GCE A level

1324/01

PHYSICS – PH4

Oscillations and Fields

A.M. MONDAY, 20 June 2016

1 hour 30 minutes plus your additional time allowance

Surname ______________________

Other Names ______________________

Centre Number ______________________

Candidate Number 2 ______________________

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	13	
2.	12	
3.	9	
4.	11	
5.	11	
6.	10	
7.	14	
Total	80	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a DATA BOOKLET.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen or your usual method.

Write your name, centre number and candidate number in the spaces provided on the front cover.

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.

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.

Answer ALL questions.

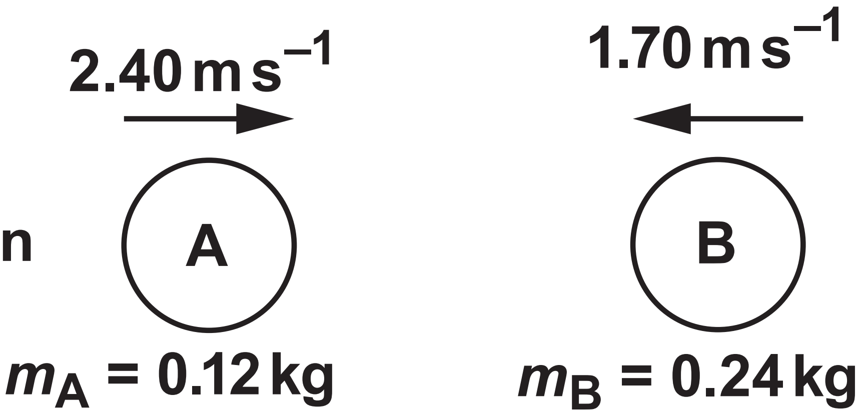
1(a) State:

(i) Newton's second law of motion; [2]

(ii) the principle of conservation of momentum. [2]

1(b) Two discs A and B of masses $m_A = 0.12\,kg$ and $m_B = 0.24\,kg$ on a frictionless horizontal surface slide directly towards each other and collide head-on. Before the collision the speed of disc A is $2.40\,m\,s^{-1}$ and the speed of disc B is $1.70\,m\,s^{-1}$.

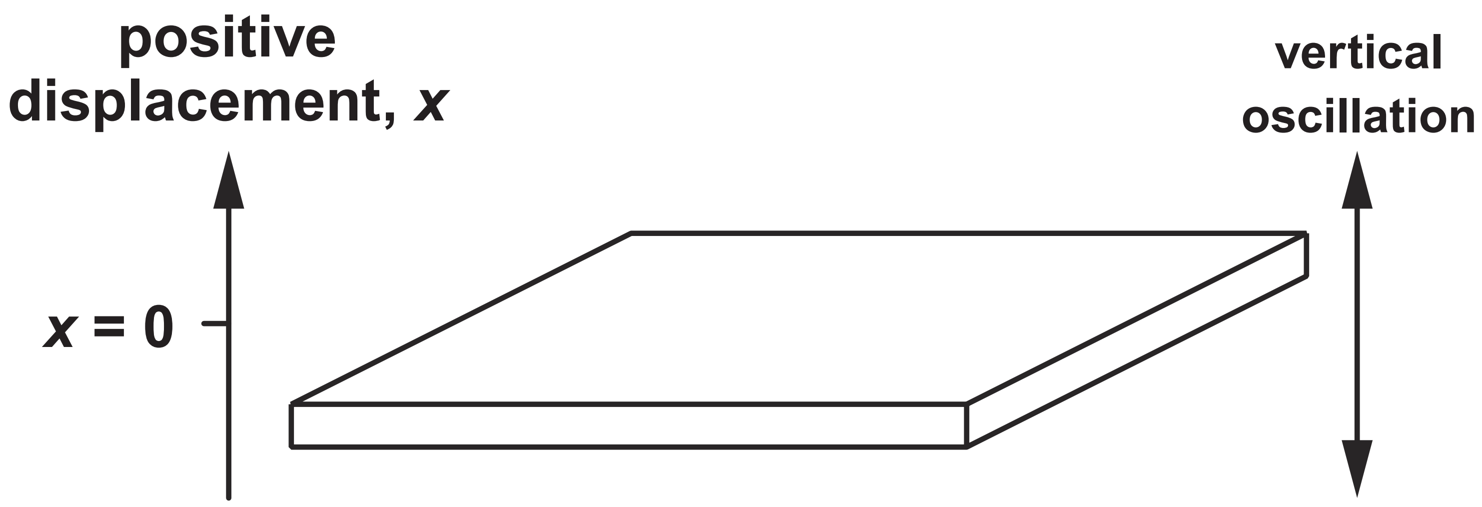
Before collision



1(b) (i) **After the collision the direction of disc A is reversed. Its speed is $2.24\,m\,s^{-1}$. Determine the speed of disc B after collision. [3]**

1(b) (ii) Calculate the total kinetic energy lost during the collision. [3]

1(b) (iii) **The collision duration is 0.30 s. Calculate the mean force on disc A AND state its direction. [3]**


positive
displacement, x
x = 0
vertical
oscillation

2. **A horizontal platform shown opposite oscillates vertically with Simple Harmonic Motion (shm).**

(a) **The amplitude, *A*, of oscillation is 0.030 m. The frequency, *f*, is 0.50 Hz. State what is meant by:**

(i) **amplitude, *A*;** **[1]**

(ii) **frequency, *f*.** **[1]**

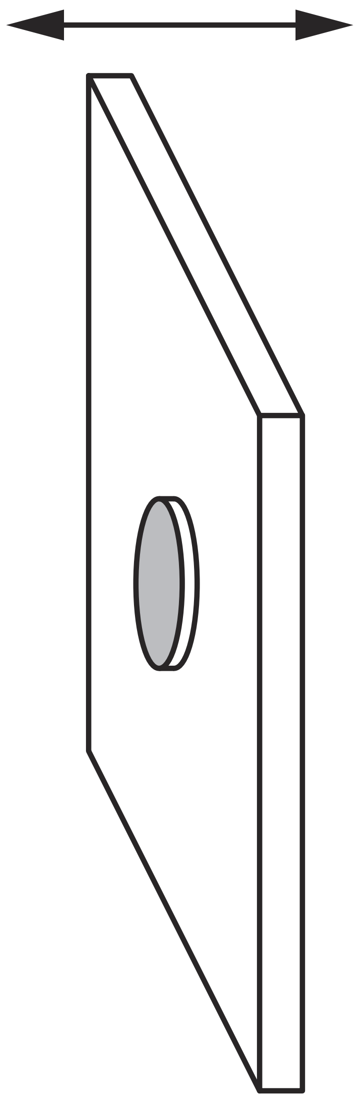
2(b) Taking the platform to be at the centre of oscillation ($x = 0$) when time, $t = 0$ calculate:

(i) the maximum velocity of the platform; [2]

(ii) the velocity of the platform at a displacement of $x = +\,0.020\,\text{m}$; [3]

2(b) (iii) the maximum acceleration of the platform.

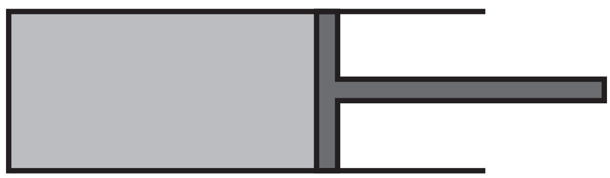
[2]



2(c) **In an experiment a small coin is placed on the platform as shown opposite.**

The platform now oscillates at a frequency of 1.00 Hz. The frequency of oscillation is then increased in equal steps of 0.50 Hz, keeping the amplitude constant at 0.030 m. Determine the LOWEST frequency at which the coin loses contact with the platform. Explain your reasoning clearly. [3]

3. **Helium gas is contained in a closed cylinder with a leak-proof moveable piston at one end. Initially the volume is 1.2×10^{-3} m^3, the pressure is 3.0×10^5 Pa and the temperature is 275 K. (Relative molecular mass of helium = 4.0.)**



(a) **(i)** **Calculate the mass of the gas in the cylinder.** **[2]**

3(a) (ii) Calculate the rms speed of the molecules.

[2]

3(b) The volume of the gas is increased to $1.8 \times 10^{-3}\ m^3$ at constant pressure.

Calculate:

(i) the work done by the gas; [2]

3(b) (ii) the heat supplied to the gas. [3]

4. A metal saucepan of mass 0.9 kg contains 1.6 kg of water at a temperature of 92 °C. The water and saucepan are in thermal equilibrium, and the saucepan-water system is ISOLATED FROM ITS SURROUNDINGS.

(a) Explain what is meant by thermal equilibrium. [2]

4(b) Vegetables of mass 1.1 kg and temperature 17 °C are placed in the water, and the system is left to reach thermal equilibrium once again. Describe in terms of heat flows how thermal equilibrium is reached between the saucepan, water and vegetables. (CALCULATIONS ARE NOT REQUIRED.) [3]

4(c) Calculate the final temperature of the saucepan, water and vegetables given the specific heat capacities below. [4]

	Specific heat capacity / $J\,kg^{-1}\,°C^{-1}$
Water	4 200
Saucepan	500
Vegetables	3 500

4(d) **Explain what will happen to the final temperature if the system is not completely isolated from the surroundings. [2]**

5. The mass of the Moon is 7.34×10^{22} kg and its mean radius is 1.74×10^{6} m.

(a) Calculate the gravitational field strength at the surface of the Moon. [2]

(b) **A mass, m, is fired vertically from the surface of the Moon at a speed of $400\,\mathrm{m\,s^{-1}}$.**
Show that the greatest height above the surface reached by the mass is 51 km. (Hint: use the conservation of energy and $V_g = \dfrac{-GM}{r}$) **[4]**

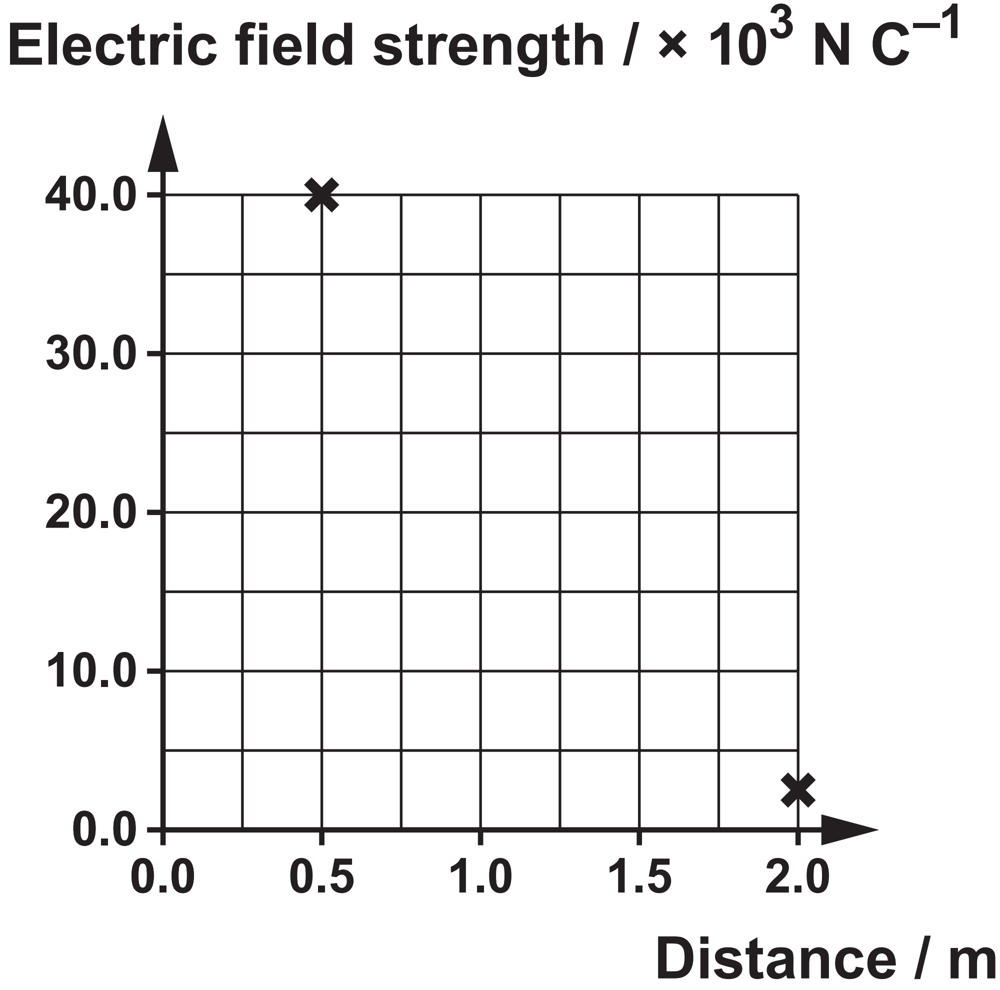
5(c) In many applications an approximate value for the height reached by an object is obtained by neglecting the variation in the gravitational field strength with height. Determine the value for the height reached by the object in part (b) assuming a gravitational field strength equal to that at the surface of the Moon. [2]

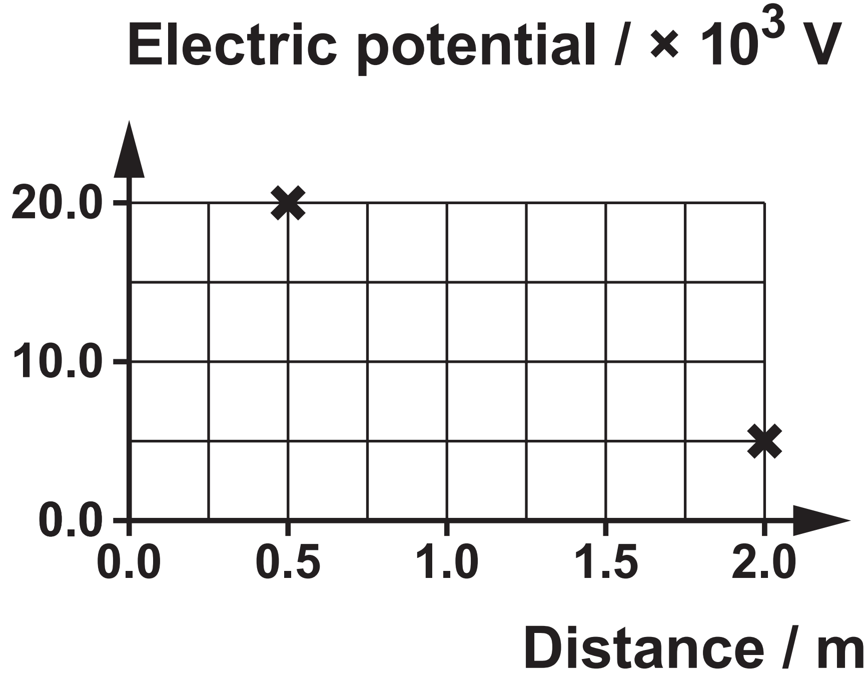
5(d) Hence determine the difference in the heights obtained in parts (b) and (c) as a percentage of the height given in part (b). [2]

5(e) **Discuss whether the use of the approximation in part (c) is appropriate in this case.** **[1]**

6. A small sphere has a charge $q = +1.11 \times 10^{-6}$ C.

(a) How many electrons have been removed from the sphere? [2]


Electric field strength / × 10^3 N C^–1
40.0
30.0
20.0
10.0
0.0
0.0
0.5
1.0
1.5
2.0
Distance / m


Electric potential / × 10^3 V
20.0
10.0
0.0
0.0
0.5
1.0
1.5
2.0
Distance / m

6(b) **On the grids opposite sketch curves between distances 0.5 m and 2.0 m from the centre of the sphere for:**

(i) **the electric field strength (first grid);**

(ii) **the electric potential (second grid).**

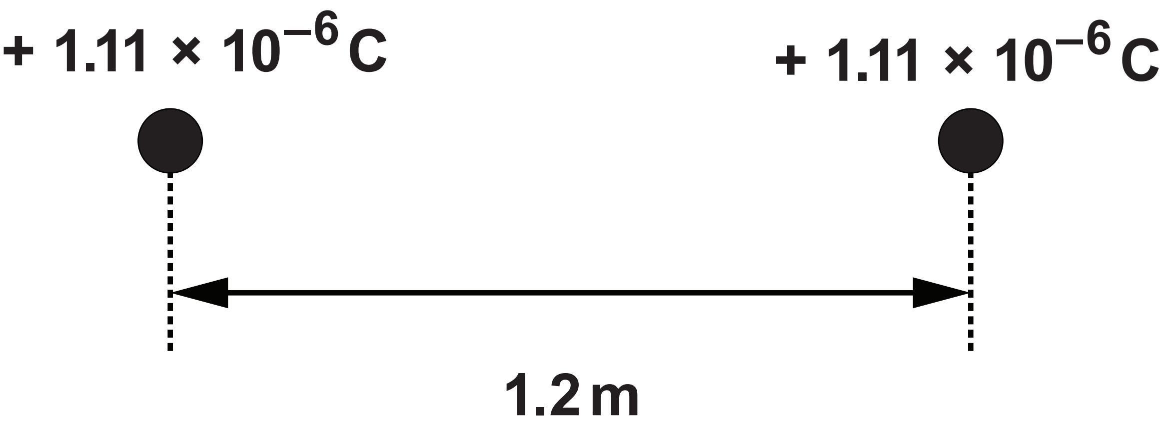
The points at 0.5 m and 2.0 m are already shown. **[3]**

You may wish to use the approximation:

$$\frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9\ \mathrm{F^{-1}\,m}.$$

Space for calculations if needed:

6(c) (i) A second identical sphere also has a charge of $+1.11 \times 10^{-6}$ C. It is brought from a distant point to a distance 1.2 m from the first sphere. Determine the work required to do this. [2]



6(c) (ii) Determine the magnitude of the electric field strength at the point between the two spheres that is 0.7 m from the left-hand side sphere. Show the direction of the field at this point. [3]

7. **A star and its companion planet are in mutual orbit about a common centre of mass. The observed spectrum of the star reveals an orbital speed of $56.0\,\mathrm{m\,s^{-1}}$ and an orbital period of 4.23 day.**

(a) **Describe how the spectrum was used to determine the orbital speed AND orbital period.**

[4]

7(b) Calculate the distance between the star and the planet given that the mass of the star is 2.21×10^{30} kg. Assume that the mass of the planet is very much smaller than the mass of the star. [5]

7(c) **Calculate the distance of the star from the centre of mass of the system. [2]**

7(d) Use your answers in parts (b) and (c) to determine the mass of the planet. [3]

END OF PAPER

GCE AS/A level

1321-1325/01-A

PHYSICS – DATA BOOKLET

A clean copy of this booklet should be issued to candidates for their use during each GCE Physics examination.

Centres are asked to issue this booklet to candidates at the start of the GCE Physics course to enable them to become familiar with its contents and layout.

VALUES AND CONVERSIONS

Avogadro constant	$N_A = 6{\cdot}02 \times 10^{23}\ \mathrm{mol^{-1}}$
Fundamental electronic charge	$e = 1{\cdot}60 \times 10^{-19}\ \mathrm{C}$
Mass of an electron	$m_e = 9{\cdot}11 \times 10^{-31}\ \mathrm{kg}$
Molar gas constant	$R = 8{\cdot}31\ \mathrm{J\ mol^{-1}\ K^{-1}}$
Acceleration due to gravity at sea level	$g = 9{\cdot}81\ \mathrm{m\ s^{-2}}$
Gravitational field strength at sea level	$g = 9{\cdot}81\ \mathrm{N\ kg^{-1}}$
Universal constant of gravitation	$G = 6{\cdot}67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$
Planck constant	$h = 6{\cdot}63 \times 10^{-34}\ \mathrm{J\ s}$
Boltzmann constant	$k = 1{\cdot}38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$
Speed of light *in vacuo*	$c = 3{\cdot}00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
Permittivity of free space	$\varepsilon_o = 8{\cdot}85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$
Stefan constant	$\sigma = 5{\cdot}67 \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{-4}}$
Wien constant	$W = 2{\cdot}90 \times 10^{-3}\ \mathrm{m\ K}$

$T/K = \theta/°C + 273{\cdot}15$

$1\ u = 1{\cdot}66 \times 10^{-27}\ \mathrm{kg}$

AS

$\rho = \frac{m}{V}$

$v = u + at$

$x = \frac{1}{2}(u + v)t$

$x = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2ax$

$\sum F = ma$

$W = Fx\cos\theta$

$\Delta E = mg\Delta h$

$E = \frac{1}{2}kx^2$

$E = \frac{1}{2}mv^2$

$Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$\text{efficiency} = \frac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$

$P = \frac{W}{t} = \frac{\Delta E}{t}$

$I = \frac{\Delta Q}{\Delta t}$

$I = nAve$

$R = \frac{\rho l}{A}$

$R = \frac{V}{I}$

$P = IV$

$V = E - Ir$

$\frac{V}{V_{total}} \left(\text{or } \frac{V_{OUT}}{V_{IN}} \right) = \frac{R}{R_{total}}$

$c = f\lambda$

$T = \frac{1}{f}$

$\lambda = \frac{ay}{D}$

$d\sin\theta = n\lambda$

$n_1 v_1 = n_2 v_2$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$E_{k\,max} = hf - \phi$

$\lambda_{max} = WT^{-1}$

$P = A\sigma T^4$

PARTICLE PHYSICS

	Leptons			Quarks	
particle (symbol)	electron (e^-)	electron neutrino (ν_e)		up (u)	down (d)
charge (e)	– 1	0		$+\frac{2}{3}$	$-\frac{1}{3}$
lepton number	1	1		0	0

$$\omega = \frac{\theta}{t}$$

$$v = \omega r$$

$$a = \omega^2 r$$

$$a = -\omega^2 x$$

$$x = A\sin(\omega t + \varepsilon)$$

$$v = A\omega\cos(\omega t + \varepsilon)$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$p = mv$$

$$Q = mc\Delta\theta$$

$$p = \frac{h}{\lambda}$$

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$$M\,/\,\text{kg} = \frac{M_r}{1000}$$

$$pV = nRT$$

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

$$U = \frac{3}{2}nRT$$

$$k = \frac{R}{N_A}$$

$$W = p\Delta V$$

$$\Delta U = Q - W$$

$$C = \frac{Q}{V}$$

$$C = \frac{\varepsilon_o A}{d}$$

$$U = \frac{1}{2}QV$$

$$Q = Q_0 e^{-t/RC}$$

$$F = BIl\sin\theta \text{ and } F = Bqv\sin\theta$$

$$B = \frac{\mu_o I}{2\pi a}$$

$$B = \mu_o nI$$

$$\phi = AB\cos\theta$$

$$V_{r.m.s.} = \frac{V_o}{\sqrt{2}}$$

$$A = \lambda N$$

$$N = N_o e^{-\lambda t} \text{ or } N = \frac{N_o}{2^x}$$

$$A = A_o e^{-\lambda t} \text{ or } A = \frac{A_o}{2^x}$$

$$\lambda = \frac{\log_e 2}{T_{1/2}}$$

$$E = mc^2$$

FIELDS

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2} \qquad E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \qquad V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} \qquad W = q\Delta V_E\,,$$

$$F = G\frac{M_1M_2}{r^2} \qquad g = \frac{GM}{r^2} \qquad V_g = \frac{-GM}{r} \qquad W = m\Delta V_g$$

ORBITING BODIES

Centre of mass: $r_1 = \frac{M_2}{M_1 + M_2}\,d$;

Period of Mutual Orbit: $T = 2\pi\sqrt{\frac{d^3}{G(M_1 + M_2)}}$

OPTIONS

A: $\frac{V_1}{N_1} = \frac{V_2}{N_2}$; $E = -L\frac{\Delta I}{\Delta t}$; $X_L = \omega L$; $X_C = \frac{1}{\omega C}$; $Z = \sqrt{X^2 + R^2}$; $Q = \frac{\omega_0 L}{R}$

B: ELECTROMAGNETISM AND SPACE-TIME

B: $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$; $\Delta t = \frac{\Delta \square}{\sqrt{1 - \frac{v^2}{c^2}}}$

B: THE NEWTONIAN REVOLUTION

$$\frac{1}{T_P} = \frac{1}{T_E} - \frac{1}{t_{opp}}$$

$$\frac{1}{T_P} = \frac{1}{T_E} + \frac{1}{t_{inf\ conj}}$$

$$r_P = a(1 - \varepsilon)$$

$$r_A = a(1 + \varepsilon)$$

$$r_P v_P = r_A v_A$$

C: $\varepsilon = \frac{\Delta l}{l}$; $Y = \frac{\sigma}{\varepsilon}$; $\sigma = \frac{F}{A}$; $U = \frac{1}{2}\sigma\varepsilon V$

D: $I = I_0 \exp(-\mu x)$; $Z = c\rho$

E: $\frac{\Delta Q}{\Delta t} = -AK\frac{\Delta \theta}{\Delta x}$ $U = \frac{K}{\Delta x}$ $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$ Carnot efficiency = $\frac{(Q_1 - Q_2)}{Q_1}$

MATHEMATICAL INFORMATION

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
10^{-2}	centi	c

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z

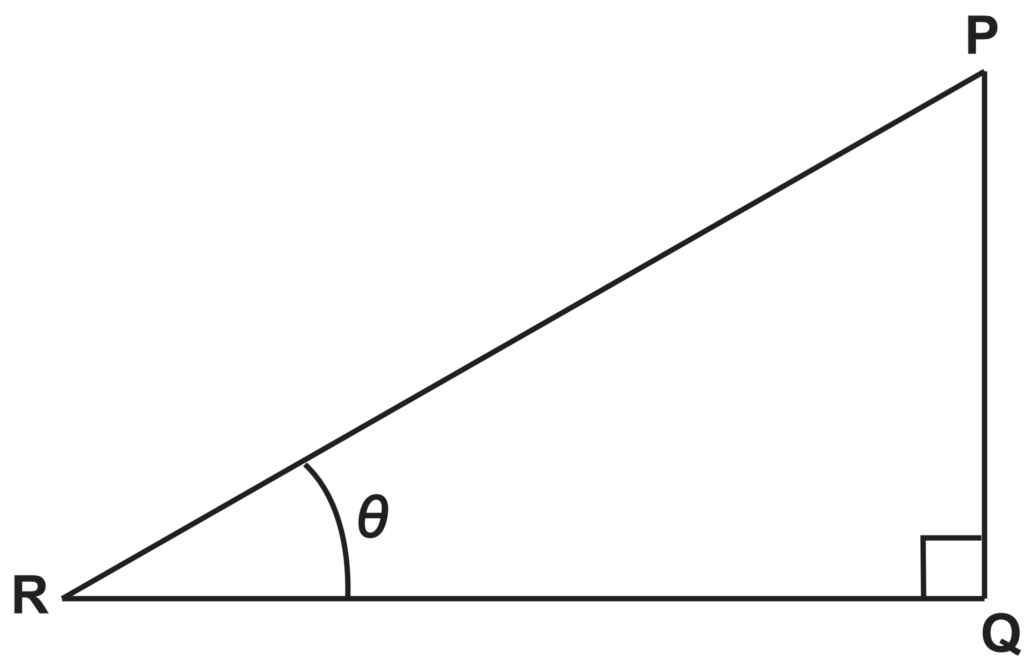
AREAS AND VOLUMES

Area of a circle = $\pi r^2 = \frac{\pi d^2}{4}$

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

TRIGONOMETRY



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

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

LOGARITHMS (A2 ONLY)

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

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

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

$\log x^n = n \log x$

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

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