Candidate Name	Centre Number	Candidate Number
		2

GCE A level

544/01

PHYSICS

ASSESSMENT UNIT PH4: OSCILLATIONS AND ENERGY

A.M. WEDNESDAY, 11 June 2008

1½ hours

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 table of "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}

BLANK PAGE

Examiner only

1. *(a)* Show that for a particle of mass m with kinetic energy E_k,

$$p^2 = 2mE_k,$$ [2]

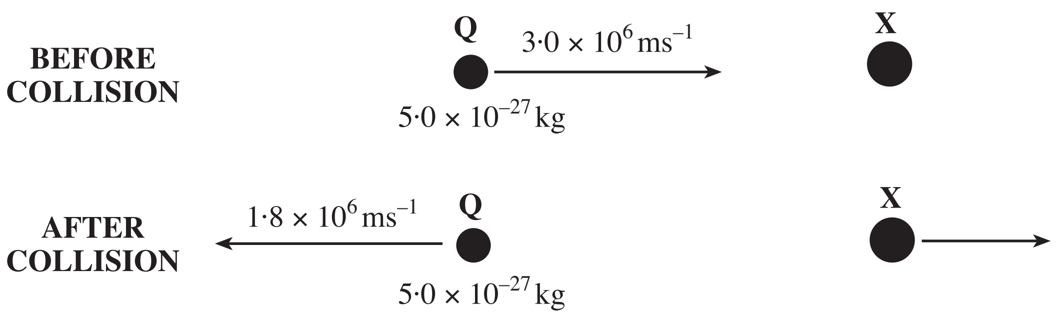
in which p is the magnitude of the particle's momentum.

....

....

....

(b) A particle **Q**, of mass $5{\cdot}0 \times 10^{-27}$ kg, moving at $3{\cdot}0 \times 10^{6}\,\text{ms}^{-1}$, makes an **elastic** head-on collision with a stationary particle **X**. **Q** rebounds with a speed of $1{\cdot}8 \times 10^{6}\,\text{ms}^{-1}$.



(i) (I) No resultant external force acts on the particles. What does the *Principle of Conservation of Momentum* tell us about such a system? [1]

....

(II) Calculate the *momentum* of **X** after the collision. [2]

....

....

....

(ii) (I) Define an *elastic* collision. [1]

....

....

(II) Calculate the kinetic energy of **X** after the collision. [2]

....

....

(iii) Use your previous answers to calculate the mass of **X**. [2]

....

....

....

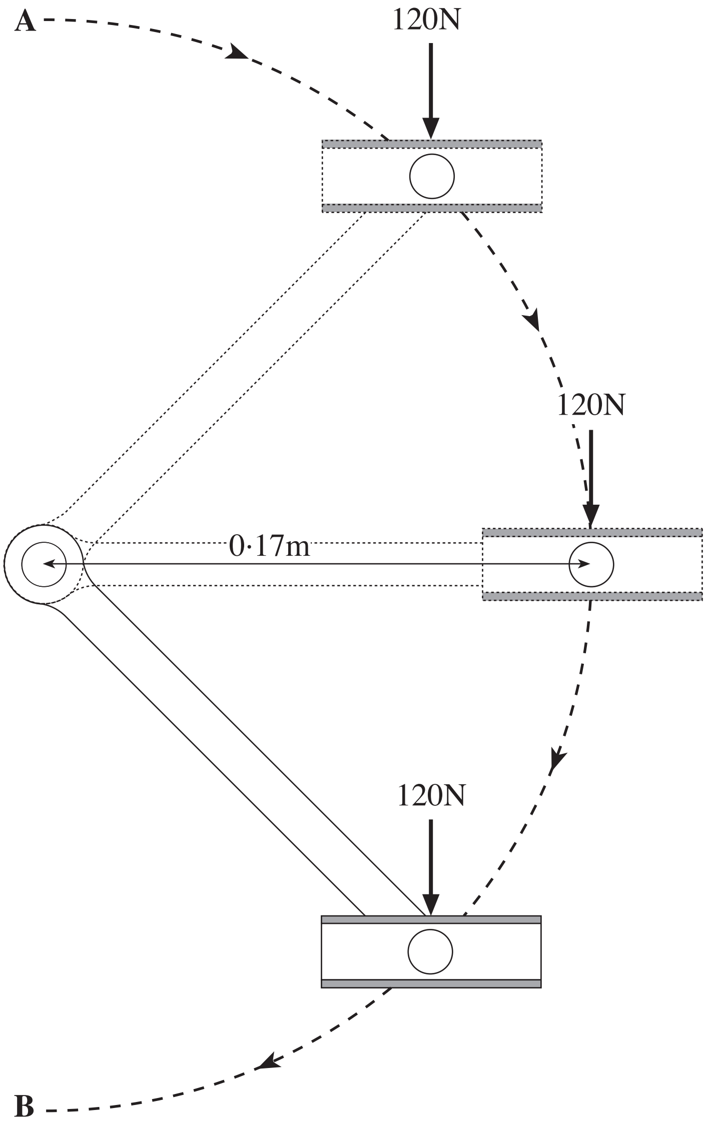
Examiner only

2. *(a)* Define the *work* done by a force. [2]

....

....

(b) Suppose a cyclist pressed vertically down, with a constant force of 120 N, on one pedal, as it moves from **A** to **B** in a semicircle of radius 0·17 m and arc length $\pi \times 0{\cdot}17$ m.



(i) Explain why the work done between **A** and **B** by the cyclist on the pedal would be considerably less than $120 \times (\pi \times 0{\cdot}17)$ J. [1]

....

....

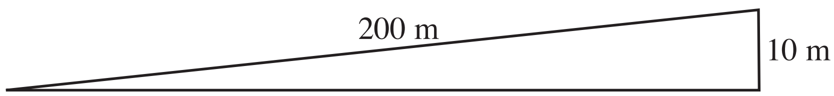
(ii) Calculate the actual work done. [1]

....

....

Examiner only

(c) While riding up the hill shown in the diagram the cyclist pedals at 72 revolutions per minute. For each revolution he now does a total of 175 J of work.



(i) Calculate the *power* he supplies. [2]

....

....

....

....

(ii) He is travelling up the hill at a steady road speed of $4{\cdot}0\,\mathrm{ms^{-1}}$. The mass of the cyclist is 75 kg, and the mass of his bicycle is 15 kg. Calculate the *efficiency* of the bicycle as a means of taking the cyclist and the bicycle up the hill. [4]

....

....

....

....

....

....

....

....

3. Up to about 12 km from the Earth's surface, the temperature and pressure of the atmosphere decrease with height. Typical values are

	temperature / K	pressure / 10^5 Pa
Ground level	290	1·00
12 km above surface	215	0·19

To simplify calculations, assume air to consist **only** of nitrogen (relative molecular mass 28).

(a) Calculate

(i) the volume occupied by 1·00 mole of air at ground level, using the *ideal gas equation of state*, [2]

....

....

....

(ii) the density of air at ground level, taking the relative molecular mass as 28, [2]

....

....

....

(iii) the ratio $\dfrac{\text{density of air at ground level}}{\text{density of air at 12 km above ground}}$. [2]

....

....

....

(b) (i) Calculate the r.m.s. speed of the molecules at ground level. [2]

....

....

....

....

Examiner only

(ii) “Molecules’ speeds are greater at ground level than at 12 km above ground.”

(I) Explain why this statement is misleading. [1]

....

(II) To make it a true statement about molecular motion, what phrase should be substituted for “molecules’ speeds”? [1]

....

Examiner only

4. *(a)* The *first law of thermodynamics* may be stated in the form

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

in which ΔU is the gain in a system's *internal energy*. Give the meanings of

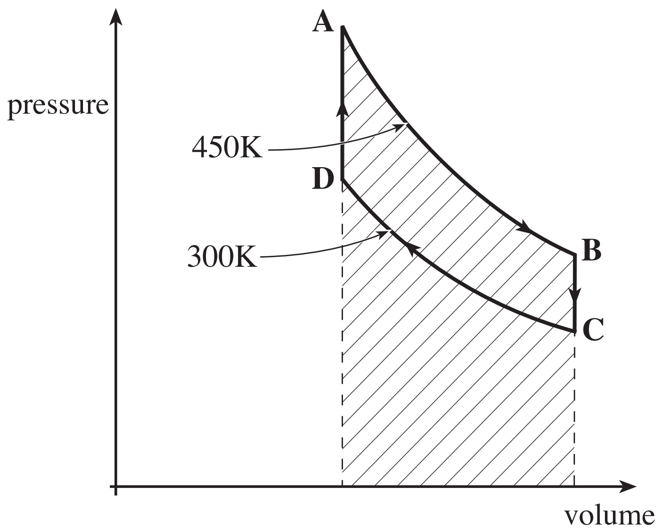
(i) Q .... [1]

(ii) W .... [1]

(b) A sample of gas is contained in a cylinder fitted with a leak-proof piston. It is taken through the cycle **ABCDA**.

The change **AB** occurs at a constant temperature of 450 K, and the change **CD** at a constant temperature of 300 K.

The gas may be treated as ideal, so that its internal energy, depends **only** on its temperature.



(i) By considering W and ΔU for **BC** and **DA**, compare the heat flows for these two changes. [You are **not** required to calculate these flows.] [3]

....

....

....

....

....

(ii) What thermodynamic quantities are represented by

(I) the total shaded area? [1]

....

(II) the area enclosed by **ABCD**? [1]

....

Examiner only

(iii) The shaded area is 416 J and the area enclosed by **ABCD** is 139 J. Explaining your reasoning, show that [3]

$$\frac{\text{Heat flow into gas during } \mathbf{AB}}{\text{Heat flow out of gas during } \mathbf{CD}} = \frac{\text{Temperature of gas during } \mathbf{AB}}{\text{Temperature of gas during } \mathbf{CD}}$$

....

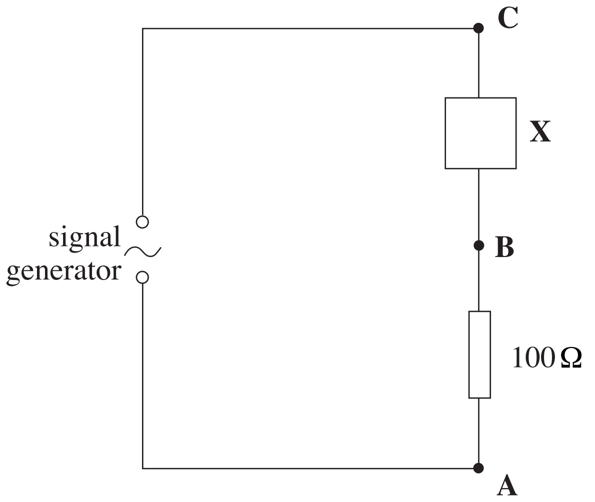
....

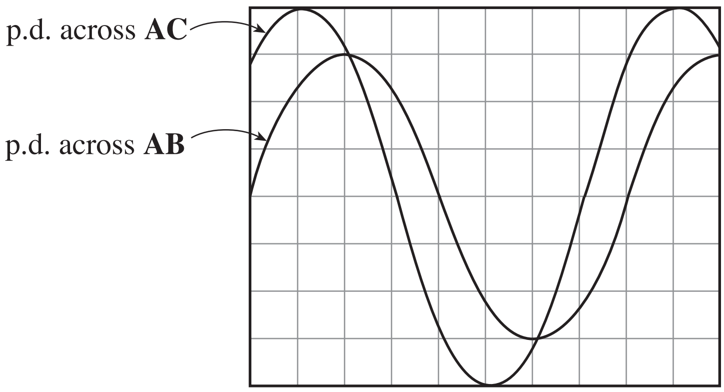
....

....

....

5. In a practical class, students are given the circuit shown on the left. **X** is known to be either a capacitor or an inductor (with negligible resistance). They have to investigate the voltages across **AB** and **AC**, and make deductions. One student uses a 'double-beam' *oscilloscope* to produce simultaneous voltage-time graphs, as shown.





(a) Explain how the student could have deduced, correctly, that **X** is an inductor. [2]

....

....

....

(b) Draw a labelled phasor (vector) diagram for the voltages across **AB**, **BC** and **AC**. [2]

(c) The y-gain of the oscilloscope is set to 2·0 V per division, and the time-base to 1·0 ms per division.

(i) Show that the frequency of the signal generator output is 125 Hz. [1]

....

....

....

(ii) Calculate

(I) the peak current, [Refer again to the circuit diagram.] [1]

....

....

....

(II) the inductance of the inductor, **X**. [4]

....

....

....

....

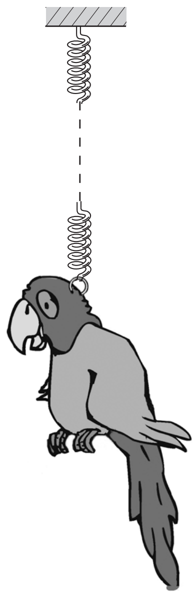
....

....

....

Examiner only

6. *(a)* A toy parrot, of mass 0·80 kg, hangs by a long light spring from the ceiling of a room. When the parrot is in equilibrium the length of spring is 2·23 m. The natural (unstretched) length of the spring is 0·80 m.



Calculate the spring constant, k (force per unit extension). [3]

....

....

....

(b) The parrot is pulled down and released, so that it is set oscillating up and down.

(i) Show clearly that the periodic time of the oscillations is 2·40 s. [2]

....

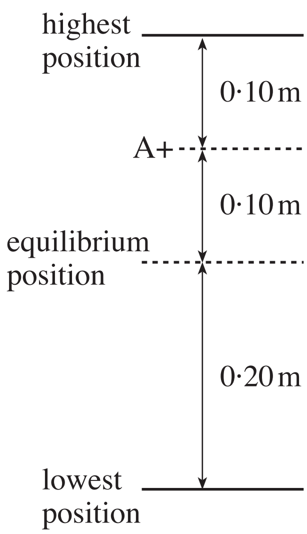
....

....

....

(ii) The amplitude of the oscillations is 0·20 m. At time $t = 0$ the parrot's beak is passing through the equilibrium position and moving upwards.

(I) Explain what is wrong with this argument: "The parrot's beak will reach its highest point at $t = 0·60$ s. Therefore at $t = 0·30$ s it will be at point **A**, midway between the equilibrium position and the highest position."



[1]

....

....

....

....

(II) Use the appropriate *simple harmonic motion* equation to calculate the *actual* displacement of the beak from the equilibrium position at time $t = 0·30$ s. [4]

....

....

....

....

....

(iii) (I) Calculate the maximum *speed* of the parrot when it is oscillating with an amplitude of 0·20 m. [2]

....

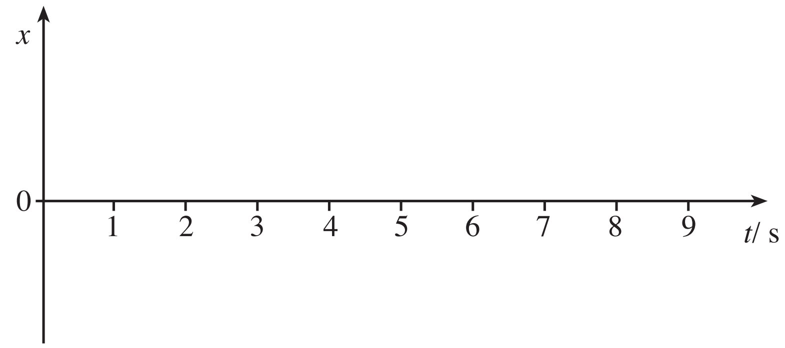
....

....

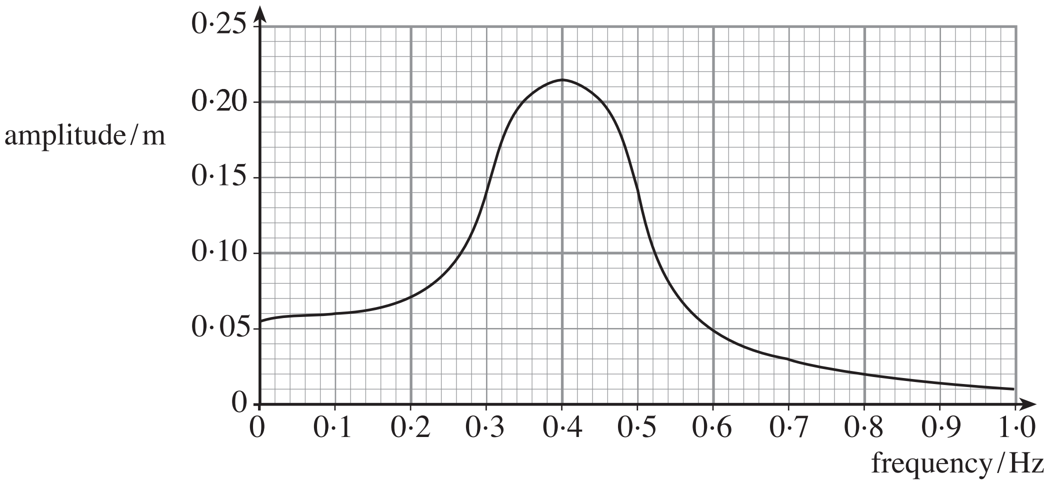
(II) State the position (or positions) of the parrot at which it has this speed. [1]

....

(c) If the wings are outstretched, the oscillations of the parrot, when displaced and released, are noticeably *damped*. Sketch a possible graph of displacement, *x,* against time, *t*, for these damped oscillations. [3]



(d) As part of a project, a student investigates *forced oscillations* of the parrot-spring system. She attaches the top of the spring to the vibrating pin of a vibration generator, and measures the amplitude of the parrot's oscillations when it has reached a steady value. She repeats the measurements for different frequencies of vibration of the pin. The graph of her results is given.



(i) Write down the frequency of resonance. .... [1]

(ii) Discuss whether this is the expected result. You will need to support your view with a calculation. [3]

....

....

....

Turn over.

Examiner only

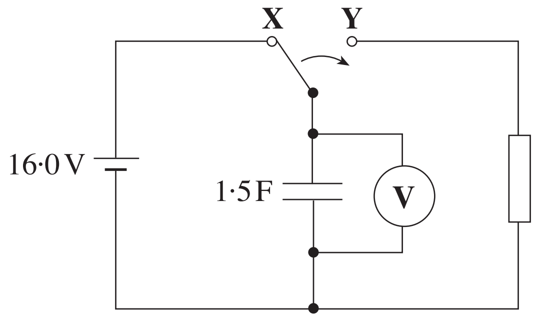
7. *(a)* Describe briefly the structure of a capacitor. [2]

....

....

(b) A 1·5 F capacitor is charged to a p.d. of 16·0 V as shown in the diagram. The switch is moved from **X** to **Y** at time $t = 0$, so that the capacitor starts to discharge through the resistor.

At time $t = 5{\cdot}0$ s the p.d. across the capacitor has fallen to 8·0 V.



(i) Use the equation $Q = Q_0 e^{-\frac{t}{CR}}$ to show clearly that the time constant is 7·2s. [3]

....

....

....

....

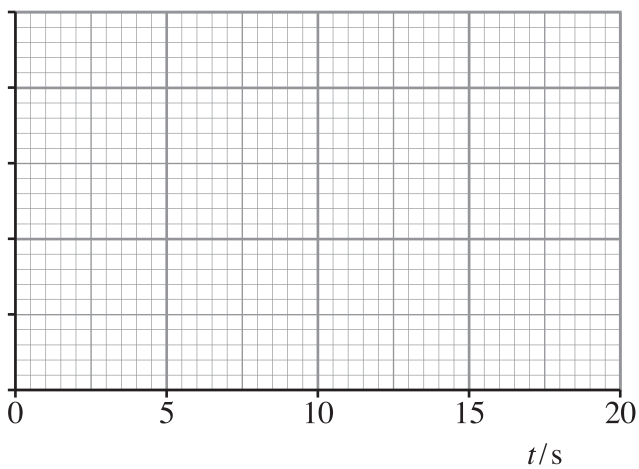
....

(ii) Hence find the resistance of the resistor. [1]

....

....

(iii) Use the grid to plot a graph of ***charge*** against time, from $t = 0$ to $t = 20$ s. Plot points at intervals of 5 s. You should not need to use the equation above. [5]



(iv) (I) Find from the graph the time taken for the capacitor plates to lose 63% of their charge. [1]

....

(II) Comment on this result. [1]

....

....

(c) The same circuit is now used in an attempt to measure the energy stored in the capacitor when it is charged to a p.d. of 16·0 V. This is done by discharging the capacitor and observing the effect of the electrical energy lost by the system, as follows...

The resistor is electrically insulated and immersed, together with a thermometer, in 0·080 kg of water in a styrofoam cup. The initial thermometer reading is 14·0°C. Using the switch, the capacitor is charged, and then discharged through the resistor, 10 times (that is 10 charge-discharge cycles). The final thermometer reading, after stirring, is 19·2°C.

(i) Calculate from these readings the mean internal energy gained by the water **each time** the capacitor is discharged. [s.h.c. of water = 4200 $\text{J kg}^{-1}\ \text{K}^{-1}$.] [3]

....

....

....

....

....

(ii) Calculate a theoretical value for the energy stored in the capacitor, and suggest two reasons why your answer is different from *(c)*(i). [4]

....

....

....

....

....

....

....

Examiner only

Examiner only

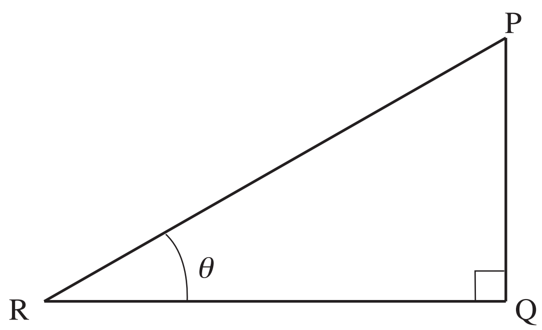
Mathematical Data and Relationships

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

Logarithms

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

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

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

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

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

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

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