

Candidate Name	Centre Number	Candidate Number

WELSH JOINT EDUCATION COMMITTEE
General Certificate of Education
 Advanced/Subsidiary/Advanced



CYD-BWYLLGOR ADDYSG CYMRU
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542/01

PHYSICS

ASSESSMENT UNIT PH2: QUANTA AND ELECTRICITY

A.M. FRIDAY, 8 June 2007

(1 hour 30 minutes)

ADDITIONAL MATERIALS

In addition to this paper, you may require a calculator.

INSTRUCTIONS TO CANDIDATES

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

You are advised to spend not more than 45 minutes on questions 1 to 5.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 90.

The number of marks is given in brackets at the end of each question or part question.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

Your attention is drawn to the information “Mathematical Data and Relationships” on the back page of this paper.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

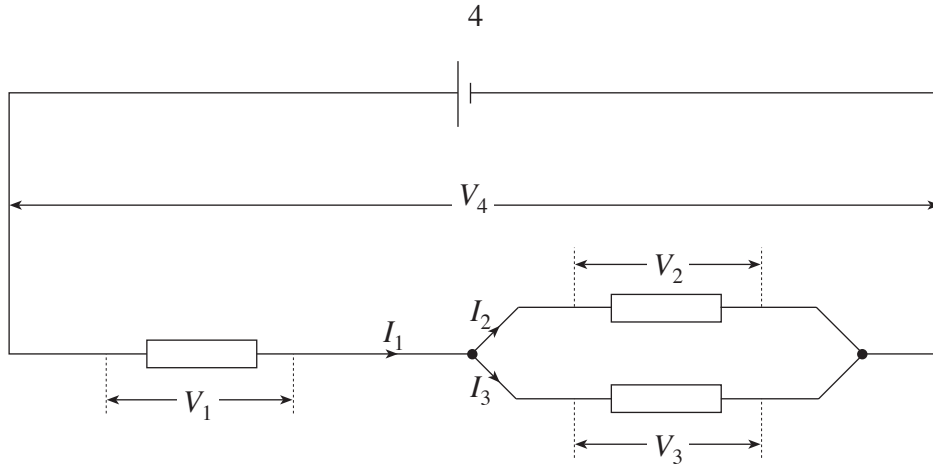
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Fundamental Constants

Avogadro constant	$N_A = 6.0 \times 10^{23} \text{ mol}^{-1}$
Fundamental electronic charge	$e = 1.6 \times 10^{-19} \text{ C}$
Mass of an electron	$m_e = 9.1 \times 10^{-31} \text{ kg}$
Mass of a proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
Molar gas constant	$R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1}$
Acceleration due to gravity at sea level	$g = 9.8 \text{ m s}^{-2}$
[Gravitational field strength at sea level	$g = 9.8 \text{ N kg}^{-1}$]
Universal constant of gravitation	$G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Planck constant	$h = 6.6 \times 10^{-34} \text{ J s}$
Unified mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
Speed of light <i>in vacuo</i>	$c = 3.0 \times 10^8 \text{ m s}^{-1}$
Permittivity of free space	$\epsilon_0 = 8.9 \times 10^{-12} \text{ F m}^{-1}$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$

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1. (a)



Some of the equations below are correct (whatever the values of the resistors in the circuit). Put a tick in the box against each correct equation only. [3]

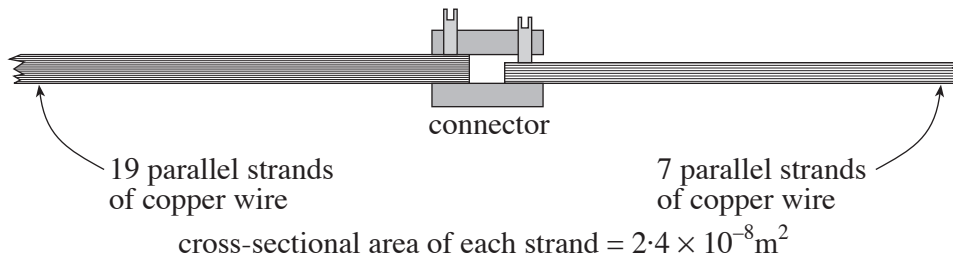
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| $V_1 = V_2 + V_3$ | <input type="checkbox"/> | $V_4 = V_1 + V_2$ | <input type="checkbox"/> | $I_1 = I_2 + I_3$ | <input type="checkbox"/> |

(b) The current through a metal conductor is related to the drift velocity of its free electrons by the formula

$$I = nAve.$$

(i) What is the meaning of n ? [1]

(ii) In a series circuit a thicker piece of copper wire is connected to a thinner piece.



(I) The drift velocity of free electrons in the thicker wire is $2.1 \times 10^{-4} \text{ms}^{-1}$. Calculate the current. [For copper, $n = 8.5 \times 10^{28} \text{m}^{-3}$. Refer also to the data on page 2.] [2]

(II) If v_1 is the drift velocity in the thicker wire and v_2 is the drift velocity in the thinner wire, show in clear steps, justifying each one, that

$$19v_1 = 7v_2 \quad [4]$$

2. (a) A lamp is marked '4.5V, 0.90W'. Calculate

(i) the current through the lamp when 4.5 V is placed across it. [1]

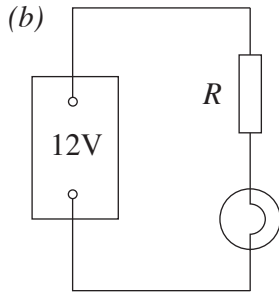
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(ii) the resistance of the lamp when 4.5 V is placed across it. [1]

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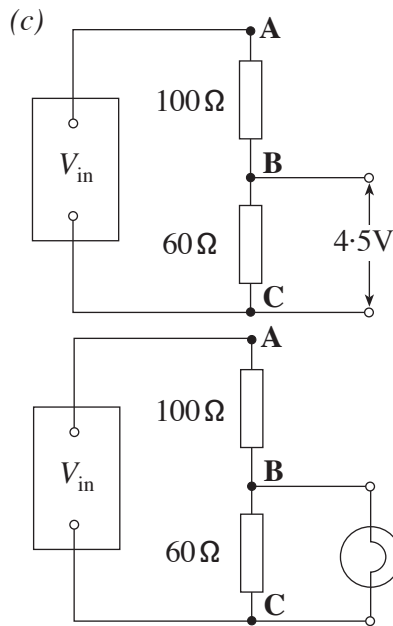


Calculate the resistance R that needs to be placed in series with the lamp of part (a), for it to operate normally from a 12V supply (of negligible internal resistance). [2]

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A student sets up a potential divider to give an output of 4.5 V (see diagram).

(i) Calculate the input p.d., V_{in} , required. [2]

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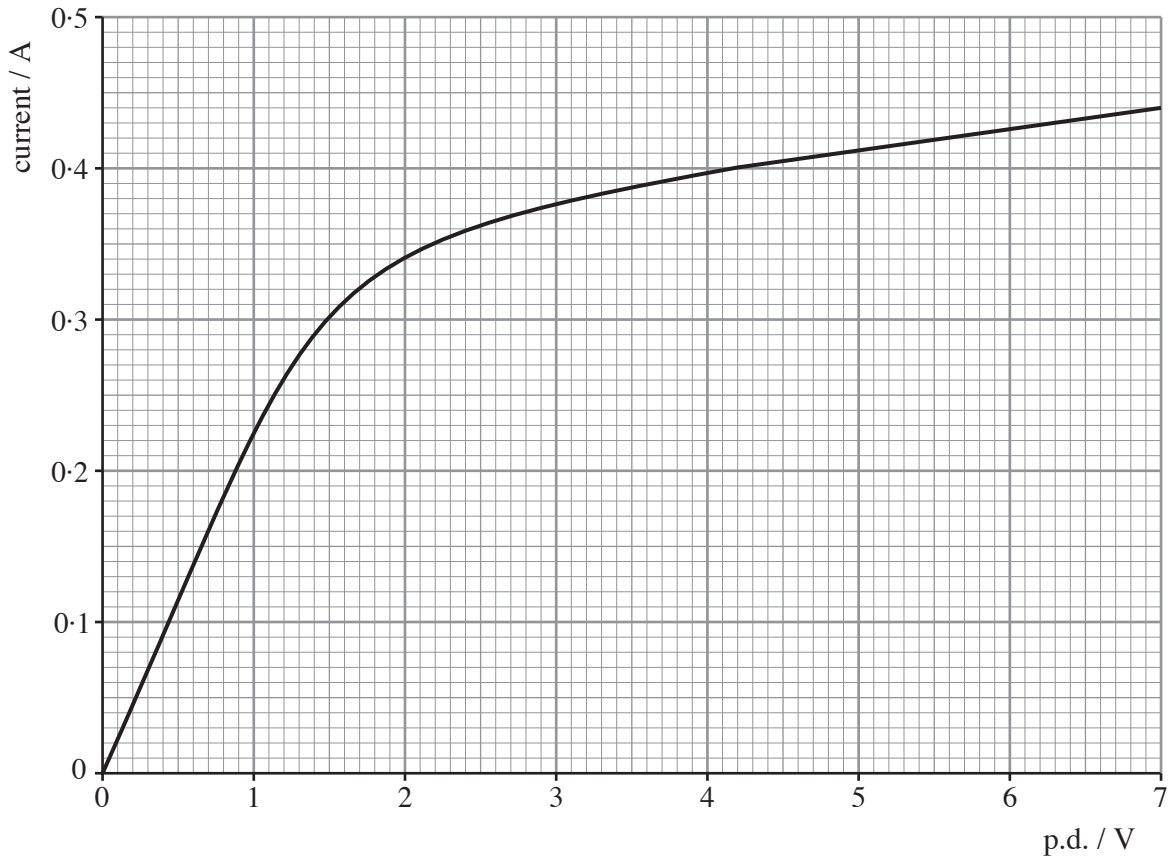
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(ii) When the student places the lamp of part (a) across the output of the potential divider, as shown, he finds that the p.d. is no longer 4.5V. Complete the table below, line by line, to explain why this is so. **Calculations are not required.** [4]

	increases or decreases when bulb connected	brief explanation of why increase or decrease occurs
resistance between B and C	<i>decreases</i>	
current through 100Ω resistor		
p.d. across 100Ω resistor		
p.d. across 60Ω resistor		

3. A graph of current against p.d. is given for a filament lamp, which is to be used in a torch.



(a) (i) State *Ohm's Law*. [2]

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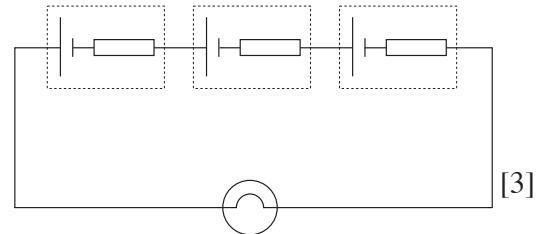
(ii) Discuss to what extent the bulb obeys Ohm's Law. [2]

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(b) In a prototype of a torch, three identical cells are connected in series across the bulb. Each cell has an e.m.f. of 1.6 V. The p.d. across the bulb is found to be 4.2 V. Show clearly that the internal resistance of **each** cell is 0.50 Ω.



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- (c) The bulb is now placed in series with more cells of the same type. The p.d. across the bulb is now 6.9 V. Making appropriate calculations, investigate whether or not there are now **five** cells in total. [3]

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4. (a) (i) Complete the table by filling in the numbers of particles in two different hydrogen atoms (different isotopes). [2]

isotope	number of protons	number of neutrons	number of electrons
${}^1_1\text{H}$			
${}^2_1\text{H}$			

- (ii) Explain the following in terms of the properties of protons, neutrons and electrons.

(I) A ${}^1_1\text{H}$ atom is electrically neutral. [1]

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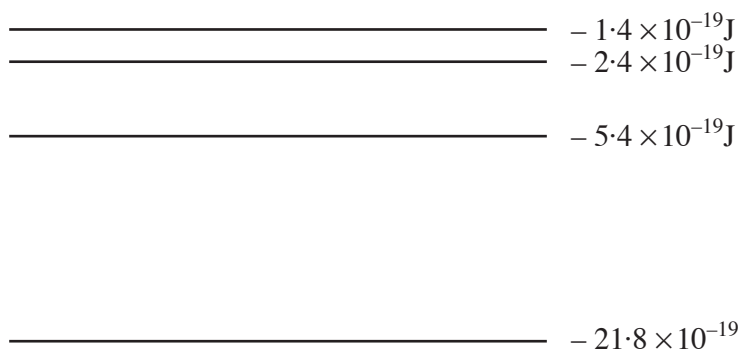
(II) A ${}^2_1\text{H}$ atom is also electrically neutral. [1]

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(III) The mass of a ${}^2_1\text{H}$ atom is approximately twice that of a ${}^1_1\text{H}$ atom. [2]

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- (b) The diagram shows the lowest four energy levels of a hydrogen atom.



- (i) A hydrogen atom in its ground state absorbs a photon of energy $19.4 \times 10^{-19}\text{J}$. Show the atomic transition which occurs by an arrow labelled 'A' on the diagram. [1]

- (ii) The excited atom then emits a photon of longer wavelength.

(I) Show the atomic transition which occurs by an arrow labelled 'B'. [1]

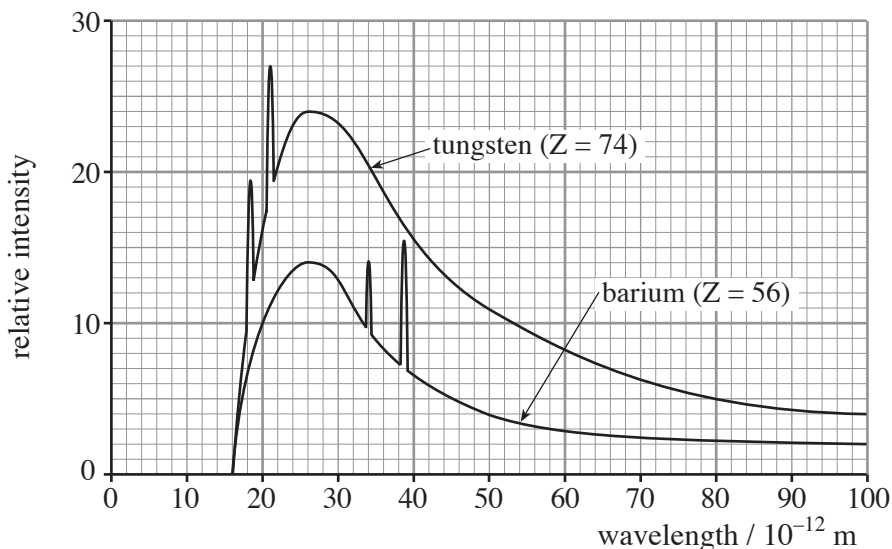
(II) Calculate the wavelength of the emitted photon. [Refer to data on page 2.] [2]

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5. (a) Name the region of the electromagnetic spectrum to which the remark applies.

- (i) The radiation penetrates several cm of lead. [1]
- (ii) 100 m is a typical wavelength. [1]
- (iii) All hot objects emit the radiation. [1]
- (iv) 3 cm is a typical wavelength. [1]

(b) Simplified X-ray spectra for two elements are given below.



(i) How do the accelerating voltages used to produce the spectra compare? Give a reason for your answer. [2]

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(ii) The X-ray spectra of different elements have a similar pattern of *lines*, but the pattern shifts to shorter wavelengths with increasing atomic number, *Z*. Quantum theory suggests the approximate formula

$$\frac{\lambda_1}{\lambda_2} = \left(\frac{Z_2}{Z_1} \right)^2$$

in which λ_1 and λ_2 are the wavelengths of corresponding lines for atoms with atomic numbers Z_1 and Z_2 .

Investigate how accurately this formula applies for the two spectra above. Give your reasoning and conclusion clearly. [Hint: ignore the continuous spectra.] [4]

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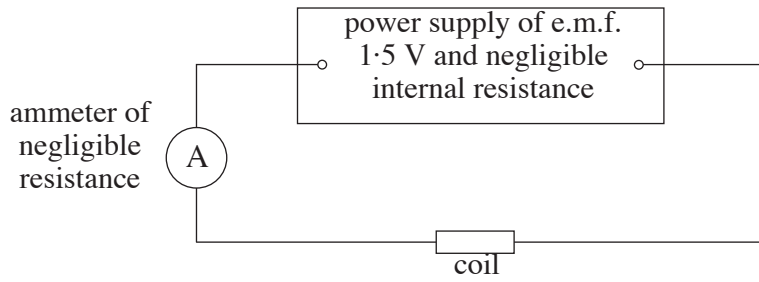
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6. A coil of insulated copper wire is wound around the end of a glass rod. The coil is wired into the circuit shown. [The power is too low for the coil to warm up by itself.]



- (a) Describe briefly how you would obtain readings for a graph of current against temperature over the range 0°C to 100°C. A labelled sketch of the apparatus (excluding power supply and ammeter) is needed. [5]

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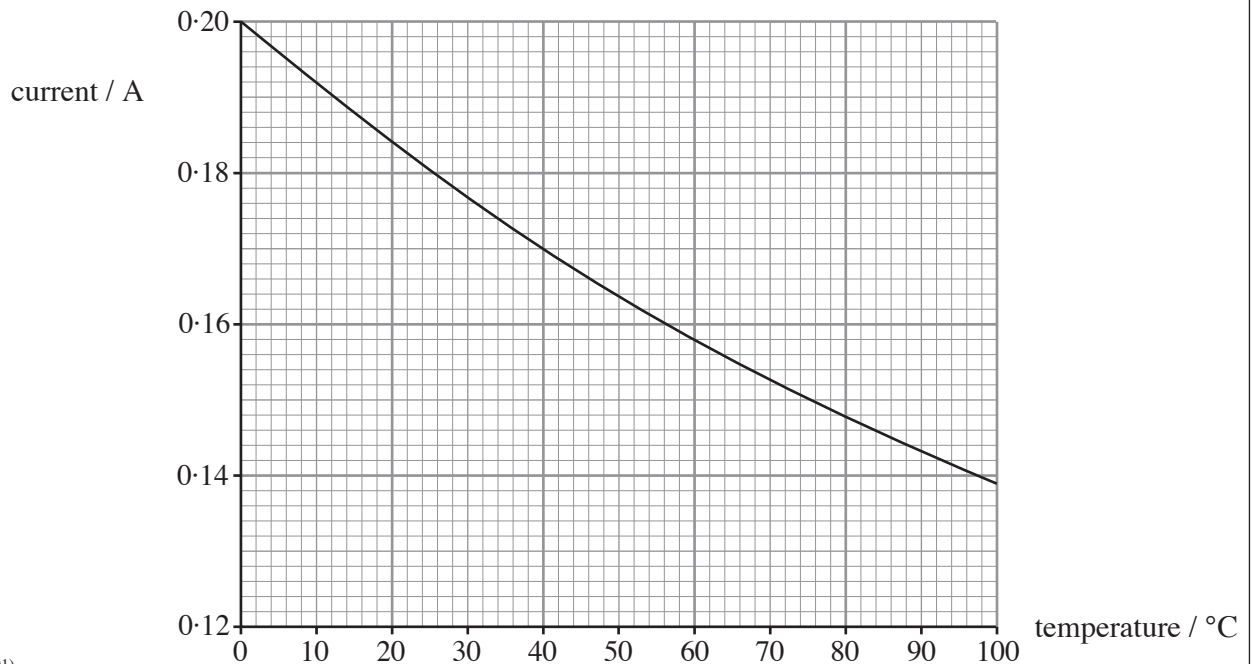
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- (b) The graph is given below.



- (i) Explain, in terms of free electrons, why the current is less at 100°C than at 0°C. [3]

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- (ii) Calculate the resistance of the coil
(I) at 0°C, [1]

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- (II) at 100°C, [1]

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- (iii) Calculate the temperature coefficient of resistance of copper using the formula

$$\alpha = \frac{R_{\theta} - R_0}{R_0 \theta} \quad [3]$$

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- (iv) Calculate the **current** through the coil if it were heated to 200°C. [3]

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- (c) Copper wire of **diameter** 1.6×10^{-4} m was used to make the coil. Calculate the length of wire in the coil, given that the resistivity of copper at 0°C is $1.54 \times 10^{-8} \Omega\text{m}$. [4]

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7. (a) (i) What is meant by the *work function*, ϕ , of a surface? [1]

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(ii) Einstein’s photoelectric equation may be written

$$\frac{1}{2}mv_{\max}^2 = hf - \phi$$

Use it to derive the relationship between ϕ and f_{\min} . [f_{\min} is the threshold frequency of the surface, that is the minimum frequency for photo-emission.] [2]

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(iii) Explain **in terms of photons** why no electrons are emitted if radiation of a frequency lower than f_{\min} is shone on to the surface. [2]

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(iv) “Caesium will emit electrons for incident light of any frequency across the visible spectrum.” Investigate how true this claim is, using the following data.
 Work function of caesium = 3.0×10^{-19} J.
 Range of visible wavelengths = 4.0×10^{-7} m up to 7.0×10^{-7} m.
 Refer also to the data on page 2. Give your reasoning and conclusion clearly. [4]

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(b) (i) Use Einstein's equation to calculate the maximum kinetic energy of electrons emitted from a caesium surface when it is illuminated by

(I) violet light of frequency 7.4×10^{14} Hz, [2]

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(II) blue light of frequency 6.4×10^{14} Hz. [1]

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(ii) Calculate the minimum p.d. that would have to be placed between the caesium surface and a nearby electrode, in order to prevent the emitted electrons from reaching this electrode when the **blue** light is used. Refer to the data on page 2. [2]

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(iii) Explain carefully, in terms of photons, whether or not increasing the intensity of the violet light would affect the maximum kinetic energy of the emitted electrons. [3]

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(iv) Two students argue about the effect of shining both the blue and the violet light on to the caesium at the same time. One claims that the maximum kinetic energy of the emitted electrons is the sum of the values for the individual colours; the other claims that it is the mean of the values for the individual colours. Who - if either - is right? Argue your case in terms of photons. [3]

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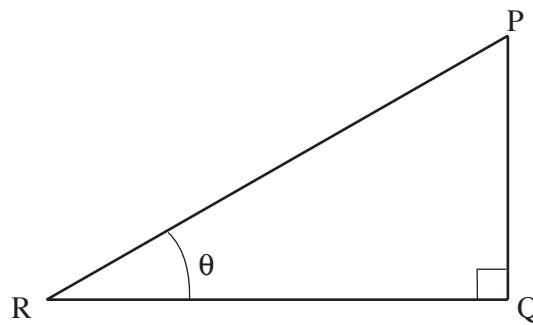
Mathematical Data and Relationships

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{-2}	centi	c
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P

Geometry and trigonometry



$$\sin \theta = \frac{PQ}{PR}, \quad \cos \theta = \frac{QR}{PR}, \quad \tan \theta = \frac{PQ}{QR}, \quad \frac{\sin \theta}{\cos \theta} = \tan \theta$$

$$PR^2 = PQ^2 + QR^2$$

Areas and Volumes

$$\text{Area of a circle} = \pi r^2 = \frac{\pi d^2}{4}$$

$$\text{Area of a triangle} = \frac{1}{2} \text{ base} \times \text{height}$$

Solid	Surface area	Volume
rectangular block	$2(lh + hb + lb)$	lbh
cylinder	$2\pi r(r + h)$	$\pi r^2 h$
sphere	$4\pi r^2$	$\frac{4}{3}\pi r^3$