General Certificate of Education
January 2007
Advanced Level Examination

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

Section A

Monday 22 January 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.

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 $= Tt$

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

$\Delta W = p\Delta V$

$pV^\gamma = \text{constant}$

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 $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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}

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

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

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

$\lambda_{max}T$ = 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 about **30 minutes** on this section.

1 A particle oscillates with undamped simple harmonic motion. Which one of the following statements about the acceleration of the oscillating particle is true?

A It is least when the speed is greatest.
B It is always in the opposite direction to its velocity.
C It is proportional to the frequency.
D It decreases as the potential energy increases.

2 A simple pendulum and a mass-spring system both have the same time period T at the surface of the Earth. If taken to another planet where the acceleration due to gravity is twice that on Earth, which line, **A** to **D**, in the table gives the correct new periods?

	simple pendulum	**mass-spring**
A	$T\sqrt{2}$	$\frac{T}{\sqrt{2}}$
B	$\frac{T}{\sqrt{2}}$	T
C	$T\sqrt{2}$	T
D	$\frac{T}{\sqrt{2}}$	$T\sqrt{2}$

3 A particle of mass 0.20 kg moves with simple harmonic motion of amplitude 2.0×10^{-2} m. If the total energy of the particle is 4.0×10^{-5} J, what is the time period of the motion?

A $\frac{\pi}{4}$ seconds

B $\frac{\pi}{2}$ seconds

C π seconds

D 2π seconds

4 A loudspeaker produces sound waves in air of wavelength 0.68 m and speed 340 m s^{-1}. How many cycles of vibration does the loudspeaker diaphragm make in 10 ms?

A 5
B 10
C 50
D 100

5 Two long pipes produce stationary waves at their fundamental frequency. Pipe X, of length l, is closed at one end. Pipe Y, which is open at both ends, produces vibrations of the same frequency as pipe X. What is the length of pipe Y?

A $\frac{l}{4}$

B $\frac{l}{2}$

C $2l$

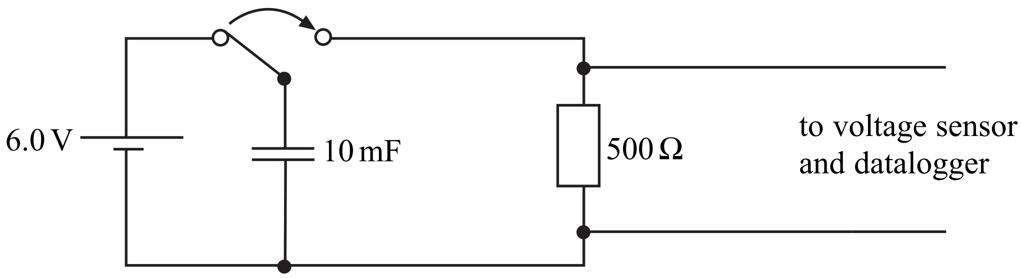
D $4l$

6 How many of the following four equations correctly represent the energy E stored by a capacitor of capacitance C when it is charged to a pd V and its charge is Q?

$$E = \frac{1}{2}\frac{Q^2}{C} \qquad E = \frac{1}{2}\frac{C}{V^2} \qquad E = \frac{1}{2}QC \qquad E = \frac{1}{2}CV^2$$

A one
B two
C three
D four

7 A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s. Which line, **A** to **D**, in the table gives the pd and the number of readings made after a time equal to the time constant of the discharge circuit?



	potential difference/V	**number of readings**
A	2.2	50
B	3.8	50
C	2.2	500
D	3.8	500

8 The relationship between two physical quantities may be inverse, inverse square or exponential. Which line, **A** to **D**, in the table shows correct relationships for

(i) pd and time in capacitor discharge,
(ii) electric field strength and distance in a radial field, and
(iii) gravitational potential and distance in a radial field?

	(i) **capacitor discharge**	(ii) **electric field strength**	(iii) **gravitational potential**
A	exponential	inverse	inverse square
B	inverse	inverse square	exponential
C	inverse square	exponential	inverse
D	exponential	inverse square	inverse

Turn over ▶

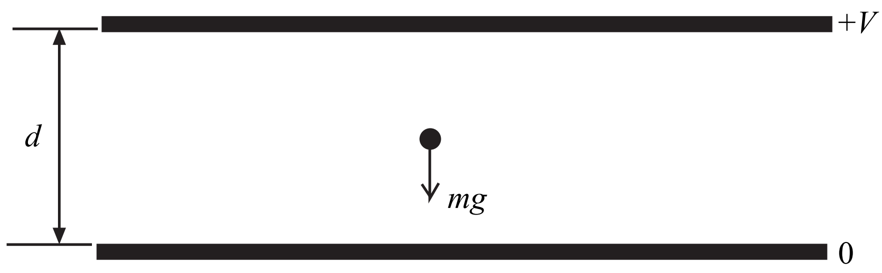
9 For a particle moving in a circle with uniform speed, which one of the following statements is **incorrect**?

A The velocity of the particle is constant.
B The force on the particle is always perpendicular to the velocity of the particle.
C There is no displacement of the particle in the direction of the force.
D The kinetic energy of the particle is constant.

10 What is the angular speed of a car wheel of diameter 0.400 m when the speed of the car is $108\,\text{km}\,\text{h}^{-1}$?

A $75\,\text{rad}\,\text{s}^{-1}$
B $150\,\text{rad}\,\text{s}^{-1}$
C $270\,\text{rad}\,\text{s}^{-1}$
D $540\,\text{rad}\,\text{s}^{-1}$

11



The diagram shows a charged oil drop of weight *mg*, which is stationary in the electric field between two parallel plates. If the potential difference between the plates is *V* and the separation of the plates is *d*, what is the charge on the oil drop?

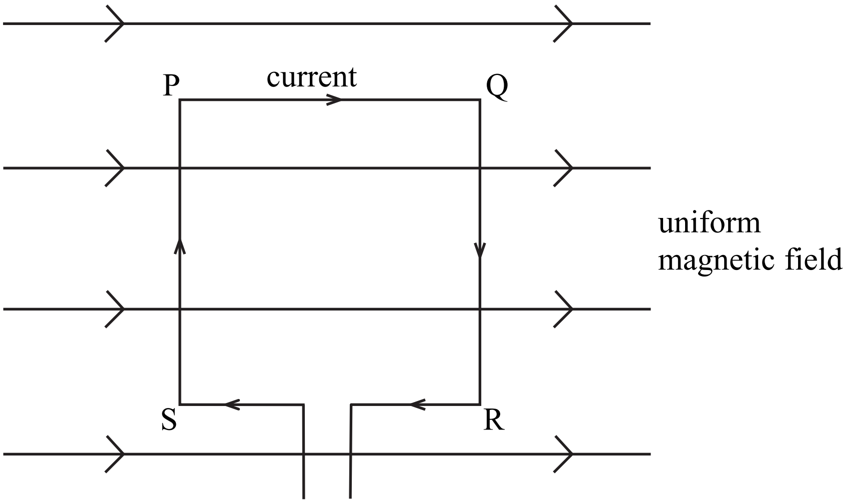
A $-\dfrac{Vd}{mg}$

B $-\dfrac{V}{mgd}$

C $-mgVd$

D $-\dfrac{mgd}{V}$

12



The diagram shows a square coil PQRS placed in a uniform magnetic field with the plane of the coil parallel to the lines of magnetic field. A constant current is passed round the coil in the direction shown, causing a force to act on side PS of the coil. Which one of the following statements about the forces acting on the other sides of the coil is correct?

A A force acts on each of the other sides of the coil.
B No force acts on sides PQ and RS of the coil.
C A force acts on side RS and an equal and opposite force to this force acts on side PQ.
D A force acts on side QR in the same direction as the force that acts on PS.

13 Which one of the following is **not** a unit of magnetic flux?

A $\mathrm{N\,m\,A^{-1}}$
B Wb
C $\mathrm{T\,m^2}$
D $\mathrm{V\,s^{-1}}$

14 The output power of a nuclear reactor is provided by nuclear fuel which decreases in mass at a rate of 4×10^{-6} kg per hour. What is the maximum possible output power of the reactor?

A 28 kW
B 50 MW
C 100 MW
D 200 MW

15 Which one of the following statements concerning a thermal nuclear reactor containing uranium is correct?

If the amount of fissile material in the reactor exceeds the critical mass, the fission reactions

A can be controlled by a suitable absorber of neutrons.
B can be controlled by a suitable moderating material.
C can be controlled if the coolant flows at a fast rate.
D cannot be controlled.

END OF SECTION A

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