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

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542/01

PHYSICS

ASSESSMENT UNIT PH2: QUANTA AND ELECTRICITY

A.M. MONDAY, 12 January 2004

(1 hour 30 minutes)

Centre Number ....

Candidate's Name (in full) ....

Candidate's Examination Number ....

INSTRUCTIONS TO CANDIDATES

Write your centre number, name and candidate number in the spaces provided above.

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.

For Examiner's use only.	
1	
2	
3	
4	
5	
6	
7	
Total	

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.

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

Fundamental Constants

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

1. *(a)* The *temperature coefficient of resistance,* α*,* of a metal is defined by the equation

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

State the meaning of the symbols on the right hand side of this equation. [2]

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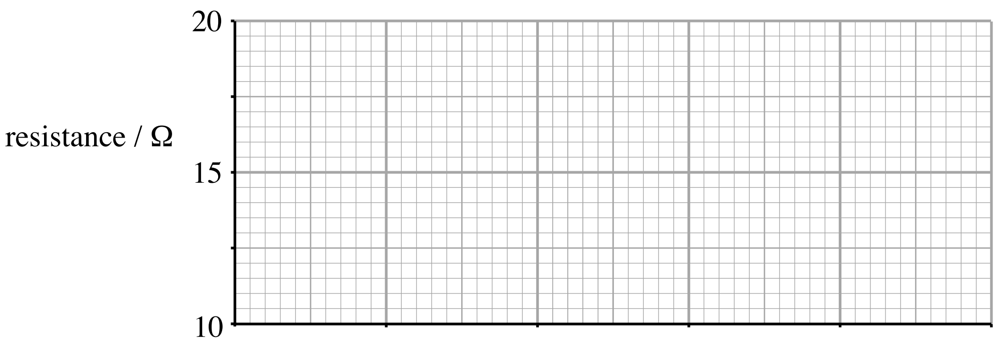
(b) The resistance of a coil of copper wire is measured at three temperatures:

temperature / °C	20	60	100
resistance / Ω	13·0	14·9	16·8

(i) Determine the temperature coefficient of copper from these results, making use of the grid below. [4]



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(ii) Calculate the resistance of the coil of copper wire at 300°C. [3]

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(iii) Suggest why it would not have been sensible to ask you to find the resistance of the coil at 3000°C. [1]

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2. *(a)* In a Physics practical class a teacher gives a student a sealed box with **two** terminals, containing a combination of two resistors. One has a known value of 10 Ω and the other has an unknown resistance, *X*. The student finds that when a p.d. of 15 V is placed across the terminals, a current of 2·5 A flows through the combination.

(i) Calculate the resistance of the combination. [1]

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(ii) Explain why the resistors cannot possibly be in series. [1]

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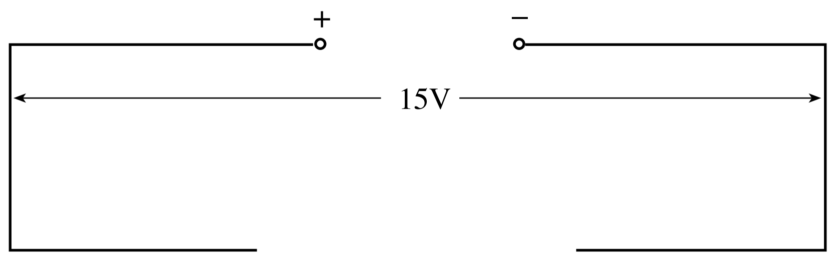
(iii) Add the resistor combination to complete the circuit diagram below. [1]



(iv) For the same p.d. of 15 V, calculate the current in

(I) the 10 Ω resistor, [1]

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(II) the other resistor. [1]

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(v) **Hence** calculate the resistance *X,* of this other resistor. [1]

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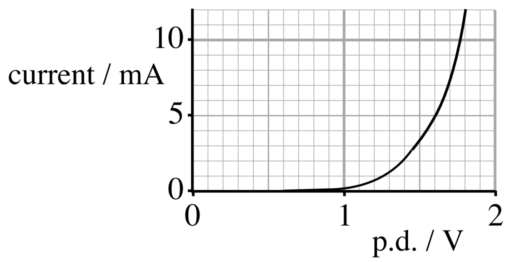
(vi) Use the appropriate resistance combination formula to check whether your answers to (i) and (v) are consistent with each other. Show your method clearly. [2]

(b) Which step in part *(a)* relies directly on the conservation of charge? Briefly explain your answer. [2]

3. A student's graph of current against potential difference for a diode is given below.

(a) (i) Calculate the resistance of the diode when the p.d. is 1·6 V. [2]

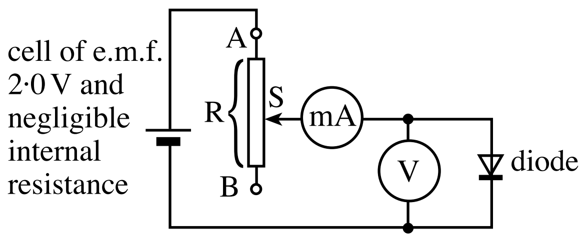


(ii) Comment on the resistance of the diode when the applied p.d. is very small. Calculation is not required. [1]

(b) (i) Explain how the graph shows that the diode does not obey Ohm's Law. [1]

(ii) Name another device to which Ohm's Law does not apply. [1]

(c) In his first attempt to obtain readings for the graph the student set up the circuit shown. By varying the position of the sliding contact, S, the student could obtain voltmeter readings in the range 1·6 V to 2·0 V, but not below 1·6 V.



(i) What was the position of S when the voltmeter read 1·6 V? [1]

(ii) Calculate the resistance of R. [3]

(iii) The student realised that to obtain the full range of readings he needed a *potential divider*. **Modify the circuit diagram** above to show the new arrangement. [1]

4. To produce X-rays from an X-ray tube, a metal target is bombarded with a stream of fast-moving electrons.

(a) The stream constitutes a current of 2·0 mA. Calculate the number of electrons which strike the target per second. (You will need to refer to the list of constants on page 2.) [2]

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(b) (i) State **two** ways in which X-rays and infrared radiation are similar. [2]

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(ii) The penetration of matter by X-rays and infrared radiation is different. State **one other** way in which X-rays and infrared radiation are different or behave differently. [1]

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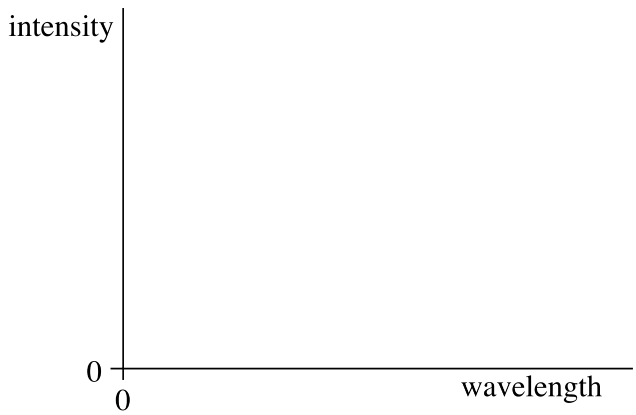
(c) Using the axes provided, sketch a typical graph of *intensity* against *wavelength* for the X-ray spectrum from an X-ray tube. [2]



(d) (i) Label on your graph the *continuous spectrum.* [1]

(ii) Explain how the continuous spectrum arises. [2]

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Turn over.

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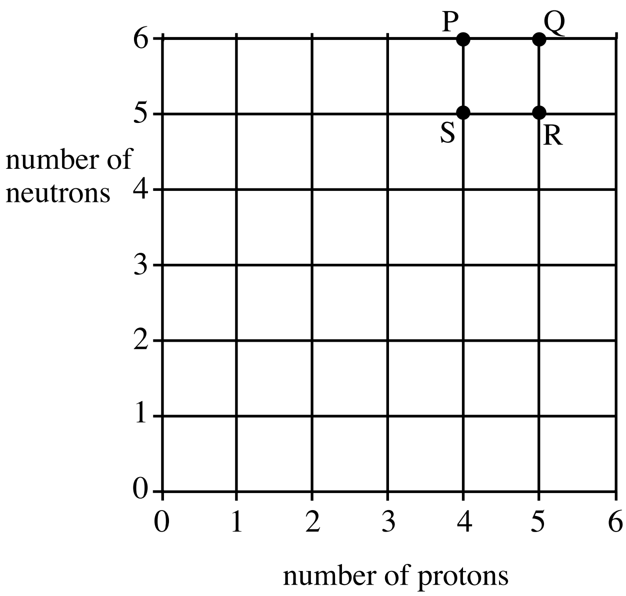
5. *(a)* In the diagram the number of neutrons is plotted against the number of protons for four nuclides, P, Q, R and S.



(i) When P is represented by the notation ${}^{A}_{Z}Be$ (in which 'Be' is the chemical symbol for the element), what are the values of the numbers

(I) *A?* .... [1]

(II) *Z?* .... [1]

(ii) Give **two** nuclides (out of P, Q, R, S) which are isotopes of the same element. [1]

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(iii) Which **two** of the four nuclides have nearly the same *mass?* Give a reason. [2]

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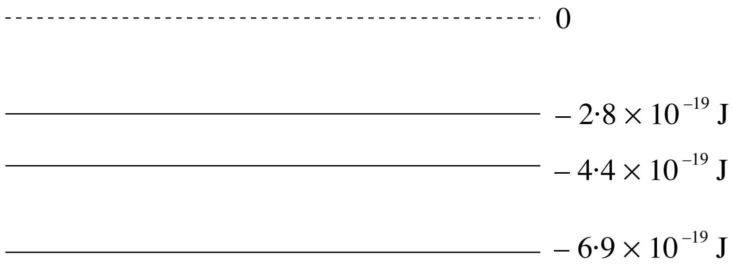
(b) A simplified energy level diagram for an atom is given below.



One of the 'lines' in the emission spectrum of the atom is due to photons with an energy of $2{\cdot}5 \times 10^{-19}$ J.

(i) Draw an arrow on the diagram to show the transition giving rise to this line. [1]

(ii) Calculate the wavelength of the line. (You will need to refer to the list of constants on page 2.) [3]

(iii) State in which region of the electromagnetic spectrum this line lies. [1]

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6. *(a)* Describe a simple experiment which **demonstrates** *the photoelectric effect*. A diagram is essential. (It is **not** required to obtain readings for plotting graphs.) [5]

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(b) (i) Write down *Einstein's photoelectric equation.* [1]

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(ii) State which of the three terms in the equation depends on

(I) the surface on which the light falls, but not on the light itself; [1]

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(II) the light (or ultraviolet) falling on the surface, but not on the surface itself. [1]

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(c) Light as described below falls on a caesium surface of *work function* $3{\cdot}0 \times 10^{-19}$ J. In **each** case calculate the maximum kinetic energy of the emitted electrons. If emission does not take place, explain why not. (You will need to refer to list of constants on page 2.)

(i) Violet light of frequency $7{\cdot}0 \times 10^{14}$ Hz. [2]

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(ii) Green light of frequency $5{\cdot}7 \times 10^{14}$ Hz. [1]

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(iii) A mixture of violet light of frequency $7{\cdot}0 \times 10^{14}$ Hz and green light of frequency $5{\cdot}7 \times 10^{14}$ Hz. (Explain your reasoning.) [2]

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(iv) Red light of photon energy $2{\cdot}8 \times 10^{-19}$ J. [2]

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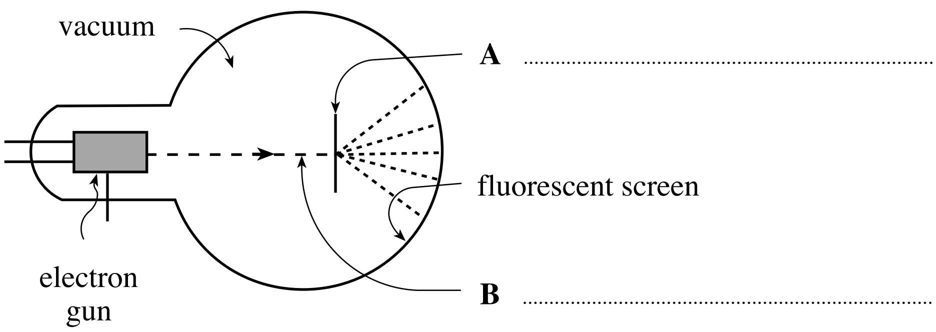
(d) In the photoelectric effect, light behaves as particles. The diagram below shows apparatus in which particles (electrons) can be seen behaving as waves.



(i) Label **A** and **B.** [2]

(ii) Describe what is seen on the screen and state how this illustrates wave behaviour. [3]

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7. *(a)* Define the *e.m.f.* of a cell. [2]

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(b) A car battery consists of six cells, **each** of e.m.f. 2·0 V and internal resistance 0·0020 Ω, connected in series.

(i) Write down the internal resistance of the car battery. [1]

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(ii) To start the car, a 'starter-motor' is connected to the battery. A current of 180 A flows through the battery and the motor. Calculate the p.d. across the battery terminals for this current. [3]

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(iii) When doing repairs under the bonnet of a car, it may be safest to remove the battery to prevent accidental short-circuits. Suppose a spanner were to be dropped and came to rest bridging the battery terminals. The spanner can be taken to have no resistance.

(I) How large would the current be? [2]

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(II) Calculate the *power* produced by the battery. [2]

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(III) Give a reason why such an accident could be very dangerous. [1]

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(c) Suppose the battery in your car is 'flat' (has run out of energy).

(i) A friend (who has not studied AS level Physics) suggests that the battery could be replaced by **a number of** cells of the type used in torches, connected in series. Each cell has an e.m.f. of 1·5 V and an internal resistance of 0·30 Ω. Explain why the **maximum** current such an arrangement could possibly supply is 5·0 A, no matter how many cells are used. [2]

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(ii) A better idea for starting the car is to use a pair of insulated copper wires (called 'jump-leads') to connect to a battery in a friend's car. Suppose that **each** wire is 3·0 m long and that the voltage drop along **each** wire is 0·72 V for a current of 180 A. The resistivity of copper is $1{\cdot}7 \times 10^{-8}$ Ωm.

(I) Calculate the cross-sectional area of the wire. [3]

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(II) Hence calculate the **diameter** of the wire. [2]

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(III) Discuss whether, ideally, jump leads should be made of wire of larger or smaller diameter. [2]

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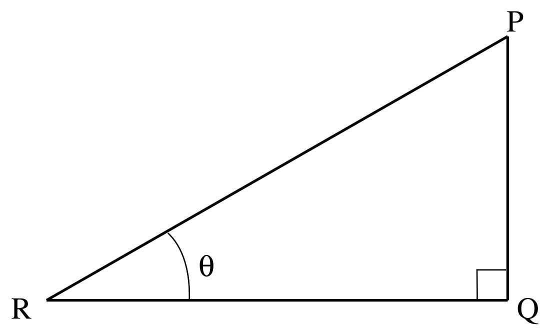
Mathematical Data and Relationships

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



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

$$PR^2 = PQ^2 + RQ^2$$

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	$4\pi r^2$	$\frac{4}{3}\pi r^3$