Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

Leave blank

General Certificate of Education
June 2003
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION A) PA10
Unit 10 The Synoptic Unit

Thursday 26 June 2003 Morning Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: 2 hours

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.

Information
- The maximum mark for this paper is 80.
- Mark allocations are shown in brackets.
- The paper carries 20% of the total marks for Physics Advanced.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
7			
8			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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 $= Tt$

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

$\Delta W = p\Delta V$

$pV^{\gamma} =$ 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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

magnitude of induced e.m.f. $= N \frac{\Delta \Phi}{\Delta t}$

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

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

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

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

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

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 $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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 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}

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

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

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

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

$v = Hd$

$P = \sigma A T^4$

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

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

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

Medical Physics

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

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ 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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

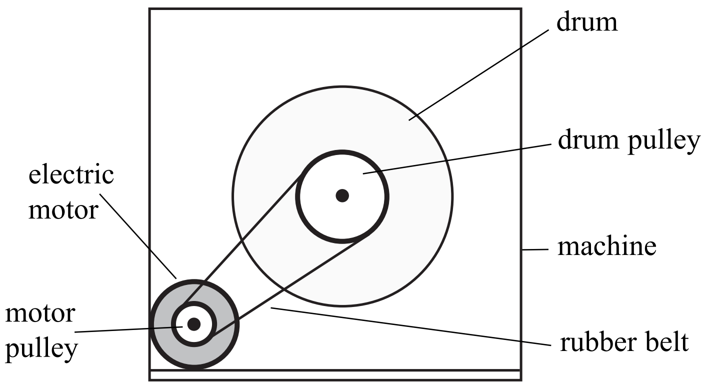
$G = 1 + \frac{R_f}{R_1}$ non-inverting

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

TURN OVER FOR THE FIRST QUESTION

Answer **all** questions.

1 An electric motor in a machine drives a rotating drum by means of a rubber belt attached to pulleys, one on the motor shaft and one on the drum shaft, as shown in the diagram below.



(a) The pulley on the motor shaft has a diameter of 24 mm. When the motor is turning at 50 revolutions per second, calculate

(i) the speed of the belt,

....

....

....

....

(ii) the centripetal acceleration of the belt as it passes round the motor pulley.

....

....

....

....

....

(5 marks)

LEAVE MARGIN BLANK

(b) When the motor rotates at a particular speed, it causes a flexible metal panel in the machine to vibrate loudly. Explain why this happens.

....

....

....

....

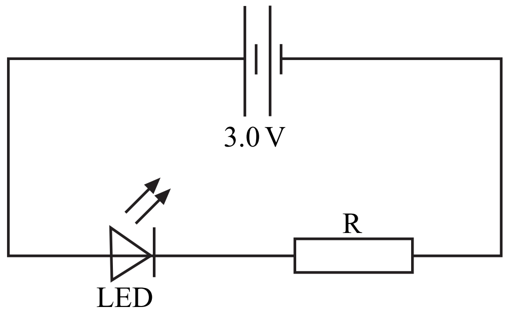
....

(2 marks)

7

TURN OVER FOR THE NEXT QUESTION

2 The circuit diagram shows a light emitting diode (LED) connected in series with a resistor, R, and a 3.0 V battery of negligible internal resistance.



(a) The LED lights normally when the forward voltage across it is 2.2 V and the current in it is 35 mA.

Calculate

(i) the resistance of R,

....

....

....

....

(ii) the number of electrons that pass through the LED each second.

....

....

....

....

(4 marks)

(b) The LED emits light at a peak wavelength of 635 nm.

(i) Calculate the energy of a photon of light of this wavelength.

....

....

....

(ii) Estimate the number of photons emitted by the LED each second when the current through it is 35 mA. Assume all the photons emitted by the LED are of wavelength 635 nm and that all the electrical energy produces light.

....

....

....

....

....

....

(4 marks)

8

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

3 (a) A solar panel of area $2.5\,m^2$ is fitted to a satellite in orbit above the Earth. The panel produces a current of 2.4 A at a potential difference of 20 V when solar radiation is incident normally on it.

(i) Calculate the electrical power output of the panel.

....

....

....

(ii) Solar radiation on the satellite has an intensity of $1.4\,kW\,m^{-2}$. Calculate the efficiency of the panel.

....

....

....

....

....

(4 marks)

(b) The back-up power system in the satellite is provided by a radioactive isotope enclosed in a sealed container which absorbs the radiation from the isotope. Energy from the radiation is converted to electrical energy by means of a thermoelectric module.

(i) The isotope has an activity of 1.1×10^{14} Bq and produces α particles of energy 5.1 MeV. Show that the container absorbs energy from the α particles at a rate of $90\,J\,s^{-1}$.

....

....

....

....

....

....

....

(ii) The isotope has a half-life of 90 years. Calculate the decay constant λ of this isotope.

....

....

....

LEAVE MARGIN BLANK

(iii) The mass number of the isotope is 239.
Calculate the mass of isotope needed for an activity of 1.1×10^{14} Bq.

....

....

....

....

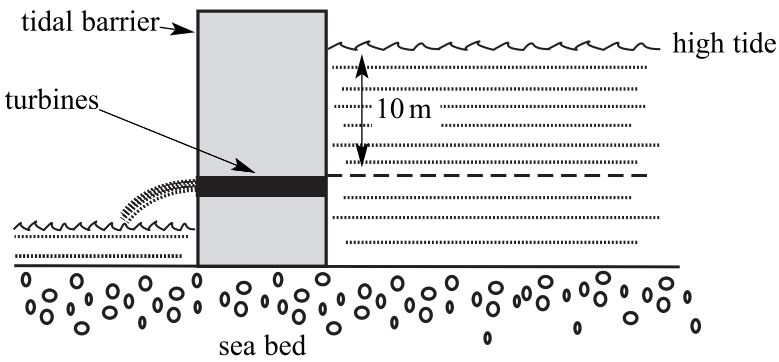
....

(7 marks)

11

TURN OVER FOR THE NEXT QUESTION

4 Tidal power could make a significant contribution to UK energy requirements. This question is about a tidal power station which traps sea water behind a tidal barrier at high tide and then releases the water through turbines 10.0 m below the high tide mark.



(i) Calculate the mass of sea water covering an area of 120 km^2 and depth 10.0 m.

density of sea water = 1100 $kg\,m^{-3}$

....

....

....

(ii) Calculate the maximum loss of potential energy of the sea water in part (i) when it is released through the turbines.

....

....

....

....

(iii) The potential energy of the sea water released through the turbines, calculated in part (ii), is lost over a period of 6.0 hours. Estimate the average power output of the power station over this time period. Assume the power station efficiency is 40%.

....

....

....

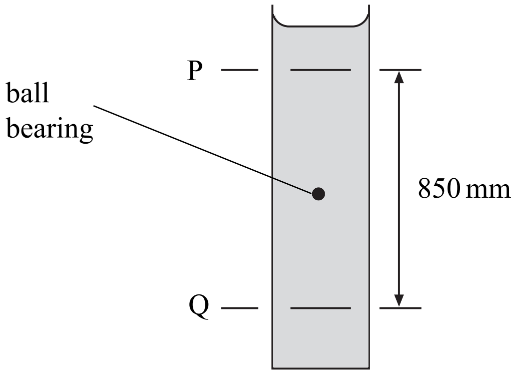
....

....

....

(7 marks)

5 A student carried out an experiment to determine the terminal speed of various ball bearings as they fell through a viscous liquid. She did this by timing their fall between two marks, P and Q, which were 850 mm apart on a vertical glass tube.



You may be awarded marks for the quality of written communication in your answer.

(a) (i) Describe the motion of a ball bearing after being released from rest at the surface.

....

....

....

....

....

(ii) In terms of the forces acting, explain why a ball bearing reaches a terminal speed under these conditions.

....

....

....

....

....

(5 marks)

QUESTION 5 CONTINUES ON PAGE 14

(b) The student's results are shown in **columns A** and **B**. Complete **column C**.

column A	**column B**	**column C**	**column D**	**column E**
radius of ball bearing r / mm	time of fall / s (through 850 mm)	terminal speed v / mm s^{-1}	$\log_{10}(r/\text{mm})$	$\log_{10}(v/\text{mm s}^{-1})$
1.62	32.0		0.210	
1.98	21.4		0.297	
2.21	17.2		0.344	
2.73	11.3		0.436	
3.40	7.2		0.531	
4.12	4.9		0.615	

(2 marks)

(c) The relationship between v and r is known to be of the form

$$v = kr^n,$$

where n and k are constants.

(i) Enter the corresponding values for $\log_{10}(v/\text{mm s}^{-1})$ in **column E** of the table in part (b).

(ii) Using the grid opposite, plot a graph of $\log_{10}(v/\text{mm s}^{-1})$ on the y-axis, against $\log_{10}(r/\text{mm})$ on the x-axis. *(4 marks)*

(d) Use your graph to determine

(i) the constant n,

....

....

....

....

(ii) the constant k.

....

....

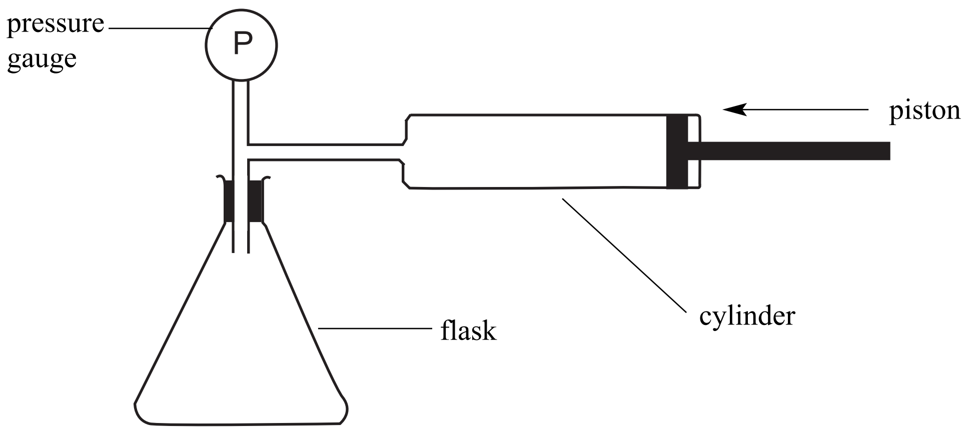
....

(5 marks)

16

LEAVE MARGIN BLANK

6 The diagram shows an arrangement that is used to measure the density of a powder. The air in the cylinder is forced into the flask and the air pressure is measured, by the pressure gauge P, before and after the change. The test is then repeated with the powder present in the flask. In both tests, the initial pressure in the flask is the same.



(a) (i) Explain why, after compression of the air the pressure in the flask is greater when the powder is present than when it is not present.

You may be awarded marks for the quality of written communication in your answer.

....

....

....

....

(ii) Calculate the pressure in the flask, after compression at constant temperature, when no powder was present. Assume that the volume of the tubes and pressure gauge is negligible.

volume of the empty flask = $2.50 \times 10^{-4}\,\text{m}^3$
volume of the cylinder = $1.00 \times 10^{-4}\,\text{m}^3$
initial pressure of the air in the flask and cylinder = 100 kPa.

....

....

....

....

....

....

(b) To test the apparatus, 0.13 kg of powder of density 2700 kg m^{-3} was placed in the flask before compression.

(i) Calculate the volume of this amount of powder.

....

....

....

(ii) The pressure of the air in the flask increased to 150 kPa when the test was carried out with this amount of powder in the flask. By carrying out an appropriate calculation, justify whether or not the test was successful.

....

....

....

....

....

....

....

....

....

(5 marks)

11

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

7 (a) An electric shower heats water from 15 °C to 47 °C when water flows through it at a rate of 0.045 kg s^{-1}.

(i) Calculate the energy supplied to the water each second by the heating element in the shower.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

....

....

....

....

(ii) Show that the power of the heating element is 6.0 kW. Assume there is no heat loss to the surroundings.

....

....

(3 marks)

(b) (i) The heating element in part (a) is connected to an alternating supply at 230 V rms. Calculate the rms current passing through the heating element in normal operation.

....

....

(ii) The live wire and the neutral wire in the connecting cable are insulated copper wires of diameter 2.4 mm. Calculate the resistance per metre length of copper wire of this diameter.

resistivity of copper = 1.7×10^{-8} Ω m

....

....

....

....

....

....

....

(iii) Show that in normal operation, the potential drop per metre along the cable is $0.20\,V\,m^{-1}$.

....

....

....

....

(iv) Electrical safety regulations require the potential drop along the cable to be less than 6.0 V. Calculate the maximum safe distance along the cable from the distribution board to the heating element.

....

....

....

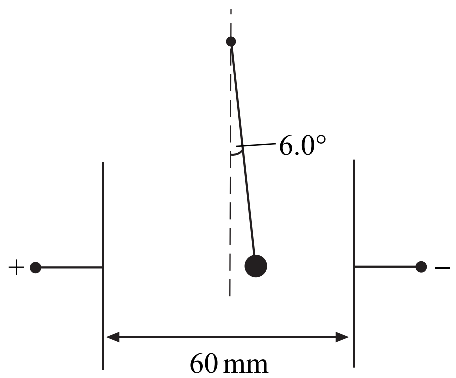
(9 marks)

12

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

8 A small charged sphere of mass 2.1×10^{-4} kg, suspended from a thread of insulating material, was placed between two vertical parallel plates 60 mm apart. When a potential difference of 4200 V was applied to the plates, the sphere moved until the thread made an angle of 6.0° to the vertical, as shown in the diagram below.



(a) Show that the electrostatic force F on the sphere is given by

$$F = mg \tan 6.0°$$

where m is the mass of the sphere.

....

....

....

....

....

(3 marks)

(b) Calculate

(i) the electric field strength between the plates,

....

....

(ii) the charge on the sphere.

....

....

....

....

(3 marks)

6

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*