General Certificate of Education
January 2009
Advanced Level Examination

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

Section A

Wednesday 21 January 2009 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 as a loose insert.
- The question paper/answer book for Section B is enclosed within this question paper.

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 The tip of each prong of a tuning fork emitting a note of frequency 320 Hz vibrates in simple harmonic motion with an amplitude of 0.50 mm.
What is the speed of each tip when its displacement is zero?

A zero
B 0.32π mm s^{-1}
C 160π mm s^{-1}
D 320π mm s^{-1}

2 What is the phase difference between the acceleration and the displacement for a particle moving with simple harmonic motion?

A $\frac{\pi}{2}$ radians

B π radians

C $\frac{3\pi}{2}$ radians

D 2π radians

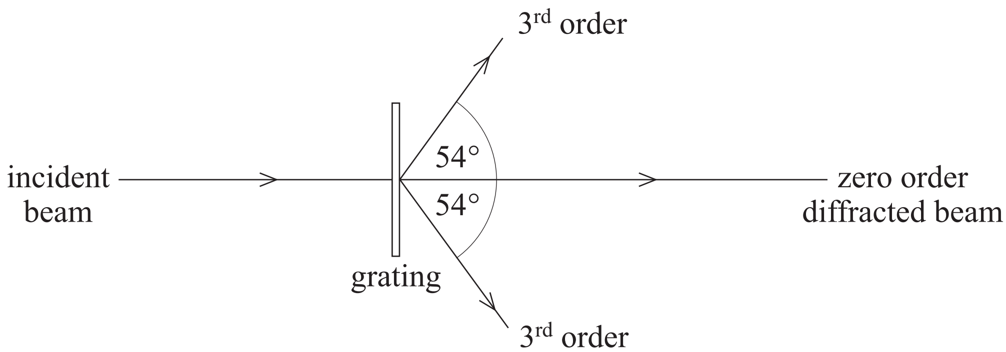
3 Which one of the following statements is **not** an application of polarisation?

A to show the strain in materials such as glass
B to reduce glare when taking photographs
C to transmit and receive radio waves
D to transmit and receive ultrasonic waves

4 Two identical waves, having a period of 2.5×10^{-3} s, and travelling in opposite directions along the same line, form a stationary wave. If the distance between adjacent nodes is 0.40 m, what is the speed of each wave?

A 160 m s^{-1}
B 320 m s^{-1}
C 400 m s^{-1}
D 480 m s^{-1}

5 A parallel beam of monochromatic light is directed normally at a plane transmission grating which has 600 lines per millimetre. A third order diffracted beam is observed at an angle of 54º to the zero order diffracted beam.

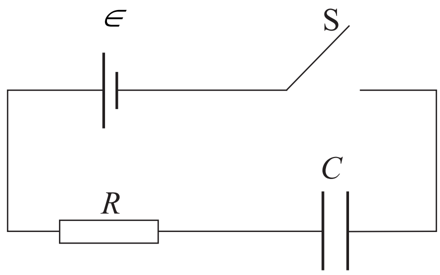


Which line, **A** to **D,** in the table gives the wavelength of the light and the angle of diffraction of the first order beam?

	wavelength / nm	**angle of diffraction of first order**
A	450	16°
B	450	18°
C	520	16°
D	520	18°

Turn over for the next question

6



When switch S is closed, the capacitor of capacitance C begins to charge from the cell of emf $\in$ through the resistor of resistance R. The initial current in the circuit is I.

The time taken for the current to decrease to $\frac{I}{2}$ is determined by the value(s) of

A $\in$ and R.
B $\in$ and C.
C C and R.
D C alone.

7 A revolving mountain top restaurant turns slowly, completing a full rotation in 50 minutes. A man sits in the restaurant 15 m from the axis of rotation. What is the speed of the man?

A $\frac{\pi}{100}\,\mathrm{m\,s^{-1}}$

B $\frac{3\pi}{5}\,\mathrm{m\,s^{-1}}$

C $\frac{\pi}{200}\,\mathrm{m\,s^{-1}}$

D $\frac{\pi}{1500}\,\mathrm{m\,s^{-1}}$

8 The gravitational field strength at the surface of the Earth, of radius R, is g and the weight of an object on the surface is W. The object is now taken to a distance of $3R$ from the centre of the Earth. Which line, **A** to **D**, in the table gives the weight of the object and the gravitational field strength at this distance?

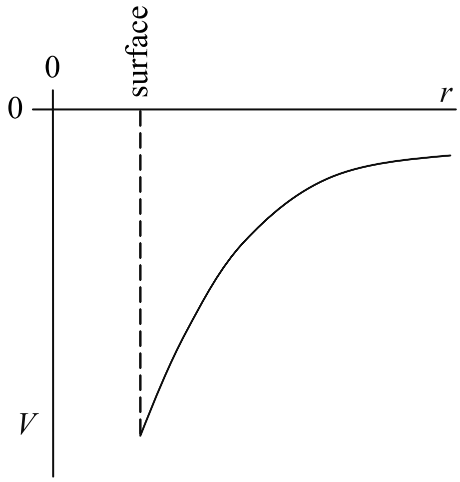
	weight	**gravitational field strength**
A	$\frac{W}{9}$	$\frac{g}{9}$
B	$\frac{W}{9}$	$\frac{g}{3}$
C	$\frac{W}{4}$	$\frac{g}{4}$
D	$\frac{W}{3}$	$\frac{g}{3}$

9 Which one of the following is a quantity that can be resolved into different directions?

A electrical potential
B gravitational potential
C electric field strength
D induced emf

Turn over for the next question

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



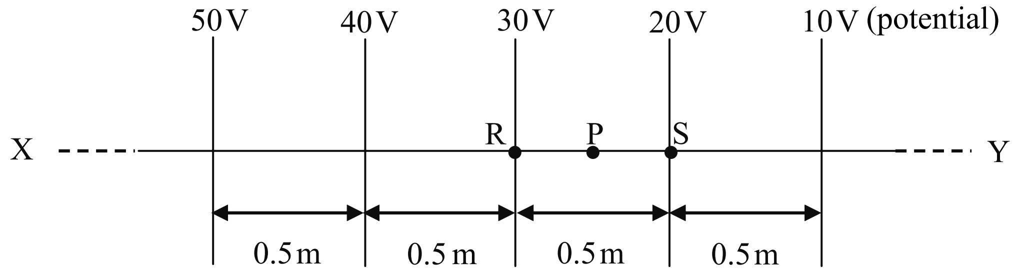
What does the gradient of the graph at any point represent?

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

11 A positive ion, with a charge/mass ratio of $2.40 \times 10^7\,\mathrm{C\,kg^{-1}}$, is stationary in a vertical electric field. Which line, **A** to **D**, in the table shows correctly both the strength and the direction of the electric field?

	electric field strength /$\mathrm{V\,m^{-1}}$	**direction**
A	4.09×10^{-7}	upwards
B	4.09×10^{-7}	downwards
C	2.45×10^{6}	upwards
D	2.45×10^{6}	downwards

12



The diagram shows how the electric potential varies along a line XY in an electric field. What will be the electric field strength at a point P on XY, which is mid-way between R and S?

A 5.0 V m^{-1}
B 10 V m^{-1}
C 20 V m^{-1}
D 30 V m^{-1}

13 An α particle moves in a circular path at a speed of 7.5×10^6 m s^{-1} in a plane perpendicular to a uniform magnetic field of flux density 1.5×10^{-2} T. The force acting on the α particle is

A 1.8×10^{-14} N parallel to the direction of the field.
B 3.6×10^{-14} N parallel to the direction of the field.
C 1.8×10^{-14} N perpendicular to the direction of the field.
D 3.6×10^{-14} N perpendicular to the direction of the field.

14 The mass of the $^{7}_{4}$Be beryllium nucleus is 7.01473 u.
What is the binding energy per nucleon of this nucleus?

Use information from the *Data Sheet*.

A 1.6 MeV nucleon^{-1}
B 5.4 MeV nucleon^{-1}
C 9.4 MeV nucleon^{-1}
D 12.5 MeV nucleon^{-1}

Turn over for the next question

15 In a thermal reactor, induced fission is caused by the $^{235}_{92}U$ nucleus capturing a neutron, undergoing fission and producing more neutrons. Which one of the following statements is true?

A To sustain the reaction a large number of neutrons is required per fission.
B The purpose of the moderator is to absorb all the heat produced.
C The neutrons required for induced fission of $^{235}_{92}U$ should be slow neutrons.
D The purpose of the control rods is to slow down neutrons to thermal speeds.

END OF SECTION A

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

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

$\Delta W = p\Delta V$

$pV^{\gamma} =$ 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 ▶

 This insert should **not** be sent to the examiner

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

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 = 1.50×10^{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}

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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