Candidate Name	Centre Number	Candidate Number

WELSH JOINT EDUCATION COMMITTEE
General Certificate of Education
Advanced

CYD-BWYLLGOR ADDYSG CYMRU
Tystysgrif Addysg Gyffredinol
Uwch

544/01

PHYSICS

ASSESSMENT UNIT PH4: OSCILLATIONS AND ENERGY

A.M. MONDAY, 22 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.

For Examiner's use only.	
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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.

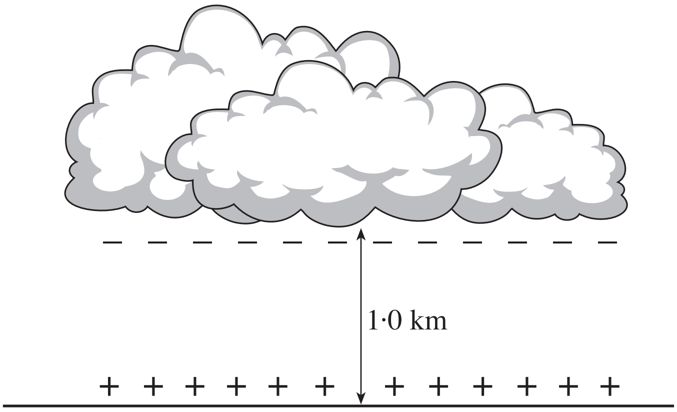
Your attention is drawn to the table of "Mathematical Data and Relationships" on the back page of this paper.

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
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}

1. Lightning strikes can occur between a storm cloud and the ground beneath it. In a simplified example the base of the cloud and the ground beneath it carry equal and opposite electric charges as shown. The base of the cloud has an area of $2{\cdot}0 \times 10^7\,\text{m}^2$ and is on average 1·0 km above the ground.



(a) Treating the base of the cloud, the ground and the intervening air-gap as a parallel plate capacitor, calculate the capacitance. [**Relative** permittivity of air = 1·0] [3]

(b) Give **two** reasons why it is not strictly correct to treat the system as a parallel plate capacitor. [2]

(c) If the p.d. across the air-gap reaches $3{\cdot}0 \times 10^{10}\,\text{V}$ the air 'breaks down' and conducts electric current.

(i) Calculate the *charge* on the base of the cloud just before breakdown occurs. [2]

(ii) Assuming that, during breakdown, the energy stored in the system is dissipated in a time of 1·0 ms, calculate the *power* of the resulting lightning flash. [3]

2. *(a)* The kinetic theory of gases makes assumptions about the behaviour of molecules that are used to derive the equation

$$p = \frac{1}{3}\rho\overline{c^2}$$

One assumption is that, between collisions, molecules move in straight lines because there are no intermolecular forces. State **two** other assumptions. [2]

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(b) At the centre of the Sun the pressure is estimated to be $1{\cdot}5 \times 10^{16}$ Pa, and the density, $1{\cdot}8 \times 10^{5}\,\mathrm{kg\,m^{-3}}$.

(i) Treating the centre of the Sun as an ideal gas of particles, calculate their r.m.s. speed. [2]

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(ii) Assuming the particles to be protons – see the data on page 2 – calculate:

(I) the number per m^3, [2]

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(II) the number of *moles* per m^3. [1]

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(iii) Hence calculate a value for the temperature of the centre of the Sun, using the ideal gas equation. [2]

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(iv) Because the centre of the Sun is *not* an ideal gas, your calculations yield order-of-magnitude estimates rather than accurate values. Take **one** of the assumptions of part *(a)* – either in the question or your answer – and explain why it does not hold at the centre of the Sun. [1]

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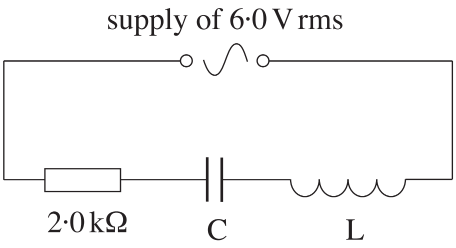
3. The reactances, X_C and X_L, of a capacitor, C, and an inductor, L, are given in the table below for frequencies of 65 Hz and 130 Hz. Use the values in this table to answer the questions below.

f / Hz	65	130	260
X_C / kΩ	8·4	4·2	
X_L / kΩ	2·1	4·2	

(a) Put the reactances at 260 Hz into the last column. [2]

(b) L, C and a 2·0 kΩ resistor are connected in series across a signal generator giving a sinusoidal output of 6·0 V r.m.s. at any chosen frequency.



(i) State the frequency at which the r.m.s. current is a maximum. [1]

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(ii) Calculate this r.m.s. current. [1]

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(iii) Calculate the r.m.s. current at a frequency of 65 Hz. [4]

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(iv) Explain, giving labelled phasor (vector) diagrams, or otherwise, why the current will be the same at a frequency of 260 Hz as at 65 Hz. [2]

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4. *(a)* The First Law of Thermodynamics may be written

$$Q = \Delta U + W.$$

What is the meaning of W? [1]

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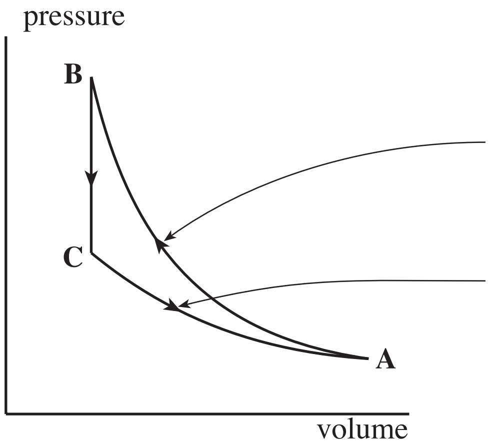
(b) The graph shows a cycle of changes, **ABC**, undergone by an ideal gas in a cylinder fitted with a leak-proof piston. The table is to contain the values of Q, ΔU and W for each stage, **AB**, **BC** and **CA** of the cycle, and for the cycle as a whole. Three cells have already been filled in.



		Q	**ΔU**	**W**
AB	rapid compression: no heat enters or leaves	**0**	(4)	**−80 J**
BC		(9)	(8)	(1)
CA	slow expansion at constant temperature	(7)	(2)	**+60 J**
whole cycle		(6)	(3)	(5)

(i) Explain why the following cells must contain zeros. [3]

cell (1) ....

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cell (2) ....

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cell (3) ....

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(ii) Enter the zeros in cells (1), (2) and (3) and complete the remaining cells, perhaps in the order (4), (5) ... (9). [3]

(iii) Consider stage BC.

(I) **Without** using symbols Q, ΔU or W, describe what is happening to the gas. [2]

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(II) Why must **BC** take place slowly (compared to **AB**)? [1]

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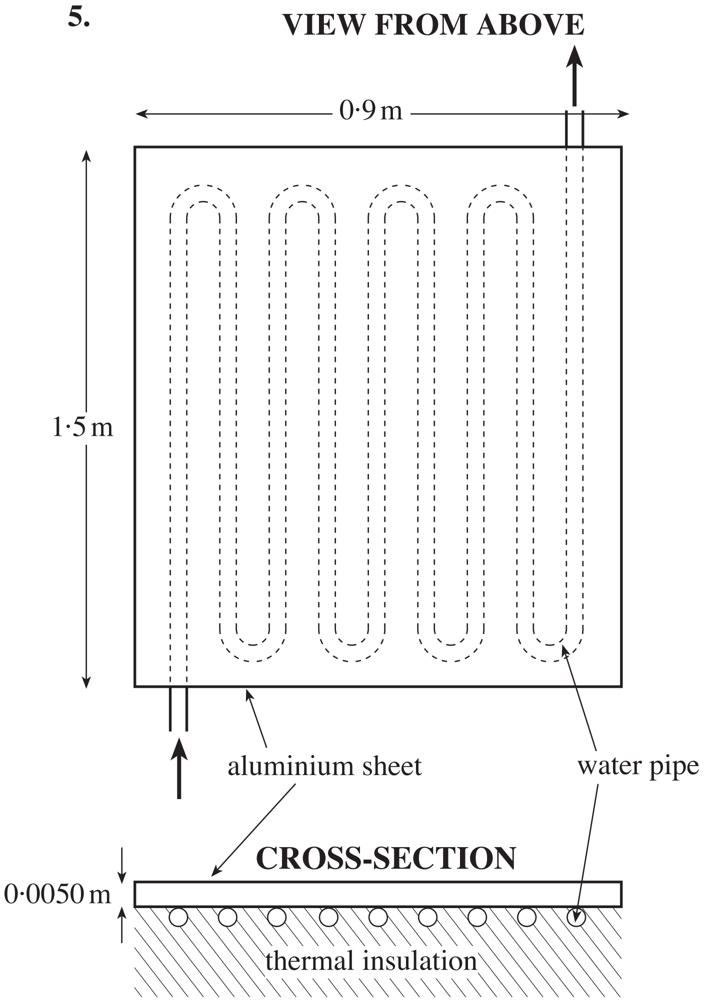

The diagrams show a simple form of 'solar collector' for heating water. A zigzag metal pipe is beneath, and in contact with, an aluminium sheet measuring 0·90 m × 1·5 m × 0·0050 m.

On a Winter day, solar infrared and visible radiation arrives at the collector at a rate of 350 W **per m^2** of the aluminium sheet.

Water is pumped through the pipe at a rate of 0·45 litre per **minute**. It enters the zigzag pipe at a temperature of 15°C and leaves at 26°C.

(a) (i) Calculate in clear steps the **percentage** of solar energy transferred to the water.
[Mass of 1·0 litre of water = 1·0 kg; specific heat capacity of water = 4200 J kg^{-1} K^{-1}] [5]

(ii) Give **two** reasons for the energy transfer not being 100%. [2]

(b) (i) The *thermal conductivity* of aluminium is 240 $\mathrm{W\,m^{-1}\,K^{-1}}$. Use the equation

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta \theta}{\Delta x}$$

to make a rough estimate of the temperature difference between the top surface and the bottom surface of the aluminium sheet. [2]

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(ii) Give **one** reason for your answer to *(b)*(i) being only a rough estimate. [1]

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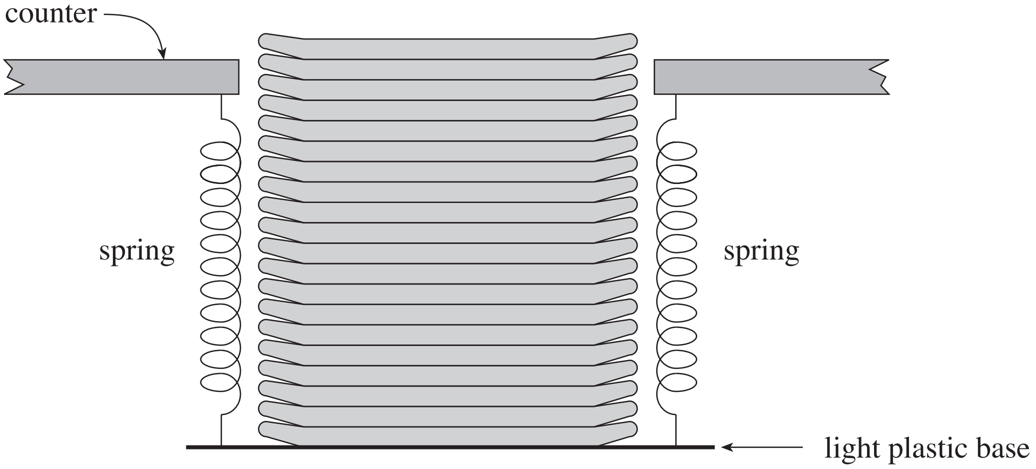
6. The diagram shows an early version of a device for storing a pile of clean plates below the serving counter of a café, yet with easy access. The device is being tested.



(a) (i) Each time a plate, of mass 0·72 kg, is added gently to the pile the springs stretch by an additional $8{\cdot}0 \times 10^{-3}$ m, so that the base of the top plate is always level with the top of the counter. Calculate the force per unit extension for **the spring system**. [3]

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(ii) What modification would need to be made in order to store plates of the same thickness but greater mass? Explain your reasoning. [2]

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(b) When a pile of plates, each of mass 0·72 kg, is pushed down and released, *natural oscillations* take place. Five cycles are timed to take 3·7 s. Calculate the number of plates in the stack. [5]

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(c) The device, loaded with plates as in part *(b)*, is made to perform *forced oscillations* at a range of frequencies including the resonant frequency.

(i) State what is needed to make the system perform forced oscillations. Experimental details are **not** needed. [2]

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(ii) Calculate the resonant frequency. [1]

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(iii) What distinguishes forced oscillations at resonance from forced oscillations at other frequencies? [1]

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(d) The device is now fitted with an (adjustable) *damping* mechanism, and the pile of plates is pushed down, and released at time $t = 0$.

(i) What is meant by *damping*? [1]

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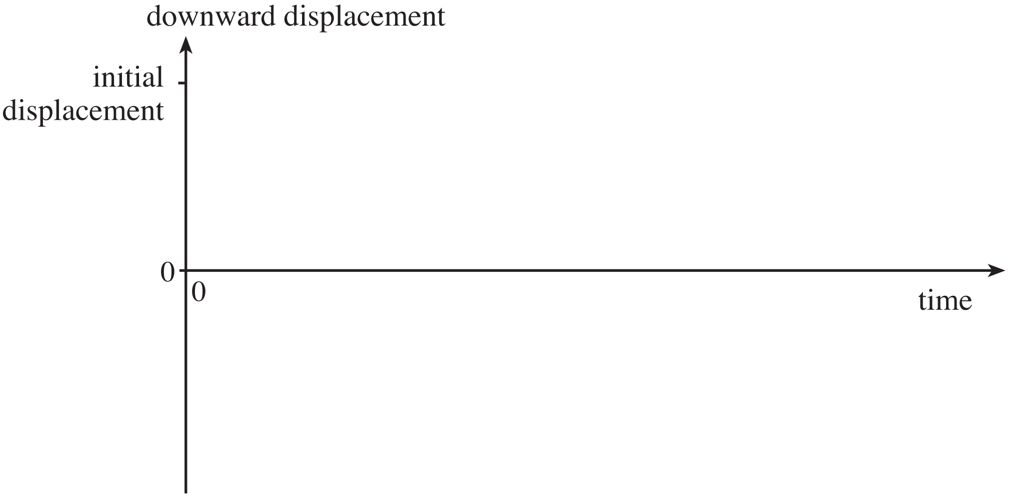
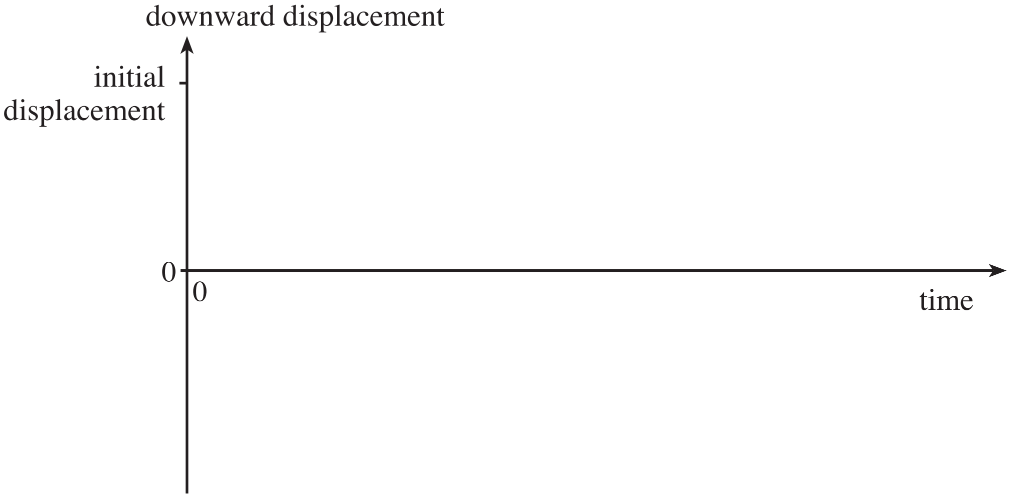
(ii) Sketch graphs of *displacement* against *time* for the pile

(I) if the damping is light (but not negligible), [2]



THE QUESTION CONTINUES ON THE NEXT PAGE

(II) if the damping is *critical*. [2]



(ii) Explain why damping **much** greater than critical would not be suitable for this plate-storage device. [1]

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Turn over.

7. *(a)* (i) Define the *momentum* of a body. [1]

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(ii) State Newton's Second Law of Motion in terms of momentum. [2]

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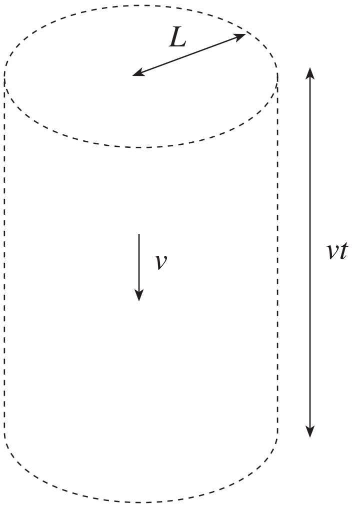
(b) The main blades of a helicopter produce a downward wind. The air which is set in motion, at speed v, in a time t may be thought of as occupying a cylinder of height vt and radius equal to the blade-length, L.



(i) Show in clear steps, that the momentum given to the air, of density ρ, in a time t, is $\pi L^2 \rho v^2 t$. [3]

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(ii) For the helicopter to be hovering (stationary in the air and not accelerating), v has to be $12\,\text{ms}^{-1}$. Explaining how you use Newton's Second Law, calculate the downward force acting on the air from the helicopter blades. [$\rho = 1{\cdot}3\,\text{kg}\,\text{m}^{-3}$, $L = 6{\cdot}6\,\text{m}$]. [2]

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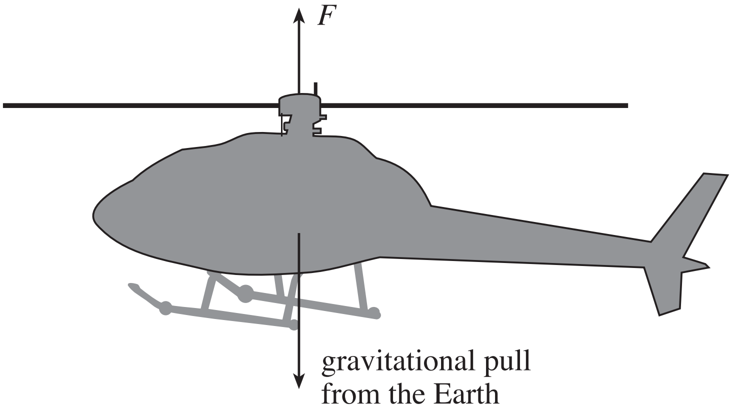
(iii) the diagram shows the two major forces acting on the hovering helicopter.



(I) State **what** exerts the upward force F, on the helicopter blades. [1]

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(II) Hence explain why the force you calculated in *(b)*(ii) must be equal to the pull of gravity on the helicopter. [2]

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(iv) Calculate the vertical acceleration of the helicopter when $v = 14\,\text{ms}^{-1}$. [5]

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(c) If the main blades are turning at a rate of 720 revolutions **per minute**, calculate

(i) the *angular velocity* of the blades, [2]

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(ii) the *centripetal force* on a portion of a blade-tip of mass 2·0 kg. [The distance of this portion from the axis of rotation is 6·6 m.] [2]

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Turn over.

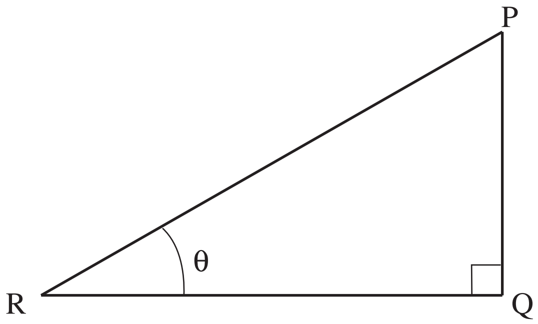
Mathematical Data and Relationships

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



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

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

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

Logarithms

[Unless otherwise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log\left(\dfrac{a}{b}\right) = \log a - \log b$

$\log(x^n) = n\log x$

$\log(kx^n) = \log k + n\log x$

$\log_e(e^{kx}) = \ln(e^{kx}) = kx$

$\log_e 2 = \ln 2 = 0{\cdot}693$