General Certificate of Education
June 2005
Advanced Level Examination

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

Section A

Thursday 16 June 2005 Morning Session

In addition to this paper you will require:
- 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.
- Section A and Section B of this paper together carry 15% of the total marks for Physics Advanced.
- 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 $= \frac{\textit{power output}}{\textit{power input}}$

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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. $= N \dfrac{\Delta \Phi}{\Delta t}$

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

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

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

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

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

Nuclear Physics and Turning Points in Physics

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

force $= Bev$

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

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

work done $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

$E = mc^2 = \dfrac{m_0 c^2}{\left(1 - \dfrac{v^2}{c^2}\right)^{\frac{1}{2}}}$

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

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

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}

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

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

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

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

$v = Hd$

$P = \sigma A T^4$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

$X_C = \dfrac{1}{2\pi f C}$

Alternating Currents

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

Operational amplifier

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

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

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

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

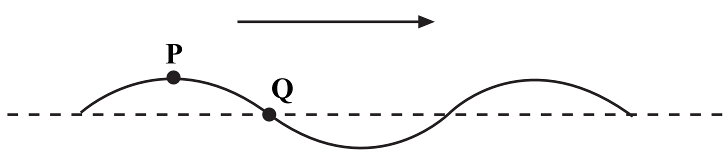
1 A spring is suspended from a fixed point. A mass attached to the spring is set into vertical undamped simple harmonic motion. When the mass is at its lowest position, which one of the following has its minimum value?

A the potential energy of the system
B the kinetic energy of the mass
C the acceleration of the mass
D the tension in the spring

2 The time period of a simple pendulum is doubled when the length of the pendulum is increased by 3.0 m. What is the original length of the pendulum?

A 1.0 m
B 1.5 m
C 3.0 m
D 6.0 m

3 The diagram shows a snapshot of a wave on a rope travelling from left to right.



At the instant shown, point **P** is at maximum displacement and point **Q** is at zero displacement. Which one of the following lines, **A** to **D**, in the table correctly describes the motion of **P** and **Q** in the next half-cycle?

	P	Q
A	falls then rises	rises
B	falls then rises	rises then falls
C	falls	falls
D	falls	rises then falls

4 The speed of sound in water is $1500\,\mathrm{m\,s^{-1}}$. For a sound wave in water having frequency 2500 Hz, what is the minimum distance between two points at which the vibrations are $\frac{\pi}{3}$ rad out of phase?

A 0.05 m
B 0.10 m
C 0.15 m
D 0.20 m

5 Which one of the following properties of light waves do polarising sunglasses depend on for their action?

Light waves may

A interfere constructively.
B interfere destructively.
C be polarised when reflected from a surface.
D be polarised by the lens in the eye.

6 Light of wavelength λ is incident normally on a diffraction grating for which adjacent lines are a distance 3λ apart. What is the angle between the second order maximum and the straight-through position?

A 9.6°
B 20°
C 42°
D There is no second order maximum.

7 The Earth has density ρ and radius R. The gravitational field strength at the surface is g. What is the gravitational field strength at the surface of a planet of density 2ρ and radius $2R$?

A g
B $2g$
C $4g$
D $16g$

8 A particle of mass m moves in a circle of radius r at uniform speed, taking time T for each revolution. What is the kinetic energy of the particle?

A $\dfrac{\pi^2 m r}{T^2}$

B $\dfrac{\pi^2 m r^2}{T^2}$

C $\dfrac{2\pi^2 m r^2}{T}$

D $\dfrac{2\pi^2 m r^2}{T^2}$

9 Two protons, each of mass m and charge e, are a distance d apart. Which one of the following expressions correctly gives the ratio $\left(\frac{\text{electrostatic force}}{\text{gravitational force}}\right)$ for the forces acting between them?

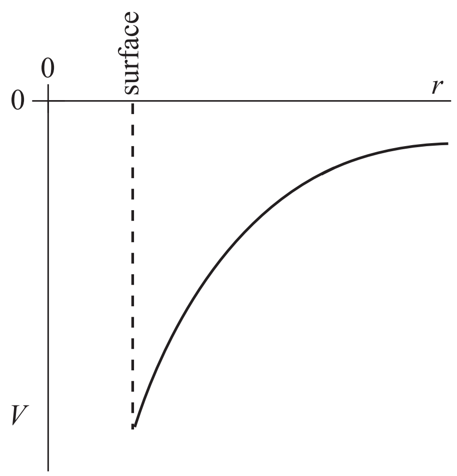
A $\dfrac{4\pi\varepsilon_0 e^2}{Gm^2}$

B $\dfrac{Ge^2}{4\pi\varepsilon_0 m^2}$

C $\dfrac{e^2 m^2}{4\pi\varepsilon_0 G}$

D $\dfrac{e^2}{4\pi\varepsilon_0 Gm^2}$

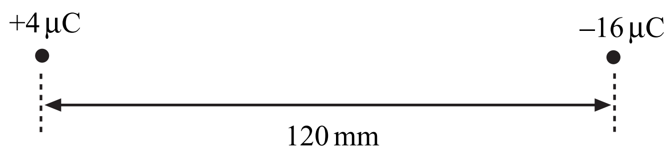
10 The graph shows how the gravitational potential, V, varies with the distance, r, from the centre of the Earth.



What does the gradient of the graph at any point represent?

A the magnitude of the gravitational field strength at that point
B the magnitude of the gravitational constant
C the mass of the Earth
D the potential energy at the point where the gradient is measured

11



The diagram shows two charges, +4 μC and –16 μC, 120 mm apart. What is the distance from the +4 μC charge to the point between the two charges, where the resultant electric potential is zero?

A 24 mm
B 40 mm
C 80 mm
D 96 mm

12 An electron travelling at constant speed enters a uniform electric field at right angles to the field. While the electron is in the field it accelerates in a direction which is

A in the same direction as the electric field.
B in the opposite direction to the electric field.
C in the same direction as the motion of the electron.
D in the opposite direction to the motion of the electron.

13 A 1000 μF capacitor and a 10 μF capacitor are charged so that the potential difference across each of them is the same. The charge stored in the 1000 μF capacitor is Q_1 and the charge stored in the 10 μF capacitor is Q_2.

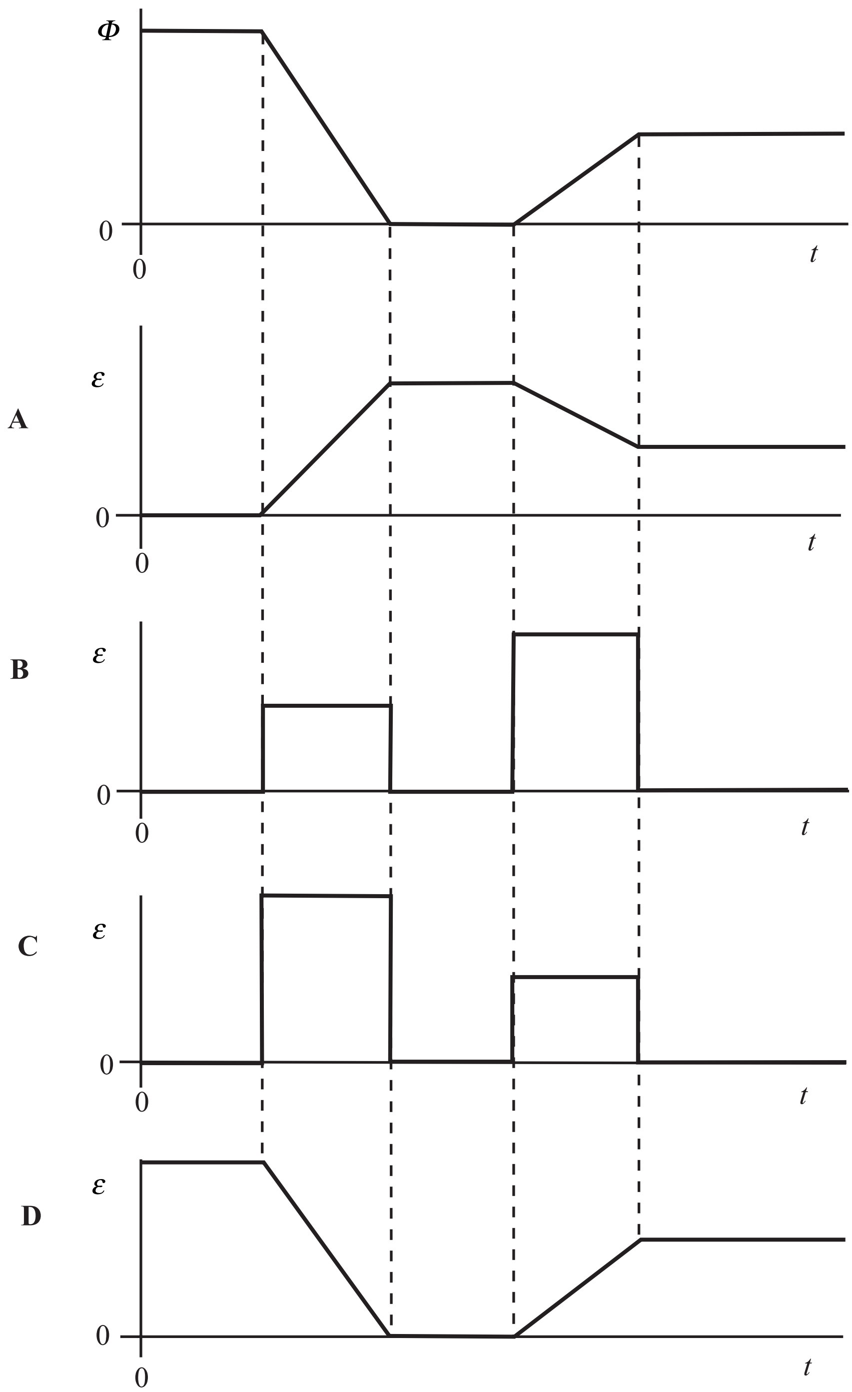
What is the ratio $\frac{Q_1}{Q_2}$?

A 100
B 10
C 1
D $\frac{1}{100}$

14 Which one of the following statements is **not** true about the control rods used in a nuclear reactor?

A They must absorb neutrons.
B They must slow down neutrons to thermal speeds.
C They must retain their shape at high temperatures.
D The length of rod in the reactor must be variable.

15 The magnetic flux, Φ, through a coil varies with time, t, as shown by the first graph. Which one of the following graphs, **A** to **D**, best represents how the magnitude, ε, of the induced emf varies in this same period of time?



END OF SECTION A

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