

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

PA04

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				Mechanics and Applied Physics		Fields, Waves, Quantum Phenomena	
Quantity	Symbol	Value	Units				
speed of light in vacuo	c	3.00×10^8	m s^{-1}	$v = u + at$		$g = \frac{F}{m}$	
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}	$s = \left(\frac{u+v}{2}\right)t$		$g = -\frac{GM}{r^2}$	
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}	$s = ut + \frac{at^2}{2}$		$g = -\frac{\Delta V}{\Delta x}$	
charge of electron	e	1.60×10^{-19}	C	$v^2 = u^2 + 2as$		$V = -\frac{GM}{r}$	
the Planck constant	h	6.63×10^{-34}	J s	$F = \frac{\Delta(mv)}{\Delta t}$		$a = -(2\pi f)^2 x$	
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$	$P = Fv$		$v = \pm 2\pi f \sqrt{A^2 - x^2}$	
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$		$x = A \cos 2\pi ft$	
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$\omega = \frac{v}{r} = 2\pi f$		$T = 2\pi\sqrt{\frac{m}{k}}$	
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}	$a = \frac{v^2}{r} = r\omega^2$		$T = 2\pi\sqrt{\frac{L}{g}}$	
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$		$\lambda = \frac{\omega s}{D}$	
the Wien constant	α	2.90×10^{-3}	m K	$E_k = \frac{1}{2} I\omega^2$		$d \sin \theta = n\lambda$	
electron rest mass	m_e	9.11×10^{-31}	kg	$\omega_2 = \omega_1 + at$		$\theta = \frac{\lambda}{D}$	
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} at^2$		${}^1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2a\theta$		${}^1n_2 = \frac{n_2}{n_1}$	
proton rest mass	m_p	1.67×10^{-27}	kg	$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$		$\sin \theta_c = \frac{1}{n}$	
(equivalent to 1.00728u)				$T = I\alpha$		$E = hf$	
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}	$\text{angular momentum} = I\omega$		$hf = \phi + E_k$	
neutron rest mass	m_n	1.67×10^{-27}	kg	$W = T\theta$		$hf = E_1 - E_2$	
(equivalent to 1.00867u)				$P = T\omega$		$\lambda = \frac{h}{p} = \frac{h}{mv}$	
gravitational field strength	g	9.81	N kg^{-1}	$\text{angular impulse} = \text{change of angular momentum} = Tt$		$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$	
acceleration due to gravity	g	9.81	m s^{-2}	$\Delta Q = \Delta U + \Delta W$		Electricity	
atomic mass unit	u	1.661×10^{-27}	kg	$\Delta W = p\Delta V$		$\epsilon = \frac{E}{Q}$	
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$		$\epsilon = I(R+r)$	
Fundamental particles				$\text{work done per cycle} = \text{area of loop}$		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	
Class	Name	Symbol	Rest energy /MeV	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$		$R_T = R_1 + R_2 + R_3 + \dots$	
photon	photon	γ	0	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$		$P = I^2 R$	
lepton	neutrino	ν_e	0	$\text{friction power} = \text{indicated power} - \text{brake power}$		$E = \frac{F}{Q} = \frac{V}{d}$	
	electron	e^\pm	0.510999	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$		$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$	
	muon	μ^\pm	105.659	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$		$E = \frac{1}{2} QV$	
mesons	pion	π^\pm	139.576			$F = BIl$	
		π^0	134.972			$F = BQv$	
	kaon	K^\pm	493.821			$Q = Q_0 e^{-t/RC}$	
		K^0	497.762			$\Phi = BA$	
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 = πr^2							
area of cylinder = $2\pi rh$							
volume of cylinder = $\pi r^2 h$							
area of sphere = $4\pi r^2$							
volume of sphere = $\frac{4}{3}\pi r^3$							

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

$$\text{work done} = eV$$

$$F = 6\pi\eta rv$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

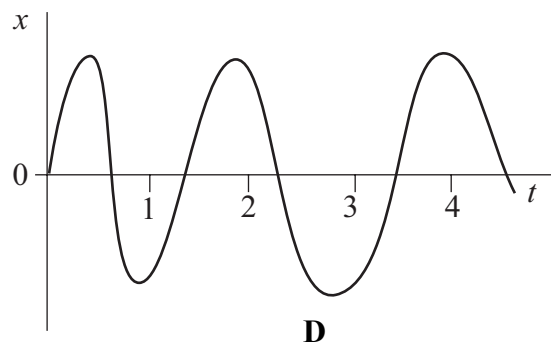
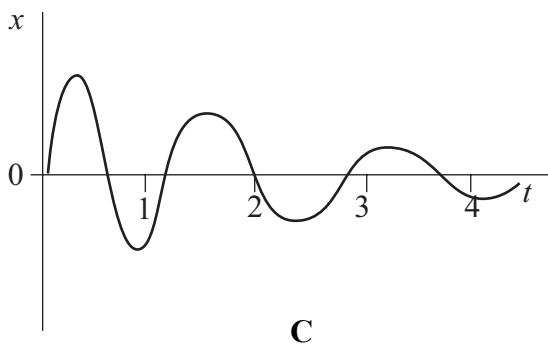
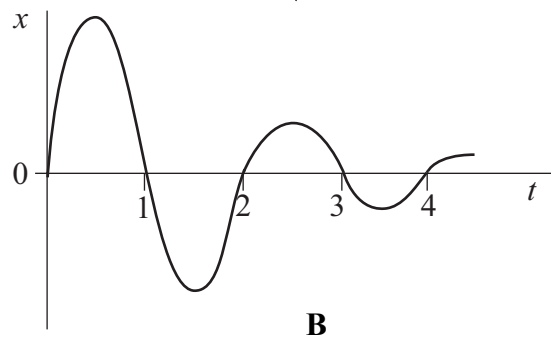
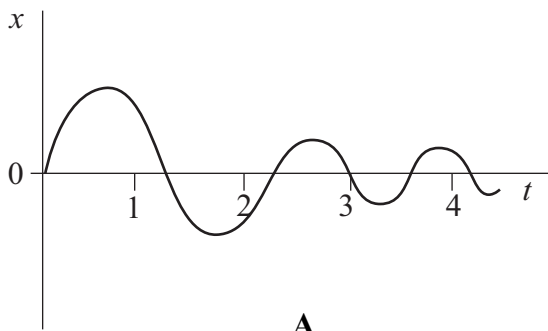
$$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right) \quad \text{summing}$$

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.

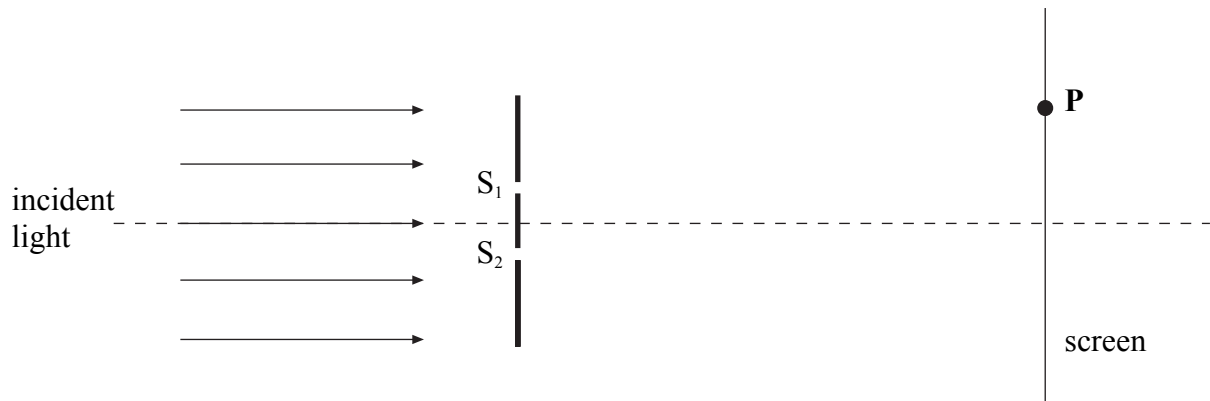
- 1 The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same, which one of the following is also doubled?
- A the time period
 - B the total energy
 - C the maximum velocity
 - D the maximum acceleration
- 2 Which one of the graphs, **A** to **D**, best shows how the displacement, x , of a damped oscillator that performs simple harmonic motion varies with time t ?



Turn over ►

-
- 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 m s^{-1}
- B 320 m s^{-1}
- C 640 m s^{-1}
- D 1280 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

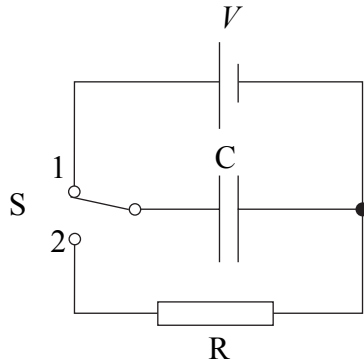
- 7 Using a diffraction grating with light of wavelength 500 nm incident normally, a student found the second order diffracted maxima in a direction at 30° to the central bright fringe. What is the number of lines per metre on the grating?
- A** 2×10^4
- B** 2×10^5
- C** 4×10^5
- D** 5×10^5

Turn over ►

8 A capacitor of capacitance $2500 \mu\text{F}$ is charged by a **constant** current of $200 \mu\text{A}$. 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 $G = \frac{M}{gR^2}$

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

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

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

12 What is the unit of gravitational potential?

A J

B J kg^{-1}

C m s^{-2}

D N kg^{-1}

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

A 14 mV

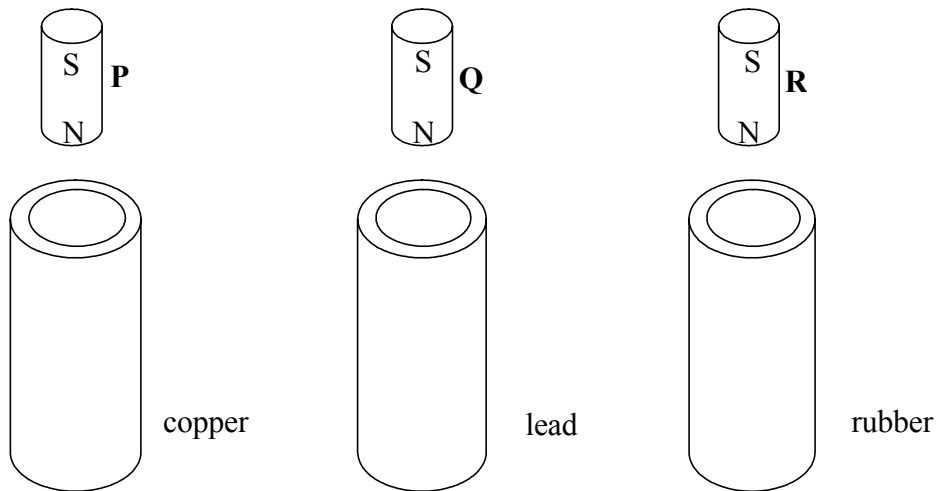
B 16 mV

C 30 mV

D 80 mV

Turn over ►

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?

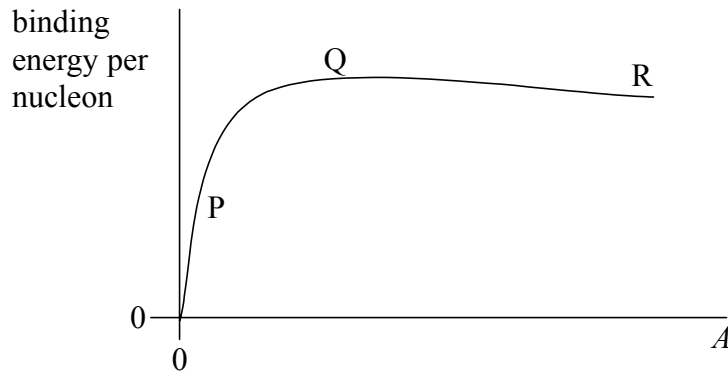
$$\text{resistivity of copper} = 1.7 \times 10^{-8} \Omega \text{m}$$

$$\text{resistivity of lead} = 22 \times 10^{-8} \Omega \text{m}$$

$$\text{resistivity of rubber} = 50 \times 10^{13} \Omega \text{m}$$

	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