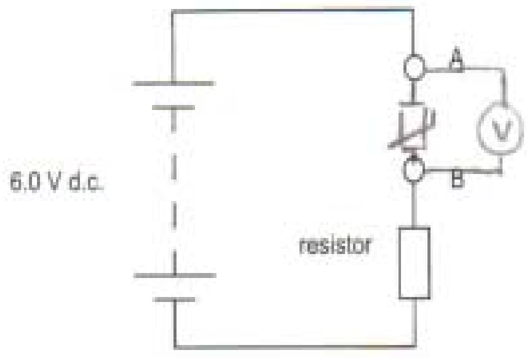
(b) Fig 3.2 shows a temperature sensing potential divider circuit where this thermistor may be connected, between terminals A and B, in series with a resistor.

(i) Draw the circuit symbol for a thermistor on Fig. 3.2 in the space between terminals <u>A and B.</u>

[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. 3.2, draw the circuit connections for a voltmeter to measure a p.d. that rises with increasing temperature.

[1]

Candidate style answer	*Examiners commentary*
 **Fig. 3.2**	

(iii) The value of the resistor in Fig. 3.2 is 200 Ω. The thermistor is at 65 °C. Use data from Fig. 3.1 to show that the current in the circuit is about 0.02 A.

[3]

Candidate style answer	*Examiners commentary*
The total resistance in the circuit is R = 300 Ω *I = V/R = 6/300 = 0.02 A*	In part (b)(iii) the candidate loses two marks, one for not stating that the thermistor resistance is 100 Ω (it appears as a B mark in the mark scheme not a C mark) and the second for not showing the answer as 0.020 A. This may appear harsh but the candidate has not otherwise shown that the calculation was actually done. Alternatively the mark is lost because the answer has not been given to two significant figures.

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

[1]

Candidate style answer	*Examiners commentary*
V = 0.02 x 200 *p.d. across resistor = ……4.0…..V*	

(c) 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.	

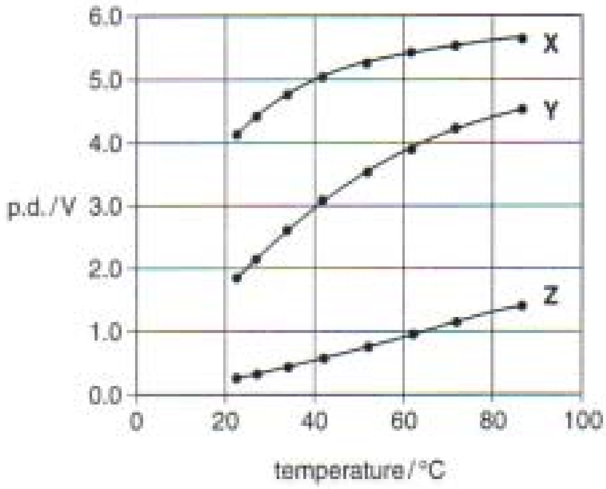


Fig. 3.3

(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]

Candidate style answer	*Examiners commentary*
X is the graph for the 1000 Ω resistor. This is because at 20 °C the resistance of the thermistor is 500 Ω. The voltages across the resistors must divide the 6 V into 4 V and 2 V with 4 V across the resistor	

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

[2]
[Total: 14]

Candidate style answer	*Examiners commentary*
Advantage. *the change in resistance is almost linear over the temperature range* **Disadvantage.** *the change in resistance is small.*	In part (c) (ii) the first marking point is given. The second point made is too vague so the second mark is not awarded.

Comments: The candidate scored 11/14 for this question.

4(a) Fig.4.1 shows the electromagnetic spectrum.

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

---→ increasing wavelength

In the spaces in Fig. 4.2, identify the principal radiations A and B and for each suggest a typical value for the wavelength.

[4]

Candidate style answer

	principal radiation	λ/m
A	*gamma-rays*	5×10^{-12}
B	*infra-red*	5×10^{-6}

Fig. 4.2

Examiners commentary

The candidate gains full marks until part (d).

(b) State two features common to all types of radiation in the electromagnetic spectrum.

[2]

Candidate style answer	*Examiners commentary*
They can travel through a vacuum at the speed of light.	

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

[1]

Candidate style answer	*Examiners commentary*
The light wave can only oscillate in one plane defined by the direction of travel of the wave and a direction perpendicular to it.	

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

[2]

Candidate style answer	*Examiners commentary*
Sound waves are longitudinal waves with vibrations parallel to the direction of travel.	

(d) Fig. 4.3 shows a student observing a parallel beam of plane-polarised light that has passed through a polarising filter.

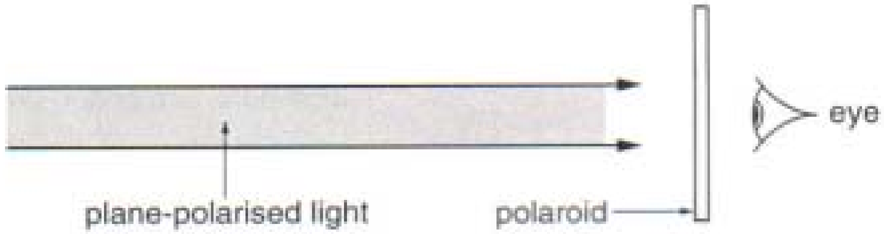


Fig. 4.3

(i) Fig. 4.4. shows how the intensity of the light reaching the student varies as the polarising filter is rotated through 360° in its own plane.

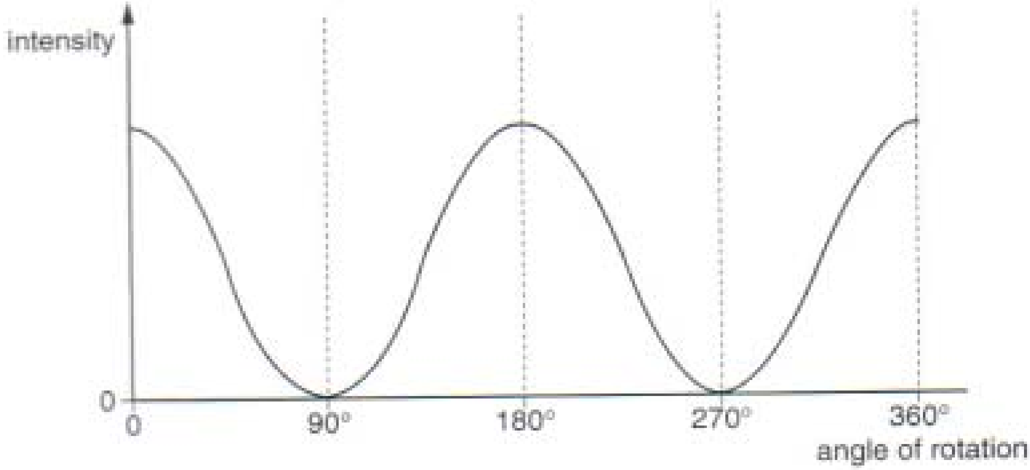


Fig. 4.4

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

[2]

Candidate style answer	Examiners commentary
When the axis of transmission of the polarising filter is parallel to the light the eye sees the maximum intensity. . When the axis of transmission of the polarising filter is at 90o to the plane of the light the eye sees no light.	In part (d) (i) the answer is adequate to earn both marks.

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

[1]

Candidate style answer	Examiners commentary
Glare is reflected light from the surroundings. The polarising filter only allows light in one direction through so it cuts out 50 % of the light.	But (ii) fails because there is no reference to partial polarisation at a reflection.

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

[2]

[Total: 15]

Candidate style answer	Examiners commentary
In a microwave transmitter the aerial is vertical so the microwaves are vertically polarised. When the detector is rotated through 90o the signal falls to zero. .	Part (e) is successful because the candidate phrases the answer in a practical context which would have been observed in a demonstration in the classroom.

Comments: The candidate showed that good knowledge of this subject which many find difficult to explain. The score is 13/15.

5(a) State and explain one difference between a progressive and a standing wave.

[2]

Candidate style answer	Examiners commentary
The phase of each oscillating point on a progressive wave is different along the wave but in a stationary wave the phase is the same between nodes	Part (a) gains both marks as a valid quantity chosen and a comparison given.

(b) 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. 5.1. 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. 5.2.

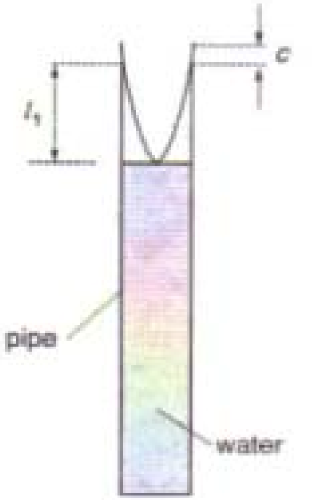


Fig 5.1

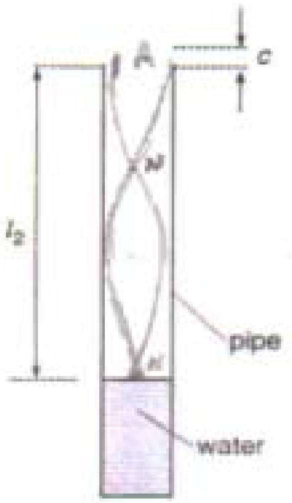


Fig. 5.2

The air at the open end 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.

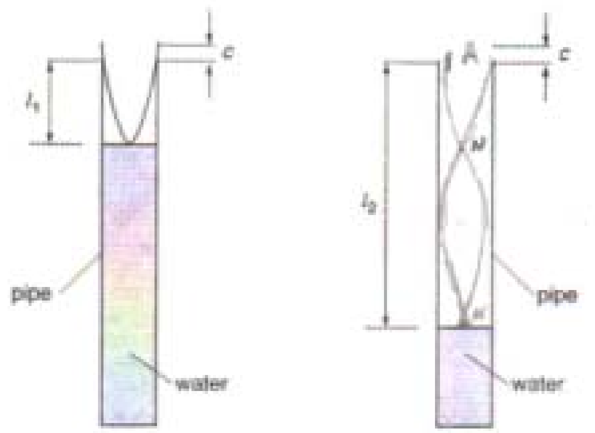
$$l_1 + c = \lambda/4 \qquad l_2 + c = 3\lambda/4$$

(i) Draw the standing wave in the pipe shown in Fig. 5.2 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]

Candidate style answer	*Examiners commentary*
	In part (b) the sketch is correct but the A label is forgotten at the middle of the half wavelength in the tube losing one mark.

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

[1]

Candidate style answer	*Examiners commentary*
$l2 + c - (l1 + c) = 3\lambda/4 - \lambda/4$ giving $l2 - l1 = \lambda/2$	

(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.

[3]

Candidate style answer	*Examiners commentary*
$\lambda/2 = 0.506 - 0.170$ $\lambda = 0.672$ $v = 500 \times 0.672 = 336$ speed =.....336........m s-1	

(c) 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: 12]**	
Candidate style answer	*Examiners commentary*
The sound at a higher frequency will have a smaller wavelength as the speed of the sound is the same. The end correction is the same for both measurements so the percentage error will be bigger when measuring the smaller wavelength of the stationary wave in the resonance tube. So the speed of sound will be less accurate.	In part (c) the candidate gives a full explanation in logical order. Whether the end correction is the same or not, the candidate has the suggested the idea that the measurement of the smaller wavelength is less accurate. Hence all four marks, one of which is the quality of written communication, are awarded.

Comments: The candidate scores 11/12.

6(a) Explain what is meant by the principle of superposition of two waves. **[2]**	
Candidate style answer	*Examiners commentary*
When two waves overlap the oscillations add together to give a new wave	In part (a) one mark is awarding for the waves overlapping. There is insufficient detail to consider a second mark.

(b) In an experiment to try to produce an observable interference pattern, two monochromatic light sources, S_1 and S_2, are placed in front of a screen, as shown in Fig. 6.1.

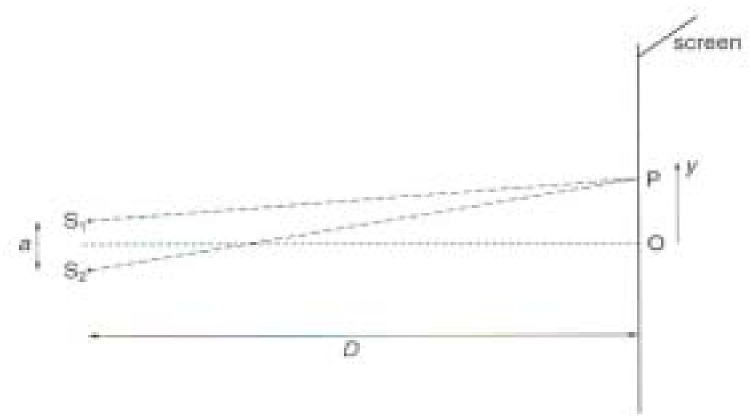


Fig. 6.1.

(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]**	
Candidate style answer	*Examiners commentary*
Both light sources are monochromatic and have the same frequency	In part (b) (i) the examiners decided to award a mark for stating that the waves have the same frequency. There is no reference to phase so one mark is awarded

(ii) In Fig 6.1, 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]

Candidate style answer	Examiners commentary
$\lambda/2$.	

(c) 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 Fig. 6.1.

(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.

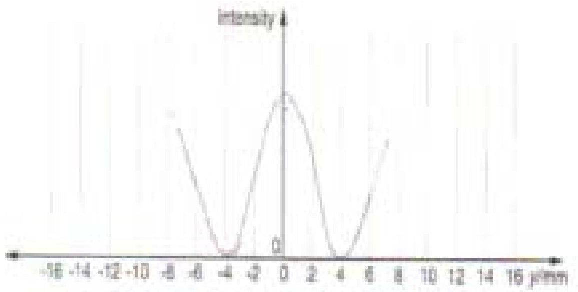
[3]

Candidate style answer	Examiners commentary
using $\lambda = ax/D$ $a = \lambda D/x$ so $a = 6.4 \times 10^{-7} \times 1.5/8.0 \times 10^{-3} = 1.2 \times 10^{-4}$ a = ……1.2×10^{-4}. m	Part (c) (i) is completed correctly but the candidate fails to draw sufficient of the pattern to gain the second mark.

(ii) Sketch on the axes of Fig. 6.2 the variation of the intensity of the light on the screen with distance y from O.

[1]

[Total:10]

Candidate style answer	Examiners commentary
 **Fig. 6.2**	

Comments: This is an example of a question which should take the candidate a shorter time to answer because there is a sketch, a simple calculation to complete and relatively little writing to do. The candidate scores 7/10.

7(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]

Candidate style answer	Examiners commentary
A photon is a quantum of electromagnetic radiation.	Full marks are awarded for parts (a), (b) (i) and (b) (ii) where the answer is considered adequate although the word *minimum* does not appear – it is implied.

(b) A laser emits a short pulse of ultraviolet radiation. The energy of each photon in the beam is 5.60 x 10^{-19} J. **(i) Calculate the frequency of an ultraviolet photon of the laser light.** **[2]**	
Candidate style answer	*Examiners commentary*
E = hf *f = 5.60 x 10-19 /6.63 x 10-34* *frequency = ... 8.45 x 1014 Hz*	Full marks are awarded for parts (a), (b) (i) and (b) (ii) where the answer is considered adequate although the word *minimum* does not appear – it is implied.

(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 x 10-19 J. Define the term work function energy.** **[1]**	
Candidate style answer	*Examiners commentary*
electrons will not be emitted by the metal unless the photon energy is greater than this value.	Full marks are awarded for parts (a), (b) (i) and (b) (ii) where the answer is considered adequate although the word *minimum* does not appear – it is implied.

2 Show that the maximum kinetic energy of the emitted electron is 8.0 x10^{-20} J. **[1]**	
Candidate style answer	*Examiners commentary*
5.60 x 10-19 - 4.80 x 10-19 = 8.0 x 10-20	

(iii) Show that the maximum speed of emission of an electron is about 4 x 10^5 m s^{-1}. **[2]**	
Candidate style answer	*Examiners commentary*
k.e = ½mv2 *8.0 x 10-20 = ½(9.1 x 10-31)v2* *v2 = 16 x 10-20 / 9.1 x 10-31* *v = 4.0 x 105 m s-1*	In part (b) (iii) there is no evidence that the candidate has completed the calculation – just quoting the answer given in the stem of the question. In fact the answer is *4.2 x 10^5 m s^{-1}* to two significant figures. There are thus two reasons for deducting one mark.

(c) (i) State the de Broglie equation. Define any symbols used. **[2]**	
Candidate style answer	*Examiners commentary*
λ = h/mv where λ is the wavelength of the electron.	The candidate has chosen the correct equation from the data sheet so scores one mark in part (c)(i) but fails to identify all of the symbols so loses the second mark.

(ii) Calculate the minimum de Broglie wavelength associated with an electron emitted in <u>(b)</u> above. **[2]** **[Total: 11]**	
Candidate style answer	*Examiners commentary*
λ = 6.6 X 10-34 /(1.67 x 10-27 x 4.0 x 105) = 1.0 x 10-12 *wavelength = ... 1.0 x 10-12 m*	In part (c) (ii) the mass of the proton is selected instead of the mass of the electron – possibly a slip when reading the data sheet. The calculation is otherwise correct so the candidate has been given one mark on the basis of deducting one mark for each error. Another examiner might have been harsher taking the mistake of a proton for an electron as a fundamental error in physics so that all further marks are invalid. Part (c)(ii) would then score zero.

Comments: The candidate has scored 8/11 on this question. He/she appears to have lost some concentration because unforced errors have appeared in the script in this question.

8 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.

[12]

Paper Total [100]

Candidate style answer	*Examiners commentary*
When an electric fire, for example, rated at 1 kW is switched on for one hour it will use 1 kW h of electricity. Using energy = power x time , 1 kW h = 1000 X 3600 = 3.6 x 10^6 J *The kilowatt hour is a convenient unit for electricity bills because otherwise the numbers would be so large..* *1 eV is the energy given to an electron when it is accelerated through a potential difference of 1 V. It is equal to 1.6 x 10^{-19} J.* *In atomic physics like question 7 the amounts of energy involved are very small with powers of 10^{-19} or smaller. Using electron volts makes the numbers easier.*	The candidate scores a total of 8/12 for this question. The answer is quite short and the last paragraph has not been addressed, possibly indicating a lack of time. The quality of written communication mark has not been awarded because there is no link to the last paragraph. The first paragraph about the kW h gains 4 marks. There is a possible fifth mark for *considering large amounts of energy* and a generous examiner might well award this mark. The second paragraph gains 2 marks. The third paragraph gains two marks; one for the reference to *atomic physics* and the other for the idea of *very small amounts of energy*. The candidate has scored a total of 80/100 on the unit. The candidate has shown a good understanding of the subject and has lost some marks possibly through a lack of knowledge of examination techniques. The paper shows promise and with further experience and application this candidate should aspire to a high grade at A2 level.