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

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542/01

PHYSICS

ASSESSMENT UNIT PH2: QUANTA AND ELECTRICITY

P.M. FRIDAY, 12 January 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 "Mathematical Data and Relationships" on the back page of this paper.

For Examiner's use only.	
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2	
3	
4	
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Total	

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}

1. *(a)* Three resistors are available. Their values are 60 Ω, 60 Ω and 30 Ω. Show that **two** of these resistors can be connected together to give a combined resistance of 20 Ω. **Draw a labelled diagram of the combination**. [4]
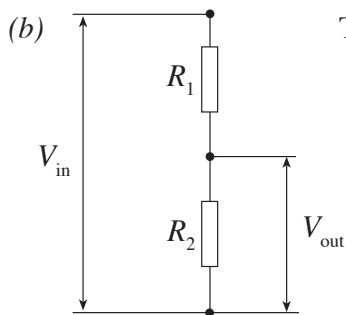
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(b) The diagram shows a potential divider.

(i) Write down an equation for the current through resistors R_1 and R_2 when an *input* p.d. V_{in} is applied as shown. [1]

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(ii) Hence show that the *output* p.d., V_{out} is given by the equation under the diagram. [1]

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

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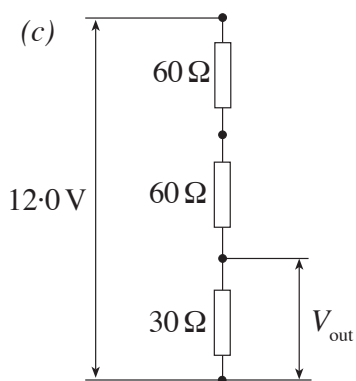
(c) (i) Calculate V_{out} when the three resistors of part *(a)* are arranged as shown to the left. [2]

60 Ω

12·0 V   60 Ω

30 Ω V_{out}

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(ii) Draw another potential divider, **using all three resistors of part *(a)***, for which $V_{out} = 9·0$ V when $V_{in} = 12·0$ V. [Use the space below for working.] [2]

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Turn over.

2. A student sets up the circuit shown, in order to investigate a battery. She obtains a reading **at each end of the range of the variable resistor**, and for two intermediate settings. The readings are plotted as shown.

(a) (i) (I) Draw the line of best fit and hence find the e.m.f. of the battery. [2]

e.m.f. = ...

(II) State how the student could modify the circuit to read the e.m.f. straight from the voltmeter. [1]

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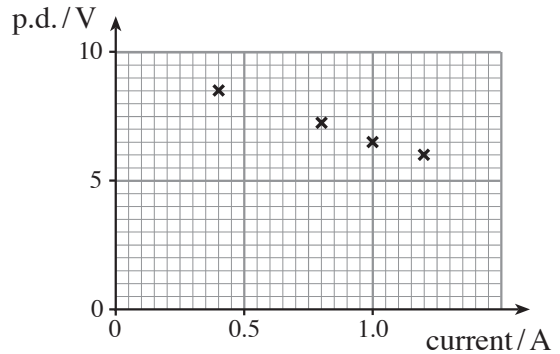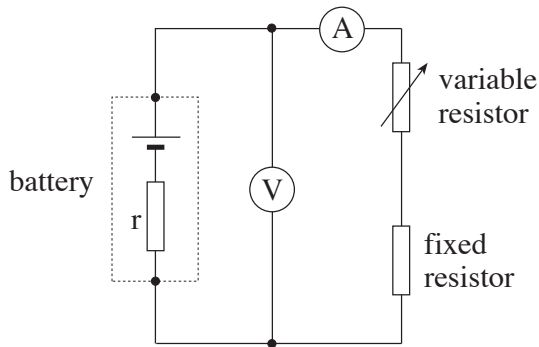
(ii) (I) Circle the point on the graph for which the variable resistor is set at zero. [1]

....

(II) Hence calculate the value of the fixed resistor. [1]

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(III) Explain why it is a good idea to include the fixed resistor in the circuit. [1]

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(b) (i) Calculate a value for the battery's internal resistance. [2]

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(ii) The manufacturers recommend that the battery be used for 'low current applications'. Explain, using the idea of internal resistance, why this makes best use of the battery's energy. [2]

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3. The current, *I*, through a wire is related to the drift velocity, *v*, of free electrons through the wire by the equation

$$I = nAve.$$

(a) (i) State the meaning of *n*. [1]

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(ii) Derive the equation, explaining your reasoning in clear steps, and giving a labelled diagram. [4]

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(b) (i) An overhead cable in the National Grid System is an aluminium conductor of **diameter** 0·040 m. For aluminium, $n = 1·8 \times 10^{29}$ m^{-3}. Calculate the drift velocity when the current is 1500 A. [Refer to the data on page 2.] [3]

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(ii) Explain why a high drift velocity would lead to more wastage of energy in the wires. [2]

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Turn over.

4. The diagram shows the spectrum of X-rays from an X-ray tube.
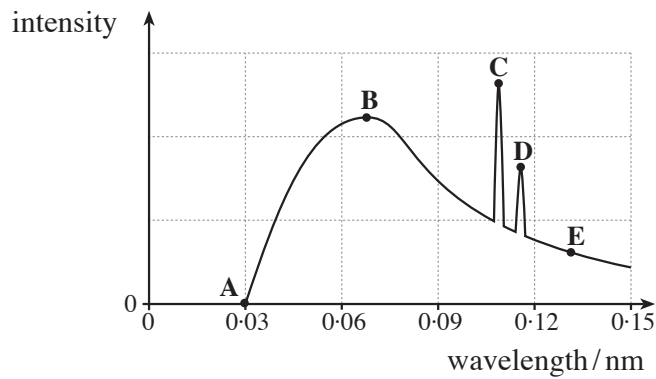
(a) **Choosing as many of the points A, B, C, D, E as are appropriate**, state which of the points correspond to photons produced

(i) with the greatest energy per photon, ... [1]

(ii) by rapidly decelerating electrons, ... [1]

(iii) after knocking out of inner electrons from atoms of the target. .... [1]

(b) For an X-ray tube

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

(i) Both sides of this equation represent energies.

(I) To what particle does the energy on the left hand side belong? [1]

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(II) What is the significance of the energy on the right hand side? [2]

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(ii) Calculate the accelerating voltage used in a tube which produces the spectrum given above. [Refer to the data on page 2.] [2]

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(c) Microwaves and X-rays both penetrate matter.

(i) State **one** similar way in which the matter is affected. [1]

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(ii) State **one** difference in the way the matter is affected. [1]

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5. *(a)* Describe a simple model of a $_{1}^{1}$H (hydrogen) atom. As part of your description state the charges of the particles which make up the atom, and describe how the mass of the atom is distributed. [3]

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(b) Distinguish between an *excited state* of a hydrogen atom and its *ground state* in terms of
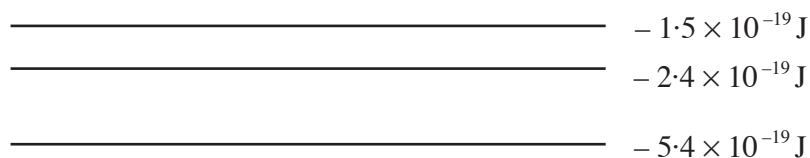
(i) energy, [1]

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(ii) the simple model you described in part *(a)*. [1]

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

$$\text{———————————— } -1{\cdot}5 \times 10^{-19}\,\text{J}$$
$$\text{———————————— } -2{\cdot}4 \times 10^{-19}\,\text{J}$$
$$\text{———————————— } -5{\cdot}4 \times 10^{-19}\,\text{J}$$

$$\text{———————————— } -21{\cdot}8 \times 10^{-19}\,\text{J}$$

A hydrogen atom in its **second** excited state returns to its ground state by emitting a photon.

(i) Draw an arrow on the diagram showing the transition which occurs. [1]

(ii) Calculate the wavelength of the radiation emitted. [Refer to the data on page 2.] [3]

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(iii) In which region of the electromagnetic spectrum does this radiation lie? [1]

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Turn over.

6. A toaster has one long slot into which two slices of bread can be placed. There are two identical heating 'elements', connected *in series*, one each side of the slot.

VIEW FROM
ABOVE
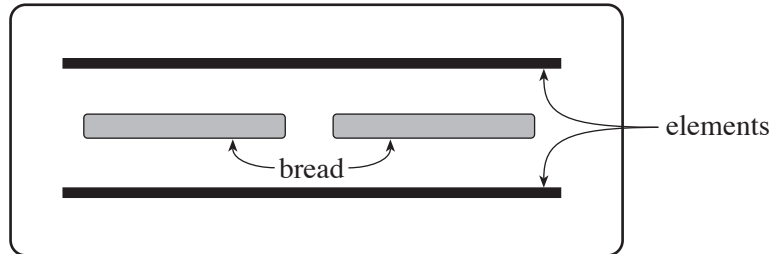
(a) The toaster is labelled '230 V, 980 W'. Show clearly that the resistance of **each** element, when the toaster is toasting, is 27·0 Ω [3]
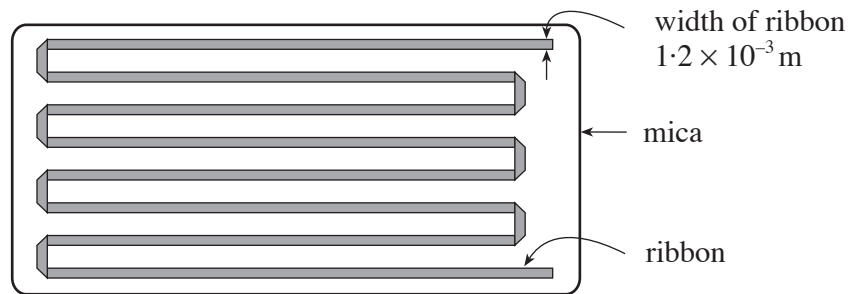
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(b) Each element consists of 2·10 m of metal ribbon bent into a zig-zag and supported on a vertical sheet of mica (an insulating material).

SIDE VIEW
OF ELEMENT

width of ribbon
$1·2 \times 10^{-3}$ m

mica

ribbon

The width of the ribbon is $1·2 \times 10^{-3}$ m and its cross-section is rectangular. Calculate its thickness, given that the resistivity of the metal is $1·10 \times 10^{-6}$ Ω. [4]

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(c) The temperature coefficient of resistance of a metal is defined by the equation

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

For the metal ribbon, $\alpha = 7 \cdot 5 \times 10^{-5}\,°C^{-1}$. The resistance of each element at 20 °C is measured to be 26·1 Ω (using a digital meter, with the toaster unplugged).

(i) What is the meaning of R_0 in the equation above? [1]

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(ii) Calculate R_0 for the element to **four significant figures**. [3]

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(iii) Explain why four significant figures are not, in fact, justified. [1]

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(iv) Calculate a value for the temperature of the metal ribbon when the toaster is in operation (and the element's resistance is 27·0 Ω). Give your answer to an appropriate number of significant figures. [3]

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Turn over.

(d) A new version of the toaster has its elements connected *in parallel*. The length and width of the ribbon on each element is the same as before, but the thickness is different. The new toaster takes the same *power* as the old when connected to 230 V mains.

    (i)   Calculate the resistance of **each** element. [2]

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    (ii)   A common cause of failure of toasters is a break occurring in a ribbon.

        (I)   By considering ribbon thickness, suggest **one** disadvantage of the new version of the toaster over the old, explaining your reasoning. [2]

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        (II)   Give **one** advantage of the new version over the old. [1]

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Turn over.

7. *(a)* (i) What is the *photoelectric effect*? [2]

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(ii) Einstein's photoelectric equation is

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

(I) Explain the meaning of ϕ. [1]

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(II) Give an account, in terms of photons, of the photoelectric effect, explaining how the theory leads to Einstein's equation. [3]

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(iii) The work function of sodium is $3\cdot8 \times 10^{-19}$ J.
Referring to the data on page 2, calculate

(I) the **frequency** of radiation needed to eject electrons with a maximum kinetic energy of $1\cdot5 \times 10^{-19}$ J from a sodium surface, [2]

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(II) the p.d. needed between the sodium surface and a nearby, negatively charged, electrode to prevent these electrons from reaching it. [2]

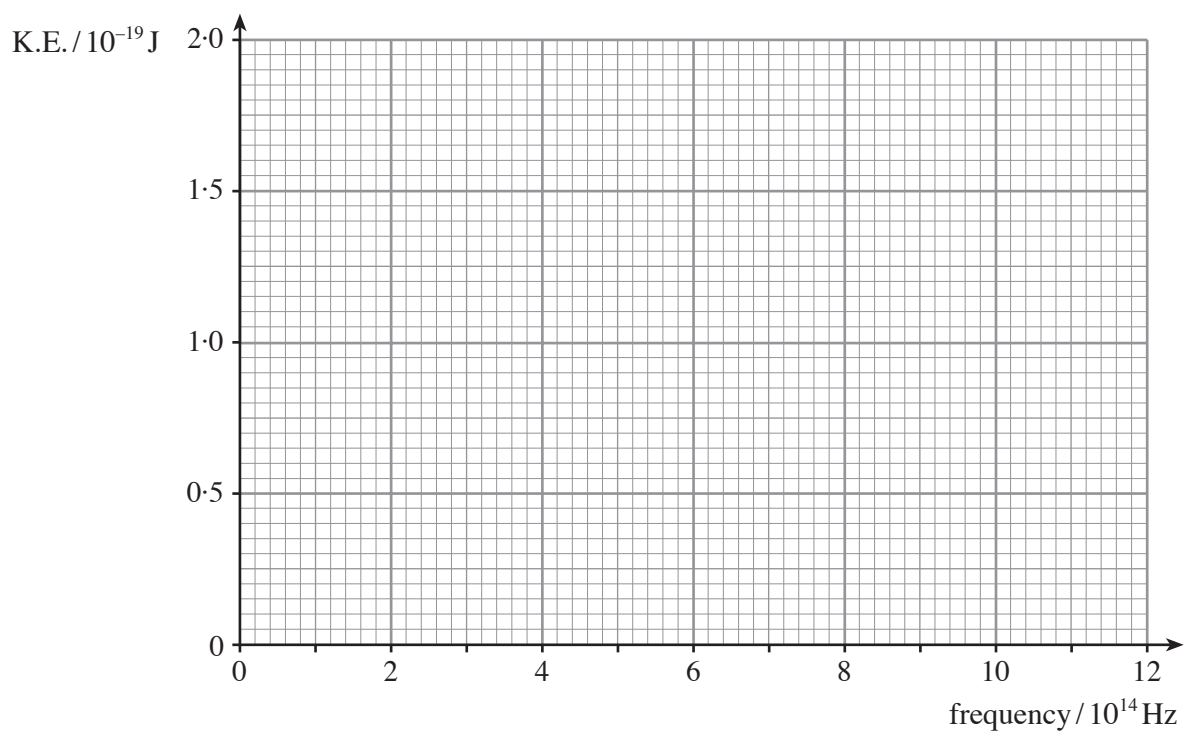...

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(III)   the minimum **frequency** of radiation needed to eject electrons from a sodium surface.   [2]

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(iv)   Making use of your answers to *(a)*(iii)(I) and *(a)*(iii)(III), draw in the graph line, for a sodium surface, on the axes below.   [2]

K.E. / 10^{-19} J

frequency / 10^{14} Hz

(v)   On the same axes draw the corresponding graph for a surface of smaller ϕ.   [2]

Turn over.

(b) When fast-moving electrons strike a very thin graphite layer in the apparatus shown, a pattern appears on the fluorescent screen.

vacuum

very thin graphite layer

fluorescent screen

electron gun

beam of fast-moving electrons
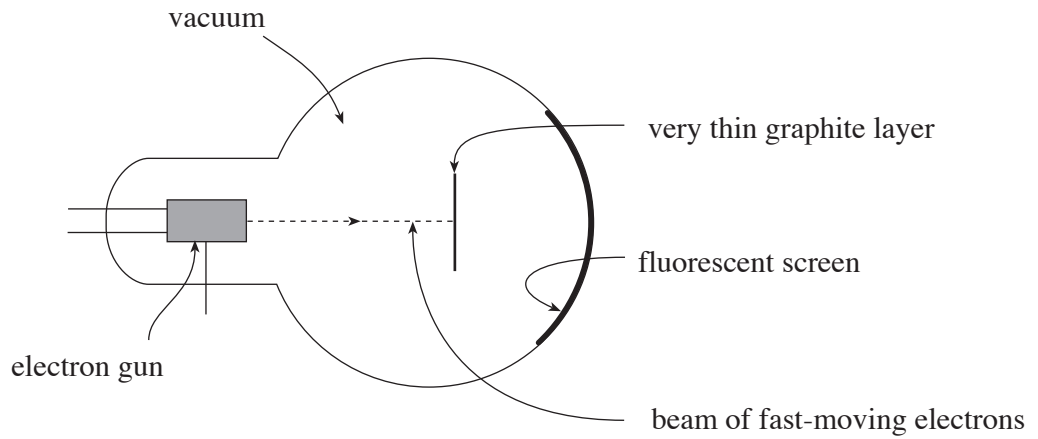
(i) Describe the pattern. [1]

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(ii) What does this pattern tell us about the behaviour of electrons? [1]

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(iii) Explain how the pattern arises. [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
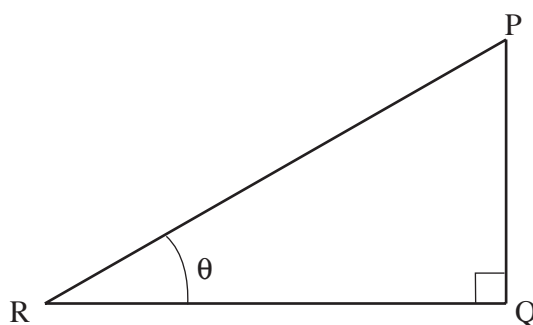
$$\sin\theta = \frac{PQ}{PR}, \quad \cos\theta = \frac{QR}{PR}, \quad \tan\theta = \frac{PQ}{QR}, \quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

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

Areas and Volumes

Area of a circle $= \pi r^2 = \dfrac{\pi d^2}{4}$ 　　　　Area of a triangle $= \frac{1}{2}$ base × height

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