General Certificate of Education
January 2006
Advanced Level Examination

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

Section A

Friday 20 January 2006 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}	$\mathrm{m\ s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
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}	$\mathrm{N\ m^2\ kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\ m^{-2}\ K^{-4}}$
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}	$\mathrm{C\ kg^{-1}}$
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}	$\mathrm{C\ kg^{-1}}$
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
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 $= Tt$

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

$\Delta W = p\Delta V$

$pV^{\gamma} =$ 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

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

$\epsilon = I(R + r)$

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

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

$P = I^2R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

magnitude of induced e.m.f. $= N\dfrac{\Delta\Phi}{\Delta t}$

$I_{\rm rms} = \dfrac{I_0}{\sqrt{2}}$

$V_{\rm rms} = \dfrac{V_0}{\sqrt{2}}$

Mechanical and Thermal Properties

the Young modulus $= \dfrac{\textit{tensile stress}}{\textit{tensile strain}} = \dfrac{F}{A}\dfrac{l}{e}$

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

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

$\Delta Q = ml$

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

$\frac{1}{2} m\overline{c^2} = \frac{3}{2} kT = \dfrac{3RT}{2N_{\rm A}}$

Nuclear Physics and Turning Points in Physics

force $= \dfrac{eV_{\rm p}}{d}$

force $= Bev$

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

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

work done $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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 = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

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

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

$M = \dfrac{f_{\rm o}}{f_{\rm e}}$

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

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

$v = Hd$

$P = \sigma AT^4$

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

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

$R_{\rm s} \approx \dfrac{2GM}{c^2}$

Medical Physics

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

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

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

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

$\mu_{\rm m} = \dfrac{\mu}{\rho}$

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

$Z = \dfrac{V_{\rm rms}}{I_{\rm rms}}$

$\dfrac{1}{C_{\rm T}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3} + \cdots$

$C_{\rm T} = C_1 + C_2 + C_3 + \cdots$

$X_{\rm C} = \dfrac{1}{2\pi fC}$

Alternating Currents

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

Operational amplifier

$G = \dfrac{V_{\rm out}}{V_{\rm in}}$ voltage gain

$G = -\dfrac{R_{\rm f}}{R_1}$ inverting

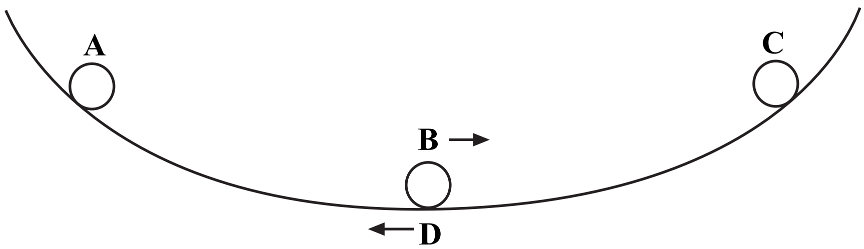
$G = 1 + \dfrac{R_{\rm f}}{R_1}$ non-inverting

$V_{\rm out} = -R_{\rm f}\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}\right)$ 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 approximately **30 minutes** on this section.

1 A ball bearing rolls on a concave surface, as shown in the diagram, in approximate simple harmonic motion. It is released from **A** and passes through the lowest point **B** before reaching **C**. It then returns through the lowest point **D**. At which stage, **A**, **B**, **C** or **D**, does the ball bearing experience maximum acceleration to the left?



2 A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$.

What is the magnitude of the acceleration when the body is at maximum displacement?

A zero
B $4\pi^2 Ab^2$
C Ab^2
D $\frac{4\pi^2 A}{b^2}$

3 By approximately how many times is the wavelength of audible sound waves greater than the wavelength of light waves?

A 10^2
B 10^6
C 10^{10}
D 10^{14}

4 A stationary wave is formed by two identical waves of frequency 300 Hz travelling in opposite directions along the same line. If the distance between adjacent nodes is 0.60 m, what is the speed of each wave?

A $180\,\text{m s}^{-1}$
B $250\,\text{m s}^{-1}$
C $360\,\text{m s}^{-1}$
D $500\,\text{m s}^{-1}$

5 Interference maxima produced by a double source are observed at a distance of 1.0 m from the sources. In which one of the following cases are the maxima closest together?

A red light of wavelength 700 nm from sources 4.0 mm apart
B sound waves of wavelength 20 mm from sources 50 mm apart
C blue light of wavelength 450 nm from sources 2.0 mm apart
D surface water waves of wavelength 10 mm from sources 200 mm apart

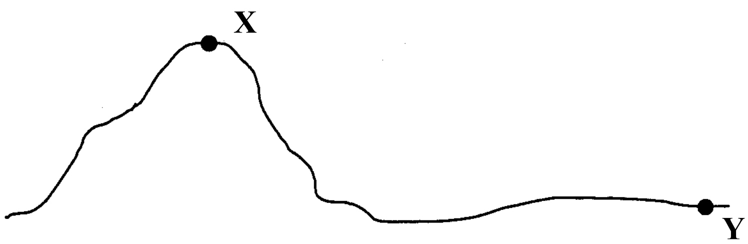
6 A 400 μF capacitor is charged so that the voltage across its plates rises at a constant rate from 0 V to 4.0 V in 20 s. What current is being used to charge the capacitor?

A 5 μA
B 20 μA
C 40 μA
D 80 μA

7 What is the value of the angular velocity of a point on the surface of the Earth?

A 1.2×10^{-5} rad s^{-1}
B 7.3×10^{-5} rad s^{-1}
C 2.6×10^{-1} rad s^{-1}
D 4.6×10^{2} rad s^{-1}

8 The diagram shows two positions, **X** and **Y**, at different heights on the surface of the Earth.



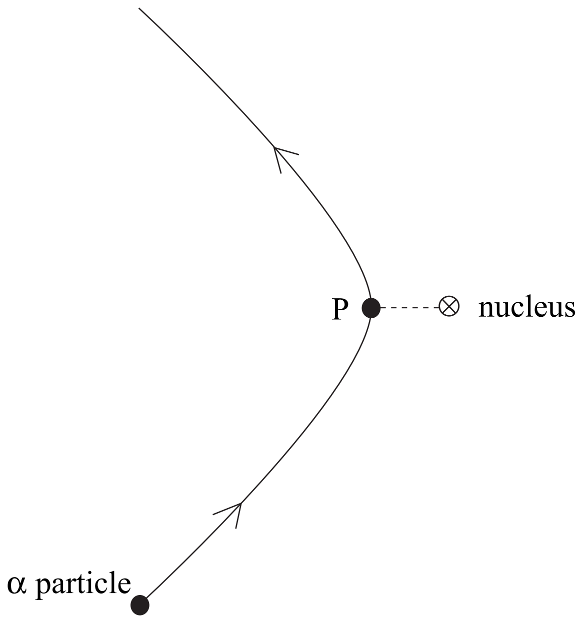
Which line, **A** to **D**, in the table gives correct comparisons at **X** and **Y** for gravitational potential and angular velocity?

	gravitational potential at X compared with Y	**angular velocity at X compared with Y**
A	greater	greater
B	greater	same
C	greater	smaller
D	same	same

9 A projectile moves in a gravitational field. Which one of the following is a correct statement for the gravitational force acting on the projectile?

A The force is in the direction of the field.
B The force is in the opposite direction to that of the field.
C The force is at right angles to the field.
D The force is at an angle between 0° and 90° to the field.

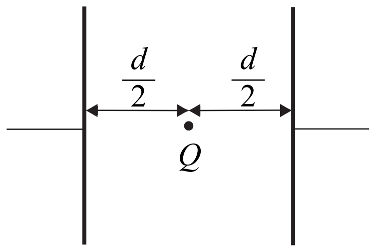
10 The diagram shows the path of an α particle deflected by the nucleus of an atom. Point P on the path is the point of closest approach of the α particle to the nucleus. Which one of the following statements about the α particle on this path is correct?



A Its acceleration is zero at P.
B Its kinetic energy is greatest at P.
C Its potential energy is least at P.
D Its speed is least at P.

Turn over for the next question

11 Two parallel metal plates separated by a distance d have a potential difference V across them. What is the magnitude of the electrostatic force acting on a charge Q placed midway between the plates?



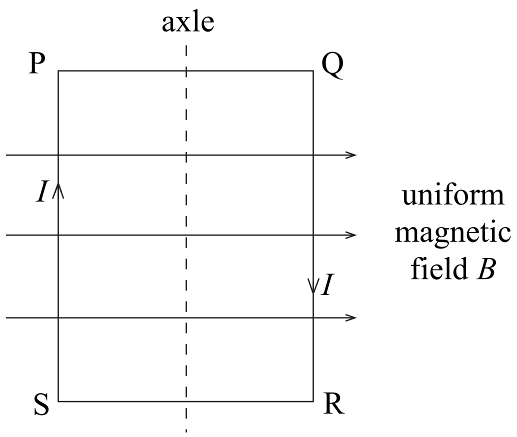
A $\frac{2VQ}{d}$

B $\frac{VQ}{2d}$

C $\frac{VQ}{d}$

D $\frac{Qd}{V}$

12



A coil, mounted on an axle, has its plane parallel to the flux lines of a uniform magnetic field B, as shown. When a current I is switched on, and before the coil is allowed to move,

A there are no forces due to B on the sides PQ and RS.
B there are no forces due to B on the sides SP and QR.
C sides SP and QR attract each other.
D sides PQ and RS attract each other.

13 Protons, each of mass m and charge e, follow a circular path when travelling perpendicular to a magnetic field of uniform flux density B. What is the time taken for one complete orbit?

A $\dfrac{2\pi eB}{m}$

B $\dfrac{m}{2\pi eB}$

C $\dfrac{eB}{2\pi m}$

D $\dfrac{2\pi m}{eB}$

14 The reaction shown below occurs when a proton and a deuterium nucleus, ${}^{2}_{1}\mathrm{H}$, fuse to form a helium nucleus, ${}^{3}_{2}\mathrm{He}$.

$$ {}^{1}_{1}\mathrm{p} \quad + \quad {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} \quad + \quad Q $$

If the energy released, Q, is 5.49 MeV, what is the mass of the helium nucleus?

mass of ${}^{2}_{1}\mathrm{H}$ nucleus = 2.01355 u
mass of proton = 1.00728 u
1u is equivalent to 931.3 MeV

A 0.00589 u
B 3.01494 u
C 3.02083 u
D 3.02323 u

15 Which line, **A** to **D**, in the table gives a combination of materials that is commonly used for moderating, controlling and shielding respectively in a nuclear reactor?

	moderating	**controlling**	**shielding**
A	graphite	carbon	lead
B	cadmium	carbon	concrete
C	cadmium	boron	lead
D	graphite	boron	concrete

End of Section A

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