GCE AS/A level

1321/01

PHYSICS

PH1: MOTION ENERGY AND CHARGE

P.M. THURSDAY, 12 January 2012

1½ hours

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.

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.

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.
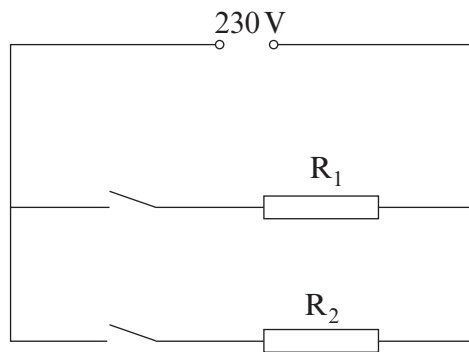
1. *(a)* (i) State Ohm's law. [2]

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(ii) What can be said about the resistance of a conductor that obeys Ohm's law? [1]

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(b) The heating circuit of a hairdryer consists of two heating elements R_1 and R_2 connected in parallel as shown. The elements are made from wire of the same material of resistivity $95 \times 10^{-8} \Omega$m and diameter 1.4×10^{-4}m.

(i) The length of wire used to make R_1 is 3.2m. Show that the resistance of R_1 is approximately 200Ω. [3]

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(ii) Calculate the power output from the heating circuit with only R_1 switched on. [1]

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(iii) With both elements switched on the **total resistance** is only a third of the resistance of R_1 on its own. Calculate the resistance of R_2. [3]

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(iv) Explain which element, R_1 **or** R_2, would provide the greater power output from the heating circuit. [2]

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(v) Calculate the total current with both elements switched on. [1]

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Turn over.

2. *(a)* (i) Draw a labelled diagram of the apparatus you would use to determine the relationship between the resistance and temperature of a metal wire. [3]

(ii) Sketch, on the axis below, a graph of the results you would expect from the experiment. [2]

Resistance / Ω

0   Temperature / °C
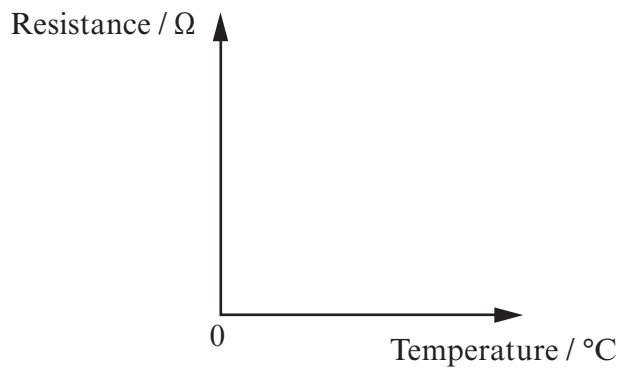
(b) (i) Explain in terms of particles how electrical resistance arises in metal conductors. [3]

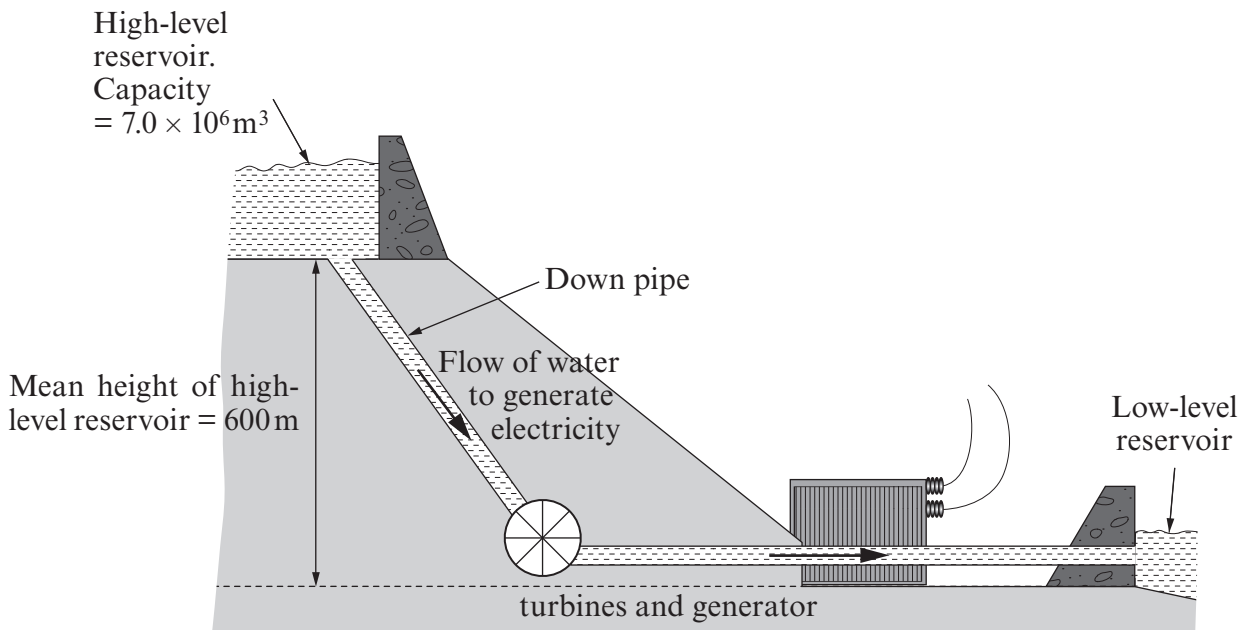...

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(ii) Hence suggest an explanation for your results to the experiment in part *(a).* [2]

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3. Two boys stand each end of a trolley as shown. The trolley is initially at rest and can move without resistance on a horizontal surface.

Gareth   Nigel

(a) (i) Define acceleration. [1]

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(ii) Gareth takes 0.80 s to throw a ball from rest to a speed of 6.0 m s⁻¹. Calculate the acceleration of the ball. [2]

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(b) Describe and explain in terms of forces, the motion of **the trolley** from the instant the ball is released by Gareth until after it is caught by Nigel. [4]

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Turn over.

4. The hydroelectric power station at Dinorwig in North Wales is the largest of its kind in Europe. A simplified diagram showing the main features of the plant is shown.

High-level reservoir. Capacity = $7.0 \times 10^6 \, m^3$

Down pipe

Flow of water to generate electricity

Low-level reservoir

Mean height of high-level reservoir = 600 m

turbines and generator

(a) Use the information in the diagram to show that the gravitational potential energy stored in the high-level reservoir is approximately 4×10^{13} J.
[Density of water = $1000 \, kg \, m^{-3}$]. [2]

(b) The power plant has six 300 MW generators. Calculate the longest time for which the stored energy could provide power at maximum output given that the generation process is 90% efficient [i.e. 10% of the gravitational potential energy stored in the high level reservoir is wasted]. [3]

(c) (i) Calculate the mean rate of flow of water (in kg s^{-1}) through the turbines of the power station when it is operating at full power. [1]

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(ii) After passing through the turbines the water enters the lower lake at a speed of $20\,\mathrm{m\,s^{-1}}$. Use your answer to *(c)*(i) to calculate the kinetic energy per second [power] of this water. [1]

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(iii) Calculate the **wasted energy per second** (power lost) during the generation process. [2]

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(iv) Hence show that your answer to *(c)*(ii) represents between 30% and 40% of the wasted power. [1]

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(v) Where else would energy be wasted during the generating process? [1]

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Turn over.

5. Two insulated metal spheres, **A** and **B** are placed in contact with each other. When a negatively charged rod is brought near, the charges become distributed on the metal spheres as shown.
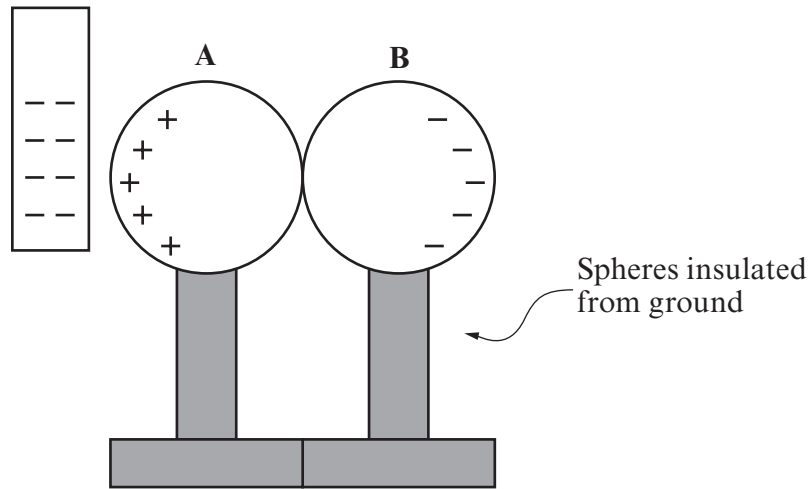
(a) (i) State the particle which carries the negative charge. [1]

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(ii) Explain why the charges become distributed as shown. [3]

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(iii) The following procedure is carried out:

- A thin insulating piece of cardboard is placed in between the spheres.
- The negatively charged rod is then removed.

Sketch the distribution of charges now on both spheres. [2]

Cardboard
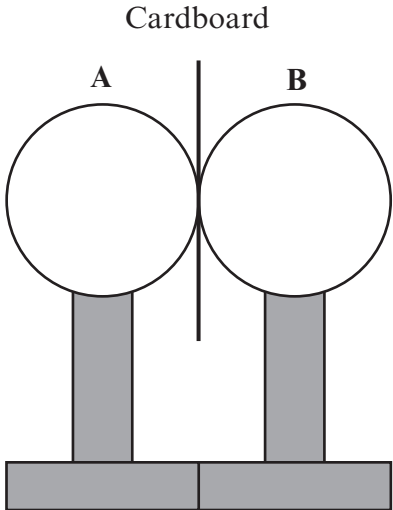
(b) (i) In another process, a negatively charged rod is rubbed against one of the spheres and in doing so places approximately 300×10^9 free negative charges onto the sphere. Calculate the charge on the sphere. [1]

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(ii) The sphere is discharged in a time of 20 ps by connecting a wire from it to the ground. Calculate the mean current. [2]

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Turn over.

6. *(a)* Define:

(i) mean speed; [1]

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(ii) mean velocity. [1]

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(b) Robot vacuum cleaners can clean carpets automatically. When sensors on the cleaner detect the presence of nearby objects the cleaner changes direction, thus avoiding collision. The diagram shows the path of such a cleaner inside a living room.
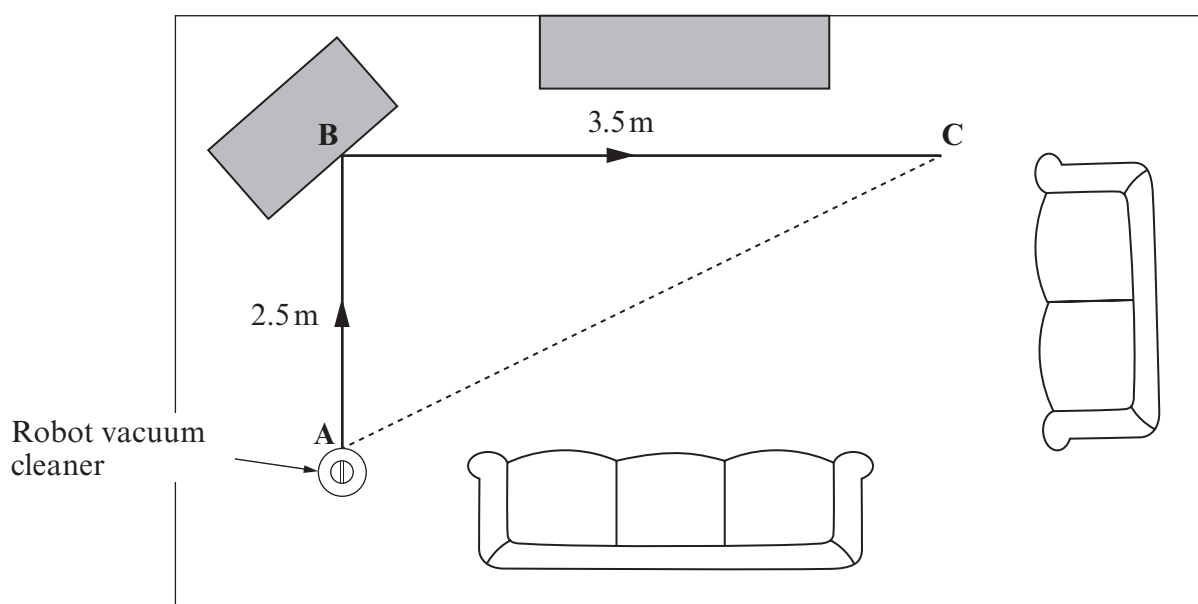
The vacuum cleaner follows the path AB and then BC. The whole journey ABC takes 25 s. Calculate

(i) the cleaner's average speed, [1]

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(ii) the magnitude of the cleaner's average velocity. [2]

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(c) The manufacturer of a robot vacuum cleaner provides the following technical information:

Battery type: 15.0 V Ni-MH (Nickel-Metal Hydride) re-chargeable.
Battery capacity: 2.5 Amp-hours (this means the battery is able to supply 2.5 A for 1 hour, or 1.25 A for 2 hours and so on).
Power when in use: 30 watts.

(i) Calculate the total energy stored in the battery. [3]

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(ii) Hence calculate the time, in hours, that the battery can be used before recharging. [2]

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(d) (i) A resistive force, *F*, acts on the cleaner in the opposite direction to the direction of motion of the cleaner. Starting from the definition of *power*, show that for the cleaner to move at a steady speed *v*, the mechanical power needed is *Fv*. [2]

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(ii) Calculate *F*, given that the mechanical power is 9 W. [2]

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Turn over.

7. The following graph gives data taken from the 'Highway Code' for 'Thinking' and 'Braking' distances for a car when stopping. Thinking distance is the distance a car travels between the driver seeing an incident and beginning to apply the brakes. Braking distance is the distance a car travels while it is decelerating.
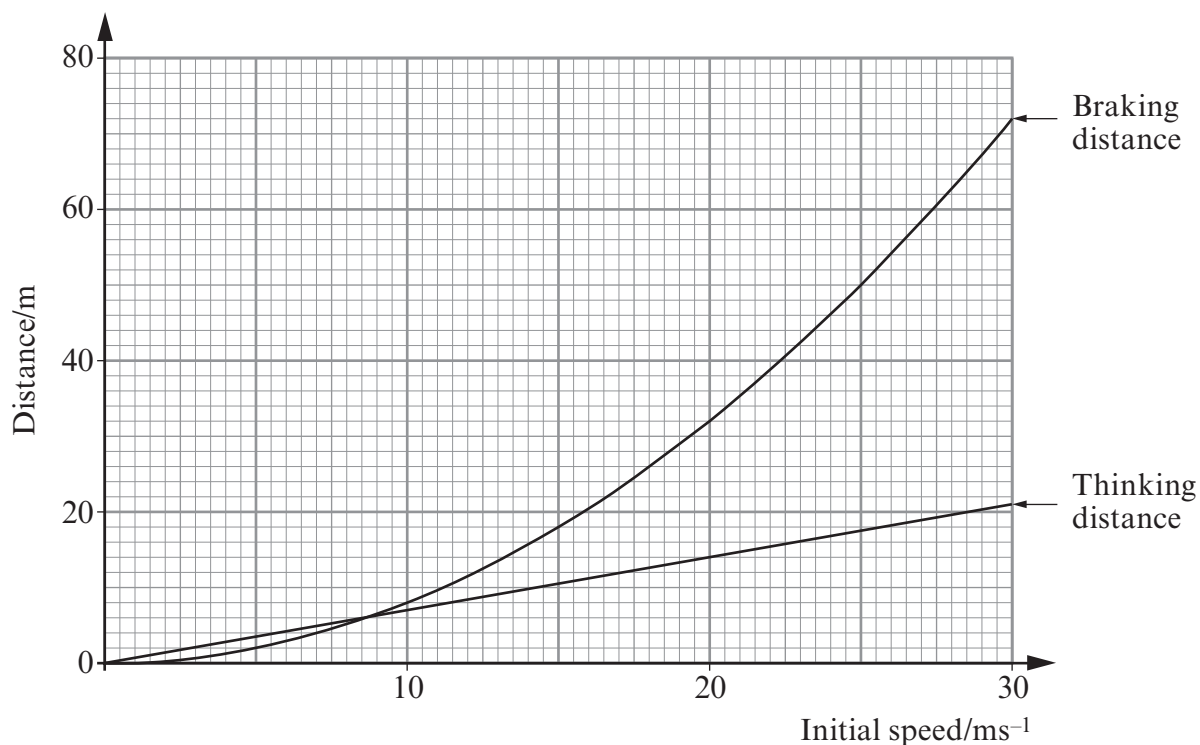
(a) The graph of braking distance against speed is curved. Use information from the graph to test whether braking distance is proportional to (initial speed)^2. [3]

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(b) (i) Calculate the mean deceleration of a car as it slows down from $15\,\mathrm{m\,s^{-1}}$ to rest. [3]

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(ii)   Hence calculate the mean braking force acting on the car given that it has a mass
         of 800 kg.   [1]

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(c)   Suggest why the graph of thinking distance against speed is a straight line.   [2]

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(d)   (i)   What is the **total** stopping distance for a car initially travelling at $30 \, m \, s^{-1}$?   [1]

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         (ii)   Ineffective brakes would increase the total stopping distance. Explain, in terms of
                 thinking distance and braking distance why this would be the case.   [2]

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(e)   'Average speed areas' are now found on many motorways. One such stretch of motorway
         has a speed limit of 50 km/hour. The average speed is monitored between two cameras
         placed 10 km apart. The driver of a car notes that he has travelled 6.0 km from the first
         camera at a speed of 80 km/hour. Determine the speed with which he has to travel the
         remaining 4.0 km in order that his average speed for the whole 10 km is 50 km/hour.   [4]

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THERE ARE NO MORE QUESTIONS IN THIS EXAMINATION

GCE PHYSICS
TAG FFISEG
Advanced Level / Safon Uwch

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

T/K = θ/°C + 273·15

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

AS

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

$$v = u + at$$

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

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

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

$$\Sigma F = ma$$

$$W = Fx\cos\theta$$

$$\Delta E = mg\Delta h$$

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

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

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

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

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

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

$$I = nAve$$

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

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

$$P = IV$$

$$V = E - Ir$$

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

$$c = f\lambda$$

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

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

$$d\sin\theta = n\lambda$$

$$n_1 v_1 = n_2 v_2$$

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

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

$$\lambda_{\text{max}} = W\,T^{-1}$$

$$P = A\sigma T^4$$

Particle Physics

particle (symbol)	Leptons			Quarks	
	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

A2

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

$$v = \omega r$$

$$a = \omega^2 r$$

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

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

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

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

$$p = mv$$

$$Q = mc\Delta\theta$$

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

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

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

$$pV = nRT$$

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

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

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

$$W = p\Delta V$$

$$\Delta U = Q - W$$

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

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

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

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

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

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

$$B = \mu_o nI$$

$$\Phi = AB\cos\theta$$

$$V_{\text{r.m.s.}} = \frac{V_0}{\sqrt{2}}$$

$$A = \lambda N$$

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

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

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

$$E = mc^2$$

Fields

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

$$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

$$W = q\Delta V_E$$

$$F = G\frac{M_1 M_2}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$V_g = \frac{-GM}{r}$$

$$W = m\Delta V_g$$

Orbiting Bodies

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

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

Options

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

B: $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$; $\quad \Delta t = \dfrac{\Delta\tau}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

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

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

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

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

Area of a triangle $= \dfrac{1}{2}$ base $\times$ height

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

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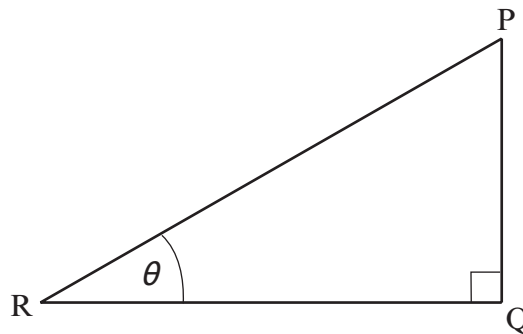
$$\sin\theta = \frac{PQ}{PR}, \quad \cos\theta = \frac{QR}{PR}, \quad \tan\theta = \frac{PQ}{QR}, \quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

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

Logarithms (A2 only)
[Unless other wise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

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

$$\log x^n = n \log x \qquad\qquad \log_e e^{kx} = \ln e^{kx} = kx$$

$$\log_e 2 = \ln 2 = 0.693$$