General Certificate of Education
June 2007
Advanced Level Examination

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

Section A

Thursday 14 June 2007 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.

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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^{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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

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

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

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

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

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

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

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 $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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}

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

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

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

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

$v = Hd$

$P = \sigma AT^4$

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

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

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

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

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

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

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

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

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

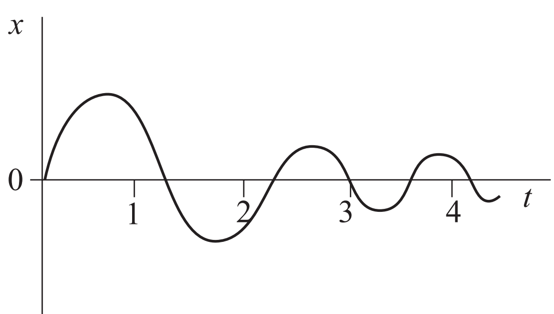
In this section each item consists of a question or an incomplete statement followed by four suggested answers or completions. You are to select the most appropriate answer in each case.

You are advised to spend approximately **30 minutes** on this section.

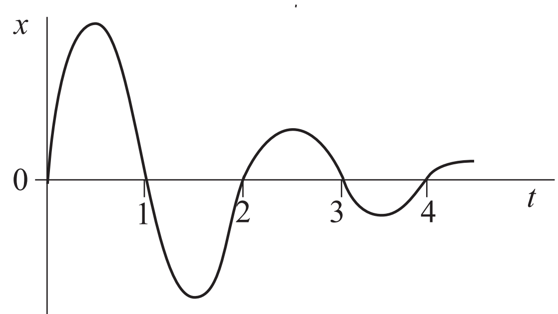
1 The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same, which one of the following is also doubled?

A the time period
B the total energy
C the maximum velocity
D the maximum acceleration

2 Which one of the graphs, **A** to **D**, best shows how the displacement, *x*, of a damped oscillator that performs simple harmonic motion varies with time *t*?



A



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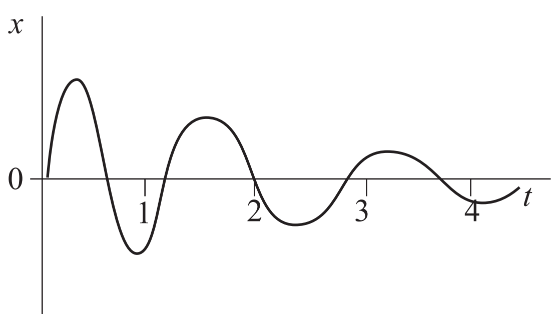

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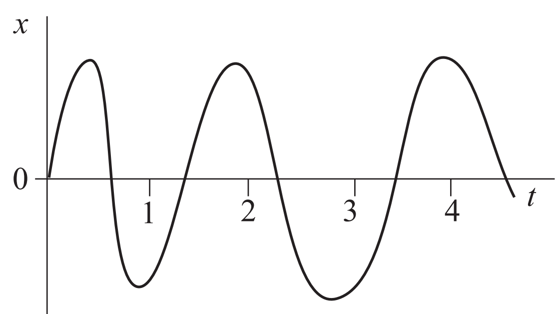


D

3 A wave motion has period T, frequency f, wavelength λ and speed c. Which one of the following equations is **incorrect**?

A $T = \frac{c}{\lambda}$

B $1 = Tf$

C $\lambda = \frac{c}{f}$

D $Tc = \lambda$

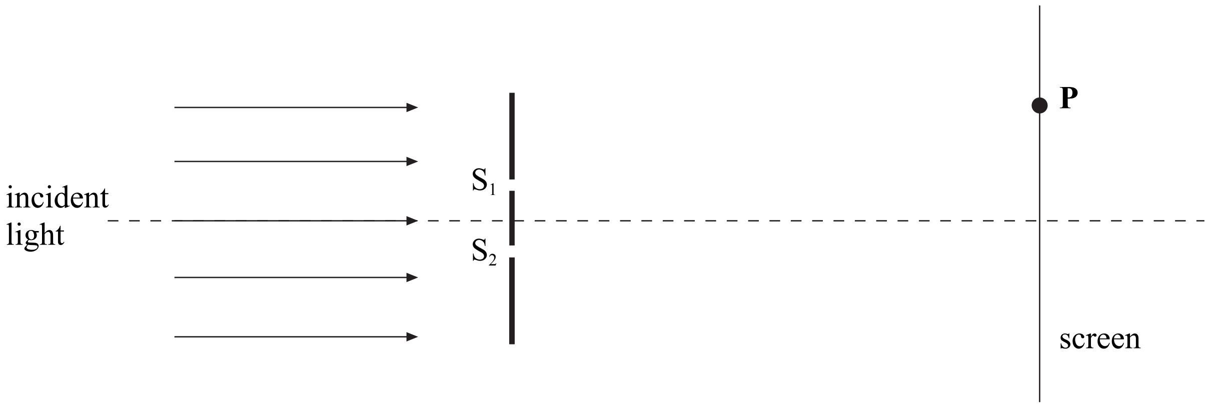
4 In a transverse progressive wave of frequency 400 Hz, the least distance between two adjacent points which have a phase difference of $\frac{\pi}{2}$ rad is 0.40 m. What is the speed of the wave?

A $160\,\mathrm{m\,s^{-1}}$
B $320\,\mathrm{m\,s^{-1}}$
C $640\,\mathrm{m\,s^{-1}}$
D $1280\,\mathrm{m\,s^{-1}}$

5 In order to produce interference effects with visible light, coherent sources must be used. The waves produced by these sources do **not** need to have the same

A amplitude.
B frequency.
C wavelength.
D photon energy.

6 When a parallel beam of monochromatic light of wavelength λ is directed at two narrow slits, S_1 and S_2, interference fringes are observed on a screen.



Which line, **A** to **D**, in the table gives the conditions for a dark fringe at point **P** on the screen? (*m* in the table represents an integer.)

	path difference $S_2P - S_1P$	**phase difference between waves at P**
A	$m\lambda$	0
B	$(m + \frac{1}{2})\lambda$	180°
C	$m\lambda$	180°
D	$(m + \frac{1}{2})\lambda$	0

7 Using a diffraction grating with light of wavelength 500 nm incident normally, a student found the second order diffracted maxima in a direction at 30° to the central bright fringe. What is the number of lines per metre on the grating?

A 2×10^4

B 2×10^5

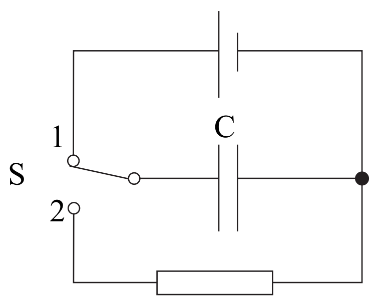
C 4×10^5

D 5×10^5

8 A capacitor of capacitance 2500 μF is charged by a **constant** current of 200 μA. What is the pd across the capacitor 25 s after starting to charge?

A 0.50 V
B 1.0 V
C 2.0 V
D 4.0 V

9



Switch S in the circuit is held in position 1, so that the capacitor C becomes fully charged to a pd V and stores energy E. The switch is then moved quickly to position 2, allowing C to discharge through the fixed resistor R. It takes 36 ms for the pd across C to fall to $\frac{V}{2}$.
After the switch has been moved to position 2, how long does it take before the energy stored by C has fallen to $\frac{E}{16}$?

A 51 ms
B 72 ms
C 432 ms
D 576 ms

10 A small mass is situated at a point on a line joining two large masses m_1 and m_2 such that it experiences no resultant gravitational force. If its distance from the centre of mass m_1 is r_1 and its distance from the centre of mass m_2 is r_2 , what is the value of the ratio $\frac{r_1}{r_2}$?

A $\frac{m_1^{\,2}}{m_2^{\,2}}$

B $\frac{m_2^{\,2}}{m_1^{\,2}}$

C $\sqrt{\frac{m_1}{m_2}}$

D $\sqrt{\frac{m_2}{m_1}}$

11 The Earth may be considered to be a uniform sphere of mass M and radius R. Which one of the following equations correctly relates the gravitational constant, G, with the acceleration due to gravity, g, at its surface?

A $G = \dfrac{M}{gR^2}$

B $G = \dfrac{gM}{R^2}$

C $G = \dfrac{R^2}{gM}$

D $G = \dfrac{gR^2}{M}$

12 What is the unit of gravitational potential?

A J

B $\mathrm{J\,kg^{-1}}$

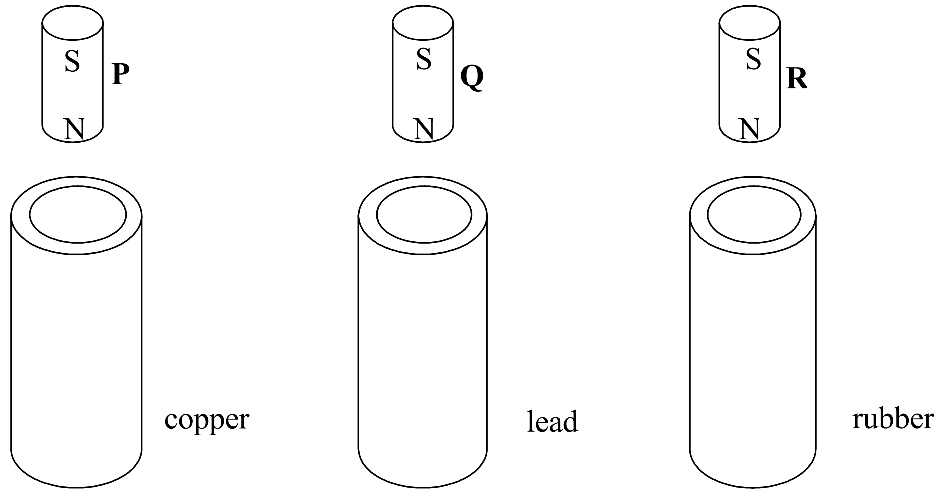
C $\mathrm{m\,s^{-2}}$

D $\mathrm{N\,kg^{-1}}$

13 The magnetic flux through a coil of 5 turns changes uniformly from 15×10^{-3} Wb to 7.0×10^{-3} Wb in 0.50 s. What is the emf induced in the coil due to this change in flux?

A 14 mV
B 16 mV
C 30 mV
D 80 mV

14



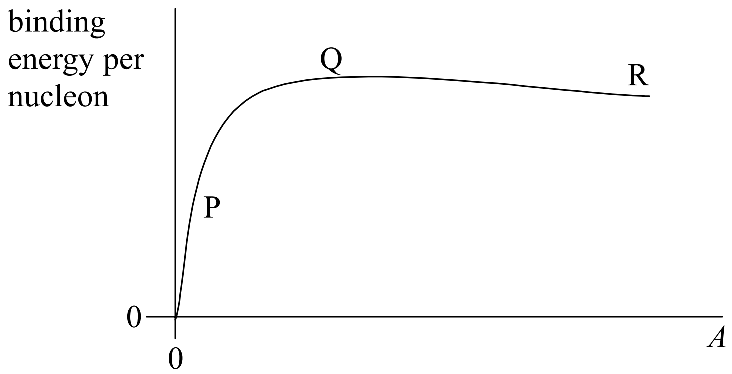
Three vertical tubes, made from copper, lead and rubber respectively, have identical dimensions. Identical, strong, cylindrical magnets **P**, **Q** and **R** are released simultaneously from the same distance above each tube. Because of electromagnetic effects, the magnets emerge from the bottom of the tubes at different times.

Which line, **A** to **D**, in the table shows the correct order in which they will emerge?

resistivity of copper $= 1.7 \times 10^{-8}\ \Omega\,\text{m}$
resistivity of lead $= 22 \times 10^{-8}\ \Omega\,\text{m}$
resistivity of rubber $= 50 \times 10^{13}\ \Omega\,\text{m}$

	emerges first	**emerges second**	**emerges third**
A	**P**	**Q**	**R**
B	**R**	**P**	**Q**
C	**R**	**Q**	**P**
D	**P**	**R**	**Q**

15



The graph shows how the binding energy per nucleon of a nucleus varies with nucleon number, A.

Which one of the following statements is **not** true?

A Energy is released in nuclear fission reactions from nuclei in region P.
B Nuclei in region Q are more stable than nuclei in region R.
C Nuclear fusion reactions bring nuclei closer to region Q.
D The binding energy per nucleon increases most significantly at lower nucleon numbers.

END OF SECTION A

There are no questions printed on this page