General Certificate of Education
January 2008
Advanced Level Examination

PHYSICS (SPECIFICATION A) **PA04**
Unit 4 Waves, Fields and Nuclear Energy

Section A

Monday 21 January 2008 9.00 am to 10.30 am

For this paper you must have:
- an objective test answer sheet
- a black ball-point pen
- a calculator
- a question paper/answer book for Section B (enclosed).

Time allowed: The total time for Section A and Section B of this paper is 1 hour 30 minutes

Instructions
- Use a black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book **not** on the answer sheet.

Information
- The maximum mark for this section is 30.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- The question paper/answer book for Section B is enclosed within this question paper.

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

Data Sheet

Fundamental constants and values

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^8	$m\ s^{-1}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$H\ m^{-1}$
permittivity of free space	ε_0	8.85×10^{-12}	$F\ m^{-1}$
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$N\ m^2\ kg^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$J\ K^{-1}\ mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	$J\ K^{-1}$
the Stefan constant	σ	5.67×10^{-8}	$W\ m^{-2}\ K^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4}u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	$C\ kg^{-1}$
proton rest mass (equivalent to 1.00728u)	m_p	1.67×10^{-27}	kg
proton charge/mass ratio	e/m_p	9.58×10^7	$C\ kg^{-1}$
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	$N\ kg^{-1}$
acceleration due to gravity	g	9.81	$m\ s^{-2}$
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

Fundamental particles

Class	Name	Symbol	Rest energy /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	pion	$\pi^\pm$	139.576
		π^0	134.972
	kaon	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}$	$+\frac{1}{3}$	-1

Geometrical equations

arc length $= r\theta$

circumference of circle $= 2\pi r$

area of circle $= \pi r^2$

area of cylinder $= 2\pi rh$

volume of cylinder $= \pi r^2 h$

area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$

Mechanics and Applied Physics

$v = u + at$

$s = \left(\frac{u+v}{2}\right) t$

$s = ut + \frac{at^2}{2}$

$v^2 = u^2 + 2as$

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

$efficiency = \frac{power\ output}{power\ input}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

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

$\Delta W = p\Delta V$

pV^γ = constant

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)

friction power = indicated power – brake power

$efficiency = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

maximum possible efficiency $= \frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

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

$g = -\frac{\Delta V}{\Delta x}$

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

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

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

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

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

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

magnitude of induced emf $= N \frac{\Delta \Phi}{\Delta t}$

$I_{rms} = \frac{I_0}{\sqrt{2}}$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

Mechanical and Thermal Properties

the Young modulus $= \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F}{A}\frac{l}{e}$

energy stored $= \frac{1}{2} Fe$

$\Delta Q = mc\,\Delta\theta$

$\Delta Q = ml$

$pV = \frac{1}{3} Nm\overline{c^2}$

$\frac{1}{2} m\overline{c^2} = \frac{3}{2} kT = \frac{3RT}{2N_A}$

Nuclear Physics and Turning Points in Physics

force $= \frac{eV_p}{d}$

force $= Bev$

radius of curvature $= \frac{mv}{Be}$

$\frac{eV}{d} = mg$

work done $= eV$

$F = 6\pi\eta rv$

$I = k\frac{I_0}{x^2}$

$\frac{\Delta N}{\Delta t} = -\lambda N$

$\lambda = \frac{h}{\sqrt{2meV}}$

$N = N_0 e^{-\lambda t}$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

$R = r_0 A^{\frac{1}{3}}$

$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

$l = l_0\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$

$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

Astrophysics and Medical Physics

Body	*Mass*/kg	*Mean radius*/m
Sun	2.00×10^{30}	7.00×10^{8}
Earth	6.00×10^{24}	6.40×10^{6}

1 astronomical unit $= 1.50 \times 10^{11}$ m

1 parsec = 206265 AU $= 3.08 \times 10^{16}$ m = 3.26 ly

1 light year $= 9.45 \times 10^{15}$ m

Hubble constant (H) = 65 km s^{-1} Mpc^{-1}

$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$

$M = \frac{f_o}{f_e}$

$m - M = 5 \log \frac{d}{10}$

$\lambda_{max} T$ = constant = 0.0029 m K

$v = Hd$

$P = \sigma AT^4$

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

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

$R_s \approx \frac{2GM}{c^2}$

Medical Physics

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

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and $m = \frac{v}{u}$

intensity level $= 10 \log \frac{I}{I_0}$

$I = I_0 e^{-\mu x}$

$\mu_m = \frac{\mu}{\rho}$

Electronics

Resistors

Preferred values for resistors (E24)
Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms
and multiples that are ten times greater

$Z = \frac{V_{rms}}{I_{rms}}$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

$C_T = C_1 + C_2 + C_3 + \cdots$

$X_C = \frac{1}{2\pi fC}$

Alternating Currents

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

Operational amplifier

$G = \frac{V_{out}}{V_{in}}$ voltage gain

$G = -\frac{R_f}{R_1}$ inverting

$G = 1 + \frac{R_f}{R_1}$ non-inverting

$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$ summing

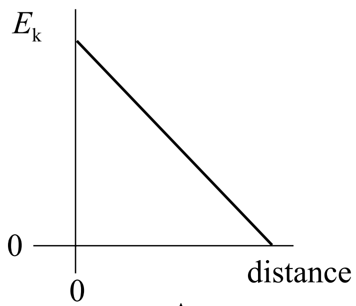
SECTION A

In this section each item consists of a question or an incomplete statement followed by four suggested answers or completions. You are to select the most appropriate answer in each case. You are advised to spend about **30 minutes** on this section.

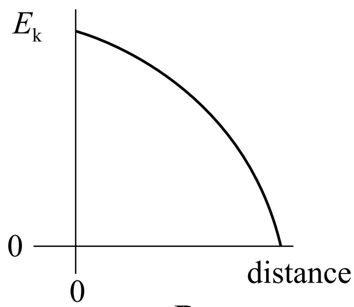
1 Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

- **A** The acceleration is always directed away from O.
- **B** The acceleration and velocity are always in opposite directions.
- **C** The acceleration and the displacement from O are always in the same direction.
- **D** The graph of acceleration against displacement is a straight line.

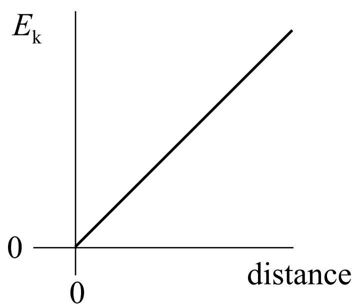
2 A body executes simple harmonic motion. Which one of the graphs, **A** to **D**, best shows the relationship between the kinetic energy, E_k, of the body and its distance from the centre of oscillation?



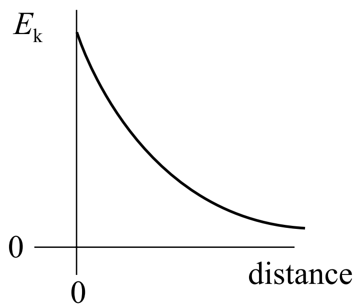
A



B



C



D

3 The displacement (in mm) of the vibrating cone of a large loudspeaker can be represented by the equation $x = 10\cos(150t)$, where t is the time in s. Which line, **A** to **D**, in the table gives the amplitude and frequency of the vibrations.

	amplitude/mm	**frequency/Hz**
A	5	$\frac{10}{2\pi}$
B	10	150
C	10	$\frac{150}{2\pi}$
D	20	$\frac{150}{2\pi}$

4 A wave of frequency 5 Hz travels at $8\,\text{km s}^{-1}$ through a medium. What is the phase difference between two points 2 km apart?

A zero

B $\frac{\pi}{2}$ rad

C π rad

D $\frac{3\pi}{2}$ rad

5 Interference fringes are produced on a screen by illuminating a double slit with monochromatic light. Which one of the following changes would reduce the separation of these fringes?

A increasing the separation of the slits
B increasing the distance from the screen to the slits
C increasing the wavelength of the light
D increasing the width of an individual slit

6 Two coherent sources produce waves which are 180° out of phase. What is a possible value for the path difference of the two waves when they meet at a point of constructive interference, if the wavelength is λ?

A 0

B $\frac{\lambda}{4}$

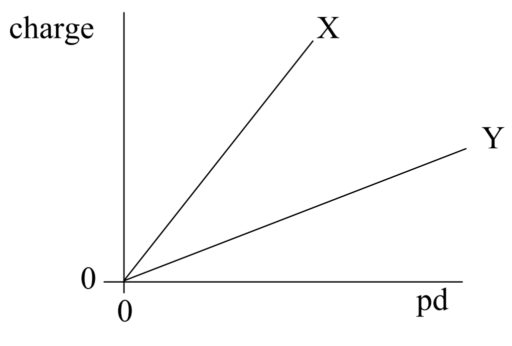
C $\frac{\lambda}{2}$

D λ

7 Light of wavelength λ is incident normally on a diffraction grating of slit separation 4 λ. What is the angle between the second order maximum and third order maximum of the diffracted light?

A 14.5°
B 18.6°
C 48.6°
D 71.4°

8 The graph shows how the charge stored by each of two capacitors, X and Y, increases as the pd across them increases.



Which one of the following statements is correct?

A The capacitance of X is equal to that of Y.
B The capacitance of Y is greater than that of X.
C The capacitance of Y is less than that of X.
D The capacitances of both X and Y are increasing.

9 A small body of mass m rests on a horizontal turntable at a distance r from the centre. If the maximum frictional force between the body and the turntable is $\frac{mg}{2}$, what is the angular speed at which the body starts to slip?

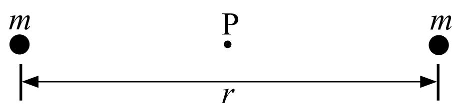
A $\sqrt{\frac{gr}{2}}$

B $\frac{g}{r}$

C $\frac{1}{2}\sqrt{\frac{g}{r}}$

D $\sqrt{\frac{g}{2r}}$

10 The diagram shows two objects of equal mass m separated by a distance r.



Which line, **A** to **D**, in the table gives the correct values of the gravitational field strength and gravitational potential at the mid-point P between the two objects?

	gravitational field strength	**gravitational potential**
A	$-\frac{8Gm}{r^2}$	$-\frac{4Gm}{r}$
B	$-\frac{8Gm}{r^2}$	0
C	0	$-\frac{4Gm}{r}$
D	0	0

11 Mars has a diameter approximately 0.5 that of the Earth, and a mass of 0.1 that of the Earth. If the gravitational potential at the Earth's surface is $-63\,\text{MJ kg}^{-1}$, what is the approximate value of the gravitational potential at the surface of Mars?

A $-13\,\text{MJ kg}^{-1}$
B $-25\,\text{MJ kg}^{-1}$
C $-95\,\text{MJ kg}^{-1}$
D $-320\,\text{MJ kg}^{-1}$

12 When two point charges, each $+Q$, are distance r apart, the force between them is F. What is the force between point charges of $+Q$ and $+2Q$ when they are distance $\frac{r}{2}$ apart?

A F
B $2F$
C $8F$
D $16F$

13 Variables x and y are defined by

$$x = \frac{\alpha z}{r} \quad \text{and} \quad y = \frac{\beta z}{r^2},$$

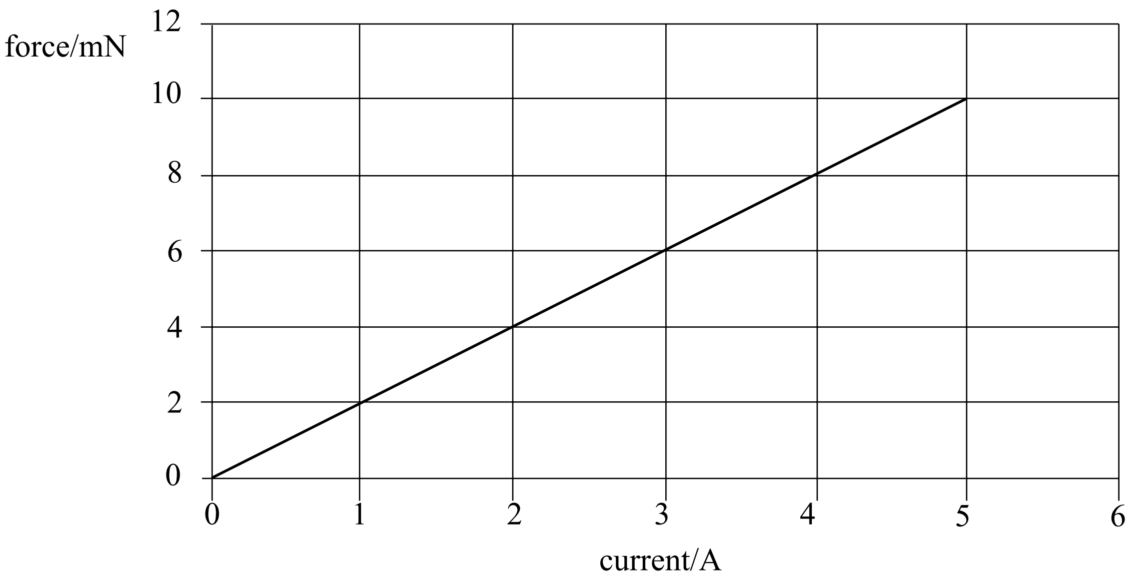
where r is a distance, z is either a mass or a charge, and α and β are constants.

Which line, **A** to **D**, in the table shows correctly the meaning of the symbols when used in this way?

	gravitational field	**electric field**
A	$\alpha = G$	y = potential
B	$\beta = \frac{1}{G}$	x = potential
C	x = field strength	$\beta = 4\pi\varepsilon_0$
D	y = field strength	$\alpha = \frac{1}{4\pi\varepsilon_0}$

Turn over ▶

14 A wire of length 0.50 m, forming part of a complete circuit, is positioned at right angles to a uniform magnetic field. The graph shows how the force acting on the wire due to the magnetic field varies as the current through the wire is increased.



What is the flux density of the magnetic field?

A 2 mT
B 4 mT
C 15 mT
D 25 mT

15 Which one of the following materials, if introduced into the core of an overheated nuclear fission reactor, would be most effective in reducing the rate of fission reactions?

A boron
B carbon
C nitrogen
D carbon dioxide

END OF SECTION A

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