Candidate Name	Centre Number	Candidate Number
		2

GCE AS/A level

542/01

PHYSICS

ASSESSMENT UNIT PH2: QUANTA AND ELECTRICITY

P.M. THURSDAY, 22 May 2008

1½ hours

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

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.

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
Boltzmann constant	k	=	$1{\cdot}38 \times 10^{-23}$ J K^{-1}
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}

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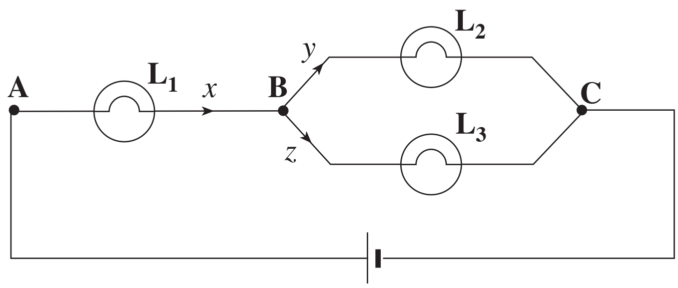
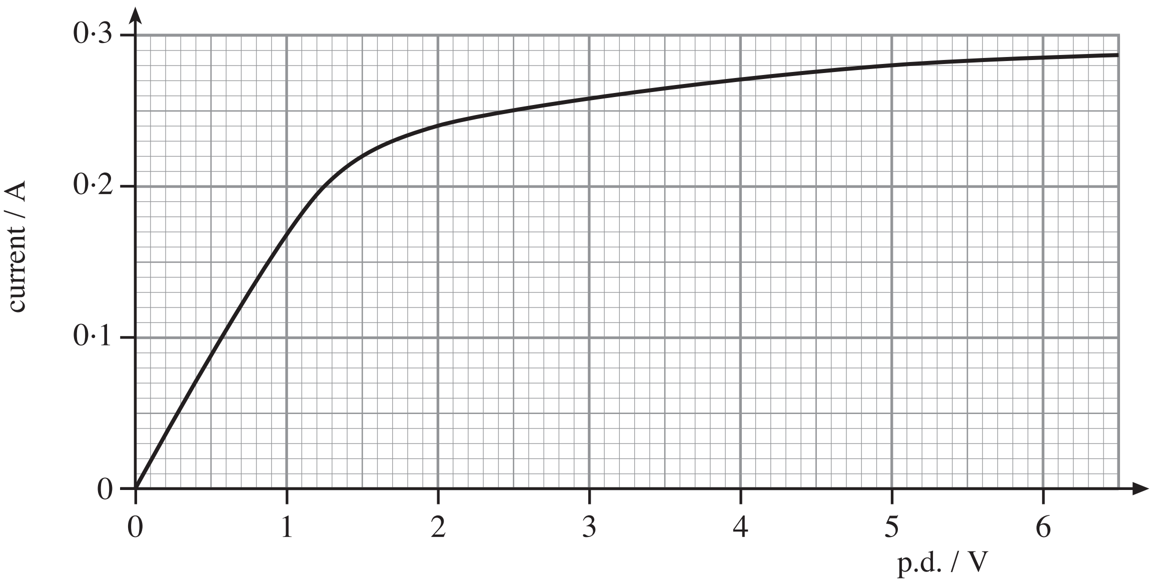
1. Three **identica**l filament lamps, $\mathbf{L_1}$, $\mathbf{L_2}$, $\mathbf{L_3}$, are connected as shown.



(a) Write down two equations relating two or three of the currents x, y and z.

(i) .... (ii) .... [2]

(b) A graph of current against p.d. for each of the lamps in the circuit is given below.



If the current x in the circuit above is 0·28 A, determine

(i) the current y, ... [1]

(ii) the p.d. across $\mathbf{L_1}$, ... [1]

(iii) the p.d. across $\mathbf{L_2}$, ... [1]

(iv) the p.d. between **A** and **C**. .... [1]

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(c) A student claims that identical lamps **always** have the same resistance. Explain why he is wrong. Use the bulbs in the circuit on page 4 as examples. [2]

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(d) What would happen to the brightness of $\mathbf{L_1}$ if $\mathbf{L_2}$ were removed? Give a reason for your answer. [2]

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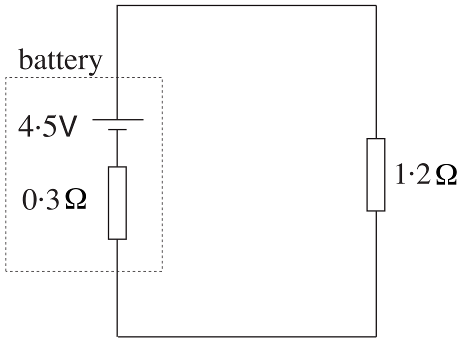
2. *(a)* A 1·2 Ω resistor is connected across a battery with an e.m.f. of 4·5V and an internal resistance of 0·3Ω.

Calculate



(i) the current, [1]

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(ii) the p.d. across the 1·2Ω resistor. [1]

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(b) (i) How much energy is converted per coulomb flowing

(I) from chemical to electrical in the cell? .... [1]

(II) from electrical form **in the 1·2Ω resistor**? .... [1]

(ii) Explain why you would expect these two answers to be different. [1]

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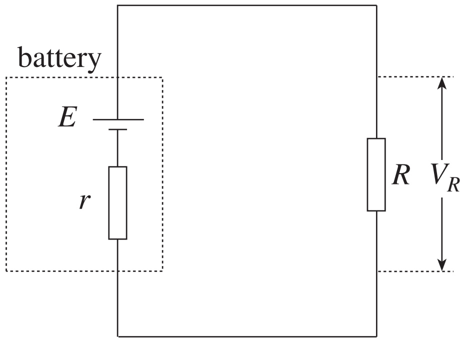
(c) The circuit alongside is the same as in part *(a)*, but with symbols replacing numbers.



(i) Using the same two steps as in part *(a)* show clearly that the p.d. V_R is given by

$$V_R = \frac{R}{R+r}E$$

[2]

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(ii) As the formula suggests, R and r can be thought of as forming a potential divider. What are the input and output voltages?

Input voltage = ... Output voltage = ... [1]

(iii) **Use the formula** to show what happens to V_R when R is very much larger than r. [You may wish to put in values for R and r.] [2]

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3. In a piece of aluminium each atom contributes 3 electrons to a 'sea' of *free electrons*. The free electrons are not attached to particular ions, but move around randomly in the metal.

(a) Explain why 'particular ions' is a more accurate phrase than 'particular atoms' in the last sentence above. [1]

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(b) A cube of aluminium measuring 10 cm × 10 cm × 10 cm contains $6{\cdot}0 \times 10^{25}$ ions. Calculate the number of free electrons **per m³** of aluminium. [3]

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(c) When a steady p.d. is applied across a piece of metal wire its free electrons acquire a *drift velocity* through the wire. Explain how and why the drift velocity changes when the metal's temperature is raised. [3]

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(d) Calculate the drift velocity when a p.d. of 6·0 V is applied across the ends of an aluminium wire of cross-sectional area $5{\cdot}0 \times 10^{-7}\,\text{m}^2$ and resistance 15 Ω. [Use your answer to part *(b)* and refer to the data on page 2.] [3]

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4. *(a)* Radio waves and X-rays are both electromagnetic radiation.

(i) Give typical wavelengths for

(I) radio waves, ... [1]

(II) X-rays. .... [1]

(ii) Radio waves and X-rays can be made to interfere, diffract, reflect and refract. State **one** other property which radio waves and X-rays have in common. [1]

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(iii) State **one** difference in the properties of radio waves and X-rays. [1]

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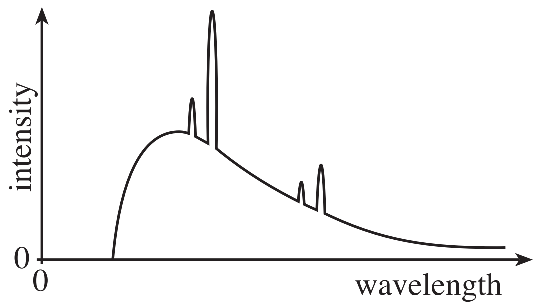
(b) In an X-ray tube, electrons are accelerated through a high potential difference and strike a metal target. The spectrum of the X-rays emitted is sketched below.



(i) The formula $eV = \dfrac{hc}{\lambda_{min}}$ can be applied.

(I) Show λ_{min} on the graph. [1]

(II) Calculate a value for λ_{min} when the accelerating voltage is 12 kV. [Refer to the data on page 2.] [1]

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(ii) Explain how the *line spectrum* arises. [4]

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Examiner only

5. *(a)* Describe how the following are distributed within an atom.

(i) mass [1]

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(ii) charge [1]

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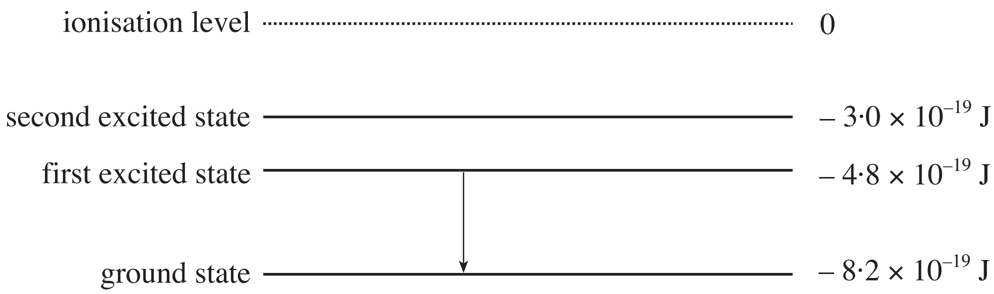
(b) A simplified energy level diagram for a sodium atom, showing the lowest three levels, is given below.



(i) A photon of yellow light is emitted when the transition shown in the diagram occurs. Calculate

(I) the photon energy, [1]

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(II) the wavelength of the yellow light. [Refer to the data on page 2.] [2]

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(III) the number of these photons emitted per second from a ‘sodium vapour lamp’ which takes an electrical input power of 60 W and converts 35% of this power to the yellow light. [2]

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(ii) Another transition between two of the levels shown in the diagram results in the emission of photons of *infrared* radiation.

(I) Show the transition by drawing another arrow on the diagram. [1]

(II) Justify your choice of transition. [2]

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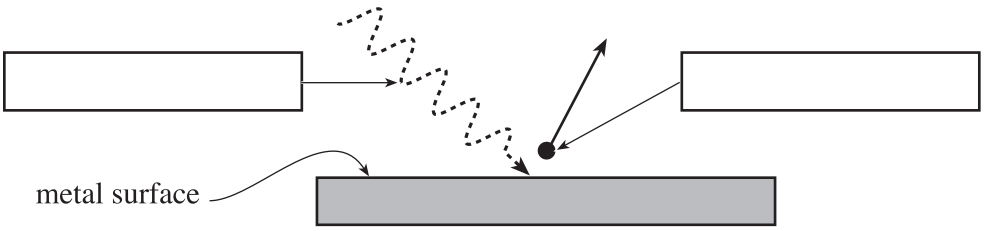
6. *(a)* A textbook has a simple diagram to illustrate the meaning of the term 'photo-electric effect'. Put labels in the boxes. [2]



(b) Einstein's photoelectric equation can be written

$$\frac{1}{2}mv_{max}^2 = hf - ø$$

(i) Name the quantity ø and state its meaning. [2]

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(ii) Einstein's equation is not valid if $hf < ø$. Explain, **in terms of electrons and photons,** why this is the case. [2]

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(iii) For a sodium surface, $ø = 3{\cdot}8 \times 10^{-19}$J. Calculate the minimum frequency of light for which photoelectric emission takes place. [Refer to the data on page 2]. [2]

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(c) When light of a particular frequency is shone on to a sodium surface ($\phi = 3{\cdot}8 \times 10^{-19}$J), electrons are found to be emitted with a maximum kinetic energy of $7{\cdot}0 \times 10^{-20}$J.

(i) Calculate the photon energy. [1]

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(ii) Show that the frequency of the light is $6{\cdot}8 \times 10^{14}$Hz. [Refer to the data on page 2.] [2]

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(iii) Suggest what colour this light would be, giving your reasoning. Take the range of visible frequencies of electromagnetic radiation to be $4{\cdot}2 \times 10^{14}$ Hz up to $7{\cdot}5 \times 10^{14}$ Hz. [2]

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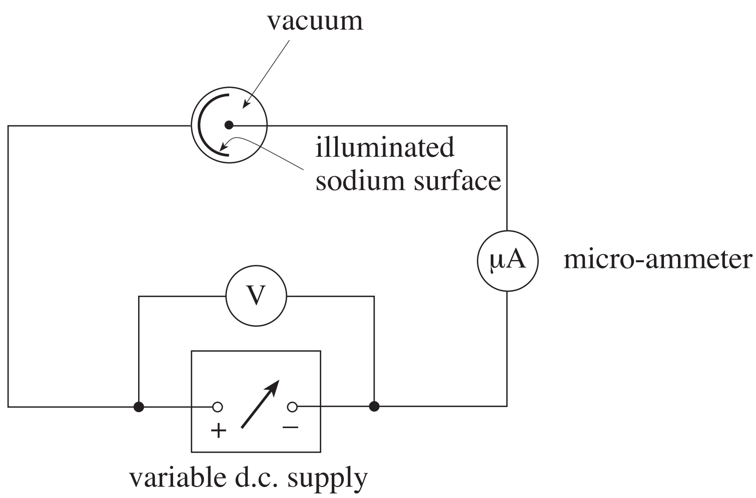
(d) The maximum kinetic energy of $7{\cdot}0 \times 10^{-20}$J [see part *(c)*] was found by measuring the stopping voltage (cut off voltage) using the apparatus shown.



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(i) Calculate the measured stopping voltage which led to this value of kinetic energy. [Refer to the data on page 2.] [2]

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(ii) (I) Describe carefully what would have happened to the reading on the micro-ammeter as the size of the p.d. was gradually increased from zero. [3]

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(II) The experiment is now repeated using a greater *intensity* of light of the same frequency ($6{\cdot}8 \times 10^{14}$ Hz). State how the readings will be similar and how they will be different. [2]

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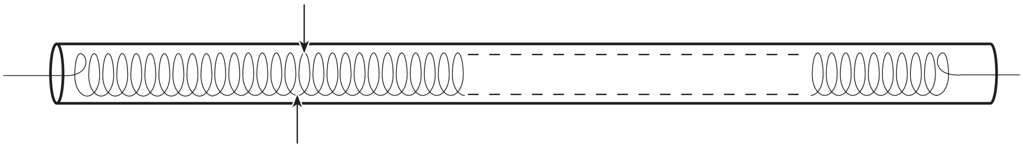
7. A heating 'element' for an electric fire has a resistance of 52·9 Ω at its normal working temperature (670 °C).

(a) The element consists of a long coil of 'nichrome' wire inside a pyrex tube.



(i) There are 200 turns on the coil, and the **diameter** of each turn is $9{\cdot}0 \times 10^{-3}$ m. Estimate the length of wire in the coil. [2]

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(ii) The **wire's diameter** is $3{\cdot}8 \times 10^{-4}$ m. Calculate the *resistivity* of nichrome at 670 °C. [4]

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

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

(i) State the meaning of R_θ. [1]

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(ii) Show clearly that $\alpha\theta$ is the **fractional** change in resistance of the metal as its temperature is increased from 0 °C to θ. [1]

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(iii) The temperature coefficient of resistance of nichrome is $6{\cdot}0 \times 10^{-5}$ °C^{-1}. Calculate the **percentage** change in resistance of the heating element between 0 °C and 670 °C. [2]

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(iv) Why would your method not work for the interval between 0 °C and 6700 °C? [1]

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(c) An electric fire has two elements of the type described. Take each element to have a constant resistance of 52·9 Ω.

(i) Calculate the total *power* dissipated if 230 V is applied to

(I) a single element, [2]

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(II) the elements in parallel, [1]

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(III) the elements in series. Explain your reasoning. [2]

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QUESTION 7 CONTINUES ON THE NEXT PAGE

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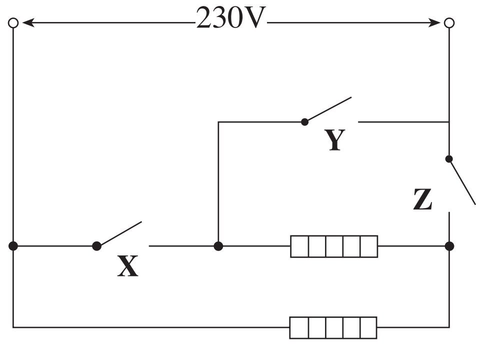
(ii) The elements can be connected in any of the arrangements (I), (II) or (III) in part *(c)* by means of switches **X**, **Y** and **Z**.

Complete the table to show which switches should be open, and which closed, in each case. The first line is completed as an example.



[2]

	X	Y	Z
(I) a single element	*open*	*open*	*closed*
(II) elements in parallel			
(III) elements in series			

(iii) A safety feature built into the fire ensures that one **pair** of switches can never be closed at the same time.

(I) Which pair of switches is this? .... [1]

(II) What would happen, without this safety feature, if they *were* closed at the same time? [1]

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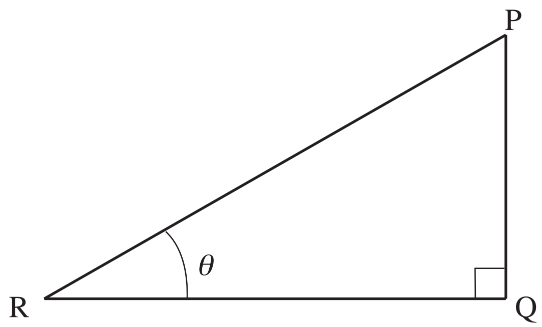
Mathematical Data and Relationships

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 $= \pi r^2 = \frac{\pi d^2}{4}$

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