Candidate Name	Centre Number	Candidate Number
		2

General Certificate of Education
Advanced Subsidiary/Advanced

542/01

PHYSICS
ASSESSMENT UNIT PH2: QUANTA AND ELECTRICITY

P.M. FRIDAY, 11 January 2008
(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 “Mathematical Data and Relationships” on the back page of this paper.

For Examiner’s use only.	
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No certificate will be awarded to a candidate detected in any unfair practice during the examination.

Fundamental Constants

Avogadro constant	N_A	$= 6{\cdot}0 \times 10^{23}\ \text{mol}^{-1}$
Fundamental electronic charge	e	$= 1{\cdot}6 \times 10^{-19}\ \text{C}$
Mass of an electron	m_e	$= 9{\cdot}1 \times 10^{-31}\ \text{kg}$
Mass of a proton	m_p	$= 1{\cdot}67 \times 10^{-27}\ \text{kg}$
Molar gas constant	R	$= 8{\cdot}3\ \text{J mol}^{-1}\ \text{K}^{-1}$
Acceleration due to gravity at sea level	g	$= 9{\cdot}8\ \text{m s}^{-2}$
[Gravitational field strength at sea level	g	$= 9{\cdot}8\ \text{N kg}^{-1}$]
Universal constant of gravitation	G	$= 6{\cdot}7 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
Planck constant	h	$= 6{\cdot}6 \times 10^{-34}\ \text{J s}$
Unified mass unit	1 u	$= 1{\cdot}66 \times 10^{-27}\ \text{kg}$
Boltzmann constant	k	$= 1{\cdot}38 \times 10^{-23}\ \text{J K}^{-1}$
Speed of light *in vacuo*	c	$= 3{\cdot}0 \times 10^{8}\ \text{m s}^{-1}$
Permittivity of free space	ε_0	$= 8{\cdot}9 \times 10^{-12}\ \text{F m}^{-1}$
Permeability of free space	μ_0	$= 4\pi \times 10^{-7}\ \text{H m}^{-1}$

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1. The battery in a car has an e.m.f. of 12·0 V and is rated at 80 ampère-hours. This means that (when fully charged) it can supply a current of 1·0 A for 80 hours (or 2·0 A for 40 hours, and so on) before it runs out of energy.

(a) Calculate, in S.I. units,

(i) the total charge that will pass through the battery while it discharges, [2]

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(ii) the total amount of electrical energy the battery will supply. [2]

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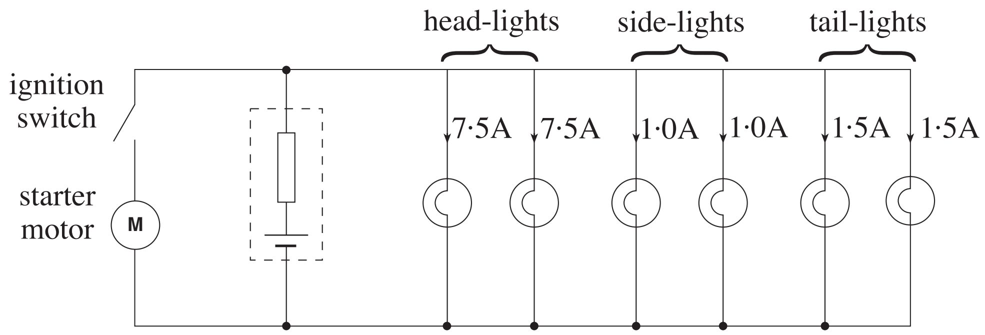
(b) The driver parks the car and leaves on all the lights accidentally. The lights are connected to the battery as shown.



(i) Calculate a value for the time **in hours** for which the lights could be left on before the battery runs out of energy. [2]

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(ii) The internal resistance of the battery is 0·020Ω.

(I) Calculate the p.d. across the battery terminals when all the lights are connected. [2]

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(II) The driver returns to the car within a few minutes, and turns the ignition key. This operates a switch connecting the starter-motor across the battery. The motor draws a current of 150A. The driver notices that the lights are dimmer while the starter-motor is connected. Explain carefully why this is so. [2]

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2. *(a)* The current in a piece of aluminium wire in an overhead power-line is 300A. Calculate **the number of electrons** passing through any cross-section of the wire per second. (Refer to the data on page 2.) [2]

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(b) Calculate the *mean drift velocity* of the free electrons in the wire, which has a cross-sectional area of $2{\cdot}0 \times 10^{-7}\,m^2$. (Each aluminium atom contributes 3 free electrons, and there are $6{\cdot}0 \times 10^{28}$ atoms per m^3 of aluminium.) [3]

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(c) Explain the difference between the *mean drift velocity* of the free electrons and their *mean speed.* [2]

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(d) Suppose that, because of a production fault, the cross-sectional area of a small portion of the wire is less than that of the rest of the wire, as shown in the diagram.

(i) How does the current in the thinner portion compare with the current in the rest of the wire? [1]

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(ii) How does the mean drift velocity of free electrons in the thinner portion compare with that in the rest of the wire? Give your reasoning. [2]

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3. *(a)* A flexible wire is made of 7 identical, parallel strands of copper wire, **each** of length 15·0 m and **diameter** $0{\cdot}12 \times 10^{-3}$ m.

(i) Calculate the resistance of single strand. (Resistivity of copper = $1{\cdot}7 \times 10^{-8}\,\Omega$m.) [3]

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(ii) Using your answer to *(a)*(i) find the combined resistance of the 7-strand wire, treating the strands as resistances in parallel. [2]

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(iii) Explain how the resistance of the 7-strand wire could be calculated from the data at the start of the question, without first finding the resistance of a single strand. [1]

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(b) (i) Show, in clear steps, that $\frac{P}{l}$, the *power* dissipated per unit length of wire, is given by

$$\frac{P}{l} = \frac{\rho I^2}{A}$$

in which ρ, I and A have their usual meanings. [2]

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(ii) **X** and **Y** are wires made of the same material. **X** has diameter d and carries current I. **Y** has diameter $2d$ and carries current $2I$. Use the formula in *(b)*(i) to show which, if either, of **X** and **Y** has the greater power dissipation per unit length. [2]

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4. *(a)* $^{200}_{80}\mathrm{Hg}$ is an isotope of mercury.

(i) Write down the numbers of protons, neutrons and electrons in a $^{200}_{80}\mathrm{Hg}$ atom. [1]

number of protons = ..., number of neutrons = ..., number of electrons = ...

(ii) Where, within the atom, are the various particles to be found? [1]

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(iii) The nucleus of another isotope of mercury has a mass 1% greater than that of a $^{200}_{80}\mathrm{Hg}$ nucleus. Put numbers in the boxes for this other isotope. $^{\square}_{\square}\mathrm{Hg}$ [2]

(b) In a fluorescent lamp, electrons move at speed through mercury vapour in a glass tube. When the electrons collide with mercury atoms, some of the atoms are put into excited states.

(i) (I) Radiation of wavelength 254 nm is emitted from the excited atoms. Show clearly that the photon energy for this wavelength is $7{\cdot}8 \times 10^{-19}$ J. (Refer to the data on page 2.) [2]

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(II) The electrical power input to the lamp is 25 W, and 52% of the energy supplied is released as radiation of wavelength 254 nm. Calculate the number of photons of this wavelength emitted per second. [2]

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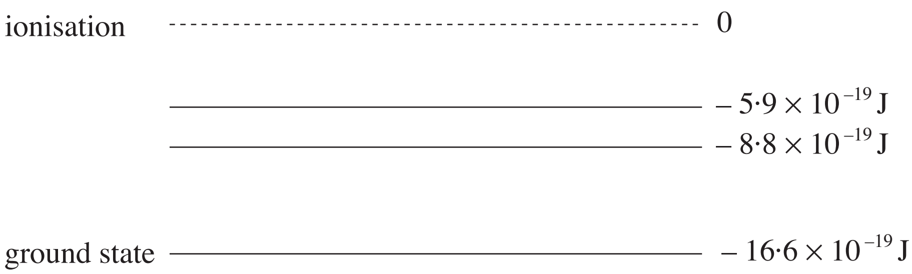
(ii) A simplified energy level diagram for a mercury atom is given. Draw an arrow on it to show the transition resulting in the emission of photons of energy $7{\cdot}8 \times 10^{-19}$ J. [1]



(iii) These photons strike a special coating on the inside wall of the glass tube, making it emit various wavelengths of light. Explain why the photons of wavelength 254 nm cannot themselves be used to provide illumination. [1]

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5. *(a)* How, briefly, are X-rays produced in an X-ray tube? [2]

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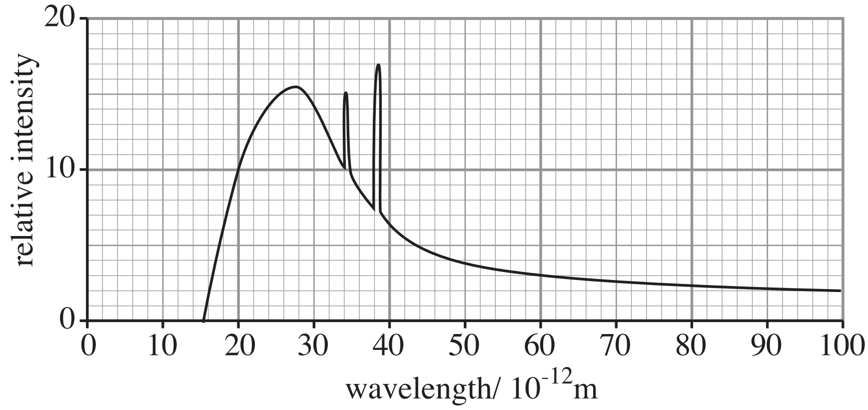
(b) A typical X-ray spectrum from an X-ray tube is given.



(i) Write down one wavelength that is characteristic of the material of the target. [1]

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(ii) Use the equation

$$eV = \frac{hc}{\lambda_{min}}$$

to calculate the accelerating voltage. (Refer to the data on page 2.) [2]

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(iii) (I) Label the *background* spectrum on the graph above. [1]

(II) Explain briefly how the background spectrum arises. [1]

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(c) Discuss how the properties of X-rays make them suitable for medical imaging (for example, when a suspected broken arm is 'X-rayed'). [3]

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6. *(a)* Describe how you would **demonstrate** the *photoelectric effect*. Include a diagram of the apparatus. [5]

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(b) Einstein's *photoelectric equation* may be written

$$\frac{1}{2}mv^2_{\text{max}} = hf - \phi$$

(i) (I) $\frac{1}{2}mv^2_{\text{max}}$ is the maximum kinetic energy of .... [1]

(II) hf is the energy of .... [1]

(ii) Explain, in terms of energy, why $\frac{1}{2}mv^2_{\text{max}}$ is less than hf. [3]

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(c) Two known frequencies of light are shone in turn on to a caesium surface, and $\frac{1}{2}mv^2_{\text{max}}$ is measured in each case.

frequency / 10^{14}Hz	4·74	6·38
$\frac{1}{2}mv^2_{\text{max}}$ / 10^{-19}J	0·13	1·21

(i) Plot the two points based on these readings on the grid provided opposite, having chosen, and labelled, a suitable vertical scale. [2]

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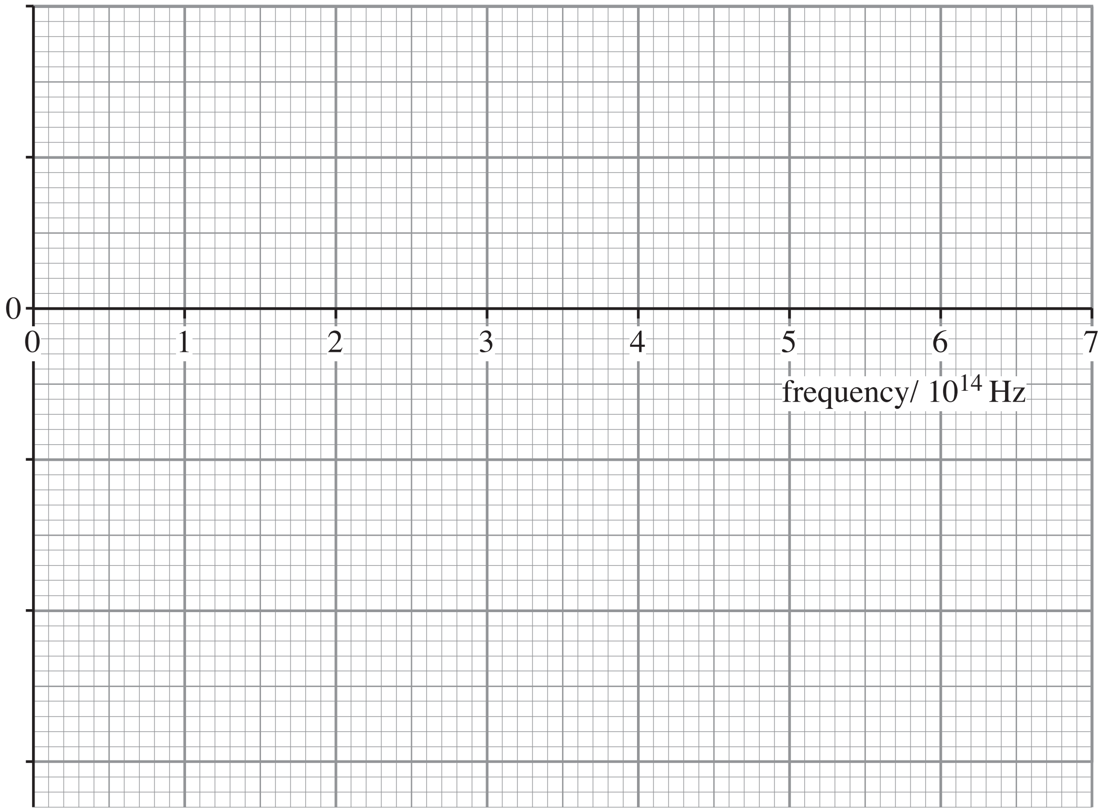

(ii) Hence, or otherwise, find the threshold frequency for caesium (the minimum frequency for which photoelectric emission takes place). [2]

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(iii) Find a value for the work function of caesium. [1]

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(iv) Obtain a value, **based on these readings, (or your graph),** for the Planck constant, showing your method of calculation clearly. [3]

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(v) In order for your calculations to be valid, do the *intensities* of the two frequencies of light used to obtain the readings in the table have to be the same? Give a reason for your answer. [2]

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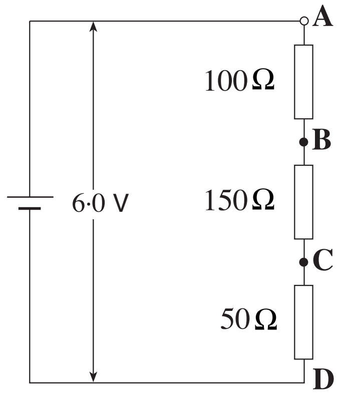
7. *(a)* The internal resistance of the battery in the circuit shown is negligible.

(i) Show that the p.d. between **C** and **D** is 1·0 V. [2]



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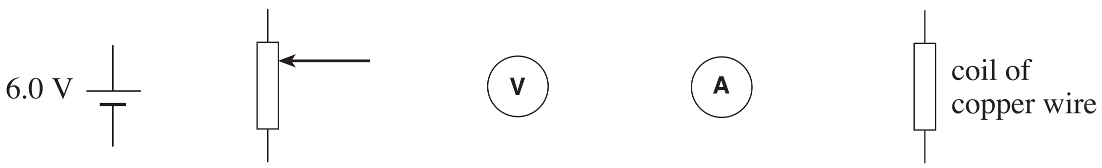
(ii) Complete the table. [2]

p.d / V	1·0	2·0	3·0	4·0	5·0	6·0
Points between which p.d. exists	**C** and **D**					**A** and **D**

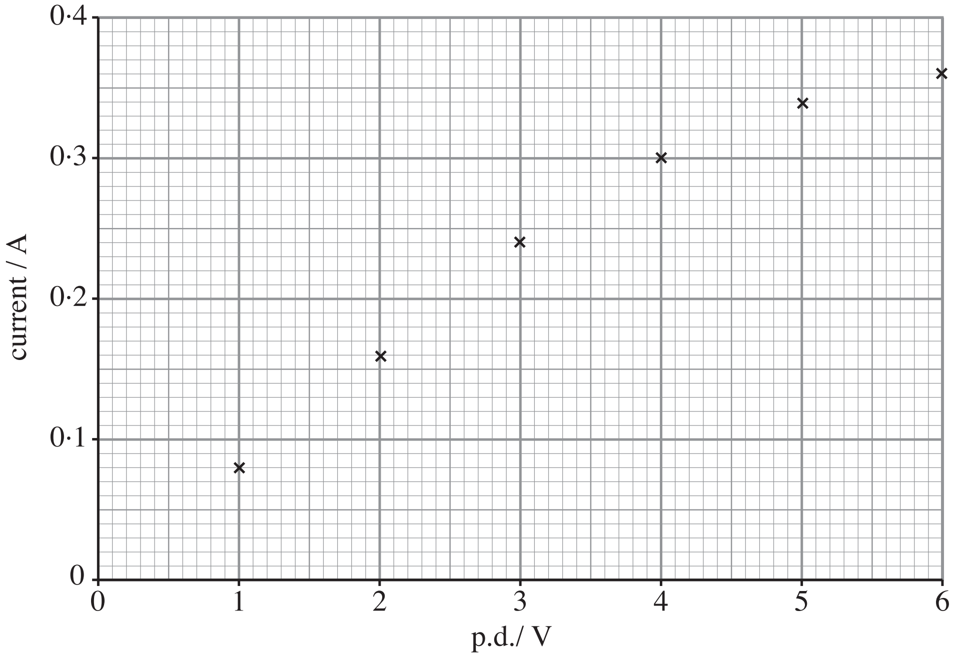
(b) A student assembles the components shown below, in order to plot a graph of current against p.d. for a coil of copper wire. (The internal resistance of the battery is negligible.)

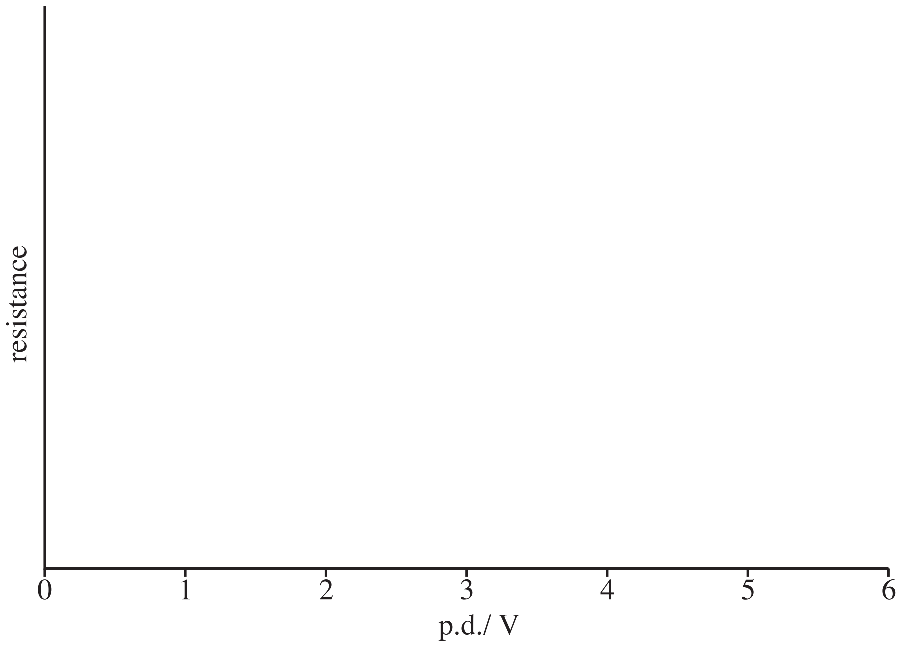


Draw a circuit diagram of the arrangement he sets up. The potential divider provides the full range of p.d.s between 0 and 6·0V. [4]

Turn over.

(c) The readings are plotted on the grid below.





(i) Complete the graph and determine the maximum p.d. for which Ohm's Law appears to apply to the coil. [1]

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(ii) Calculate the resistance of the coil

(I) at a p.d. of 1·5 V, [1]

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(II) at a p.d. of 6·0 V. [1]

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(iii) **Sketch** a graph of *resistance* against p.d. for the coil on the axes provided. **No scale is needed on the resistance axis.** [2]

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(iv) Ohm's Law ceases to apply to the coil as its temperature increases.
Explain, in terms of free electrons

(I) why a temperature rise occurs, [2]

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(II) why the increase in resistance occurs. [1]

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(v) The temperature coefficient of resistance of a conductor is defined by

$$\alpha = \frac{R_\theta - R_0}{R_0 \theta}.$$

in which, for a copper conductor, $\alpha = 0{\cdot}0044°C^{-1}$. Selecting the appropriate resistance from *(c)*(ii),

(I) show that $R_0 = 11{\cdot}3\Omega$ for the coil, taking the temperature of the laboratory as 25°C, [2]

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(II) estimate the temperature for the coil when the readings at 6·0 V were taken. [2]

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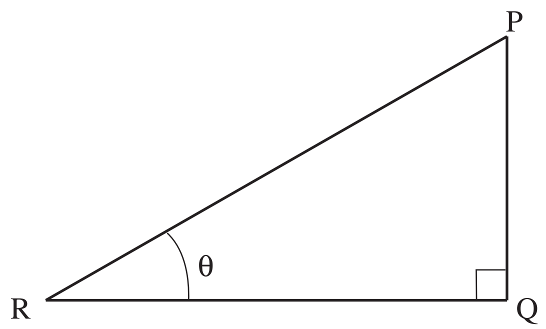
Mathematical Data and Relationships

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

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

Area of a triangle = ½ base × height

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