Candidate Name	Centre Number	Candidate Number

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

CYD-BWYLLGOR ADDYSG CYMRU
Tystysgrif Addysg Gyffredinol
Uwch Gyfrannol/Uwch

542/01

PHYSICS

ASSESSMENT UNIT PH2: QUANTA AND ELECTRICITY

A.M. THURSDAY, 12 January 2006

(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.

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 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.

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
Mass of a proton	m_p	=	$1{\cdot}67 \times 10^{-27}$ 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
Boltzmann constant	k	=	$1{\cdot}38 \times 10^{-23}$ J K^{-1}
Speed of light *in vacuo*	c	=	$3{\cdot}0 \times 10^{8}$ m s^{-1}
Permittivity of free space	ε_0	=	$8{\cdot}9 \times 10^{-12}$ F m^{-1}
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}

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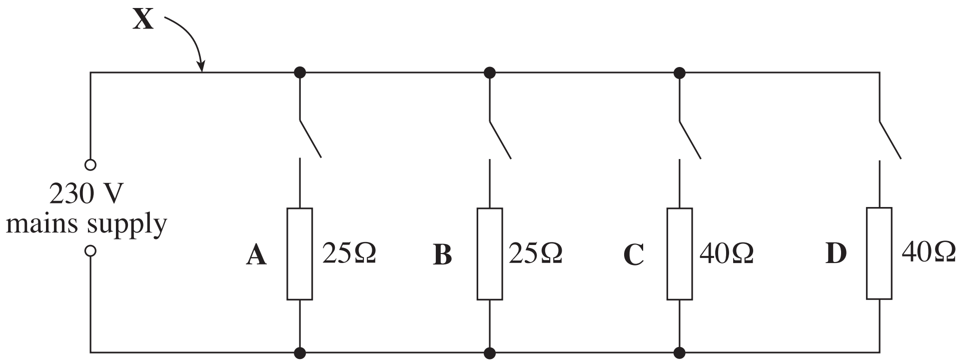
1. An electric 'hob' has four metal 'rings' on which saucepans may be heated. There are two identical large rings, **A** and **B**, and two identical small ones, **C** and **D**. Each ring is heated by passing a current throught a *heating element* (a length of wire) underneath it. [The switches are automatically turned on and off at intervals to keep the average heat output of each ring at a value selected.]



(a) Calculate the currect through

(i) element **A**, when it is switched on, [1]

....

(ii) element **C**, when it is switched on. [1]

....

(b) Calculate the overall *resistance* of the hob when **all** elements are switched on. [2]

....

....

....

(c) Calculate the *power* of

(i) element **A**, [2]

....

....

(ii) element **C**. [1]

....

....

(d) Which **two** combinations of rings, when switched on, would give a current of between 20 A and 21 A through wire **X**? Explain your reasoning. [3]

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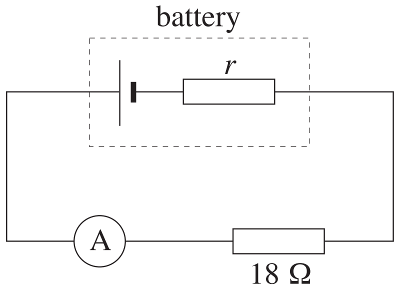
Turn over.

2. A battery is labelled "9V, 450 mAh". This may be assumed to mean that the battery has an e.m.f. of 9·0 V, and will supply a current of 450 mA for one hour before running out of energy.

It is found that a steady current of 450 mA flows when an 18 Ω resistor is connected across the battery terminals. [The resistance of the ammeter is negligible.]



(a) Calculate

(i) the battery's *internal resistance*, [2]

(ii) the total *charge* (in S.I. units) that will flow if the resistor is left connected until the battery has run out of energy, [2]

(iii) the total energy given to this charge as it passes through the battery, [1]

(iv) the **fraction** of this energy which is converted in the 18 Ω resistor. [2]

(b) Suppose that a resistor of higher resistance had been used instead of the 18 Ω resistor, so that the current was 225 mA.

(i) Calculate the resistance of this new resistor. [2]

(ii) How long, in this case, might the battery be expected to last before running out of energy? [1]

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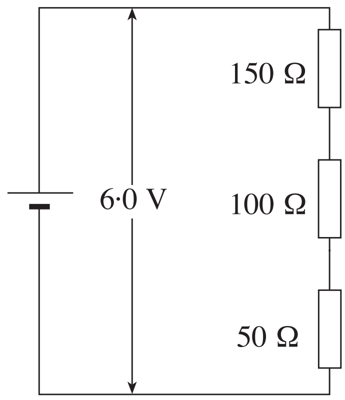
3. *(a)* The current is the same through two resistors in series.

(i) This rule can be deduced from a fundamental 'conservation' law. Name the law. [1]

(ii) Would the rule still apply if one of the resistors were to be replaced by a non-ohmic device? Justify your answer. [2]

(b) For the circuit alongside, calculate



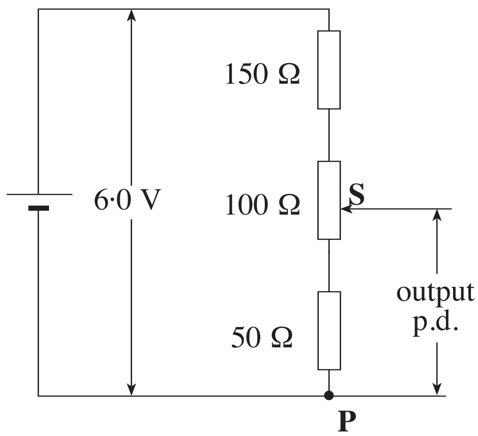
(i) the current, [1]

(ii) the p.d. across the bottom resistor (50 Ω),

the p.d. across the middle resistor (100 Ω).

[1]

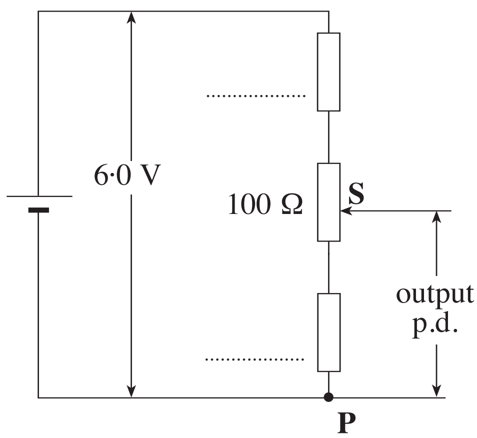
(c) The middle resistor is now replaced by a variable potential divider of total resistance 100 Ω. The slider, **S** can be moved along the whole length of the 100 Ω potential divider. A range of output p.d.s can thus be produced between point **P** and the sliding contact **S**. What will be the output p.d. when **S** is at



(i) the bottom end of the 100 Ω potential divider? [1]

(ii) the top end of the 100 Ω potential divider? [1]

(d) **If the top and bottom resistors** are replaced the output p.d. can be made to vary between 2·5 V and 4·5 V, according to the position of **S**.



(i) Explain why the current must be the same as in parts *(b)* and *(c)*. [1]

(ii) Label the top and bottom resistors with their required resistances. [2]

4. A laser gives out 1·0 mJ of energy per second as red light of frequency $4{\cdot}7 \times 10^{14}$ Hz.

(a) (i) Show that the energy of one photon is $3{\cdot}1 \times 10^{-19}$ J. [Refer to the data on page 2.] [1]

....

....

(ii) Hence calculate the number of photons emitted per second. [1]

....

....

(b) Light from the laser falls on to the surface of caesium metal. The maximum kinetic energy of electrons emitted from the surface is $2{\cdot}4 \times 10^{-20}$ J.

(i) State what is meant by the *work function* of a metal. [1]

....

....

(ii) Use Einstein's photoelectric equation to calculate the work function of caesium. [2]

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(iii) Calculate the 'stopping p.d.' (the p.d. needed between the caesium surface and a nearby electrode to prevent electrons reaching this electrode). [Refer to the data on page 2.] [1]

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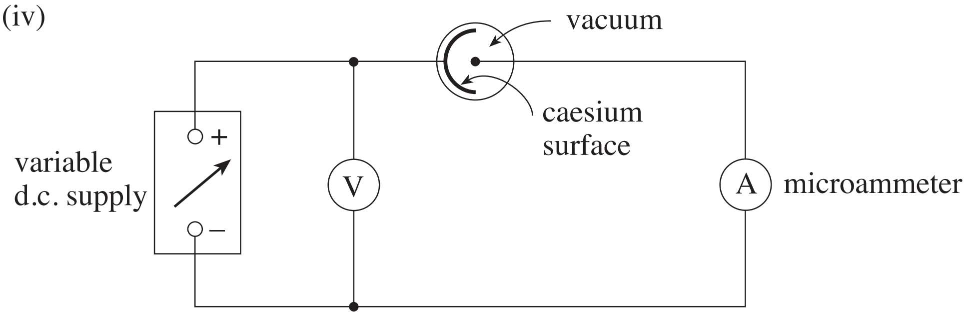
(iv)



A vacuum photocell containing a caesium surface is wired into the circuit shown. The surface is illuminated with red light from the laser. State how the current changes as the size of the p.d. is gradually increased from zero. [2]

....

....

(v) The experiment is repeated using a photocell containing a sodium surface. The work function of sodium is $3{\cdot}8 \times 10^{-19}$ J. State **and** explain what happens this time to the microammeter reading as the p.d. is increased from zero. [2]

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Turn over.

5. *(a)* The output from an X-ray tube consists of a *line spectrum* superimposed on a continuous spectrum. Show the meanings of the terms *line spectrum* and *continuous spectrum* by sketching the appropriate graph and labelling it. Labels, but not scales, are needed on the graph axes. [5]

(b) The X-ray line spectrum arises from changes occurring in the atoms of the target. Explain in detail, on an atomic level, how the X-ray **line** spectrum is produced in an X-ray tube. [5]

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6. *(a)* A lamp has a tungsten filament. Its resistance, as measured using a digital meter, is 38·0 Ω at 20°C (room temperature). The temperature coefficient of resistance of tungsten is 0·0058 °C^{-1}.

(i) The temperature coefficient of resistance is defined by

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

State what is meant by

(I) R_0, ... [1]

(II) R_θ. .... [1]

(ii) Show that R_0 for the lamp filament is 34 Ω. [2]

....

....

....

....

(iii) The lamp is marked '230 V, 100W'. For the lamp in normal use, calculate

(I) the resistance of the filament, [2]

....

....

....

(II) the temperature of the filament. [2]

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(iv) About one tenth of the energy radiated from a lamp filament is light. Almost all the rest of the radiation is of wavelengths **greater** than visible.

(I) Name the region of the spectrum in which this radiation lies. [1]

....

(II) If filaments could be made hotter they would give out a higher proportion of light. Suggest why it is not possible to make them significantly hotter. [1]

....

(b) 'Energy-saving' lamps give out a much higher proportion of visible light than do filament lamps. Inside an energy-saving lamp, electrons move fast through mercury vapour in a glass tube. Collisions between electrons and mercury atoms cause some atoms to be put in *an excited state*. Some atoms may even be *ionised*.

(i) Explain what is meant by

(I) *an excited state,* [1]

....

(II) *ionised*. [1]

....

(ii) Many of the excited atoms emit photons of energy $7{\cdot}8 \times 10^{-19}$ J.

(I) Calculate the wavelength of these photons. [Refer to the data on page 2.] [2]

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(II) Radiation of this wavelength is not visible. Name the region of the spectrum in which it lies. [1]

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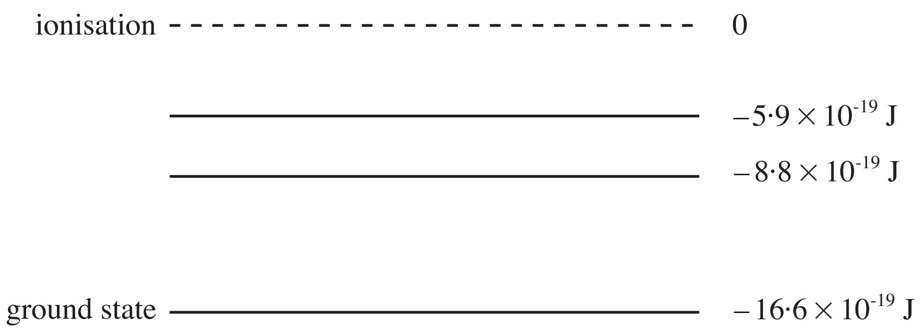
(iii) A simplified energy level diagram for a mercury atom is given.



(I) Deduce a value for the *ionisation energy* of a mercury atom. [1]

....

(II) Draw an arrow on the diagram to show the transition corresponding to emission of a photon of energy $7{\cdot}8 \times 10^{-19}$ J. [2]

(iv) The glass tube containing the mercury vapour is coated (on the inside) with chemicals called *phosphors*. These absorb the radiation from the mercury atoms and give out radiation of different wavelengths.

(I) To which region of the spectrum would you expect these wavelengths to belong? [1]

....

(II) Suggest why the phosphors are chosen so that more than one wavelength is emitted. [1]

....

7. *(a)* An ordinary piece of iron contains a mixture of isotopes, the most abundant of which are ${}^{56}_{26}Fe$ and ${}^{54}_{26}Fe$.

(i) State, giving numbers of particles,

(I) what is the same about these isotopes, [1]

....

(II) what is different about them. [1]

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(ii) In a piece of iron 7·7% of the electrons are free. Calculate the mean number of free electrons contributed by each atom. [2]

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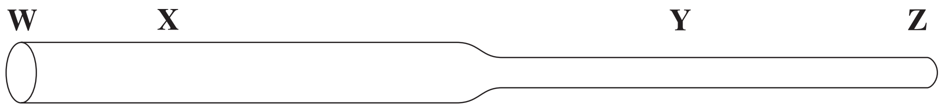
(b) A power supply is connected across the ends, **W** and **Z**, of an iron wire, whose thickness changes as shown. **Z** is connected to the positive terminal of the supply.



(i) State, giving a reason, the direction in which free electrons flow through the wire. [1]

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(ii) Throughout the length of the wire we can apply the equation $I = nAve$.

(I) State the meaning of n. [1]

....

(II) At point **X**, where the cross-sectional area of the wire is $1{\cdot}2 \times 10^{-6}\,m^2$, the drift velocity of the free electrons is $5{\cdot}0 \times 10^{-6}\,ms^{-1}$ for a current of 1·5 A. Calculate n. [Refer to the data on page 2.] [2]

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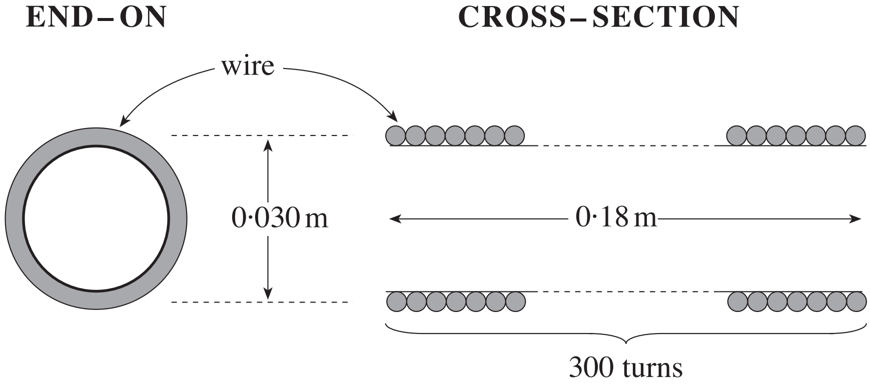
(III) Choose from the symbols **>**, **=** and **<** to compare the values of quantities in the equation $I = nAve$ at **X** and **Y**. The first comparison has been done as an example. [3]

$A_X > A_Y$ I_X ..... I_Y n_X ..... n_Y v_X ..... v_Y

(c) A coil of copper wire, to be used as an electromagnet, consists of 300 turns of copper wire wound, as a single layer, around a cardboard tube.



(i) The mean **diameter** of each **turn** (see diagram) is 0·030 m. Calculate the length of wire used to make the coil. [2]

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(ii) The turns cover a **tube** of length 0·18 m, and each turn touches its neighbours. [The wire is coated with a very thin layer of insulation.] Show clearly that the cross-sectional area of the **wire** is $2{\cdot}8 \times 10^{-7}\,\text{m}^2$. [2]

....

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(iii) Calculate the *resistance* of the coil, given that the resistivity of copper is $1{\cdot}7 \times 10^{-8}\,\Omega\text{m}$. [2]

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....

(iv) The coil is now re-made, on the same tube, using thinner copper wire. It is found that 600 turns of this wire are needed to cover the same length of tube (0·18 m). How many times larger is the resistance of this coil than the resistance of the previous one? Explain your reasoning carefully. [3]

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Turn over.

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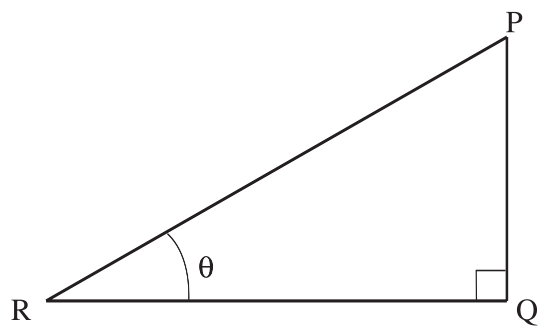
Mathematical Data and Relationships

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