Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Subsidiary Examination

PHYSICS (SPECIFICATION A) **PA02**
Unit 2 Mechanics and Molecular Kinetic Theory

Friday 8 June 2007 9.00 am to 10.00 am

For this paper you must have:
- a calculator
- a pencil and a ruler.

Time allowed: 1 hour

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

Information
- The maximum mark for this paper is 50.
- Two of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- The marks for questions are shown in brackets.
- **A *Data Sheet* is provided on pages 3 and 4. Please do not attempt to detach this sheet at the start of the examination as this page is not perforated.**
- Questions 2(d) and 3(b) should be answered in continuous prose. In these questions you will be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

For Examiner's Use			
Question	Mark	Question	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
TOTAL			
Examiner's Initials			

Data Sheet

- A *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.
- Please do not attempt to remove the data sheet as the page is not perforated.

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

magnitude of induced 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

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

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

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

$\Delta Q = ml$

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

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

Nuclear Physics and Turning Points in Physics

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

$\text{force} = Bev$

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

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

$\text{work done} = eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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 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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

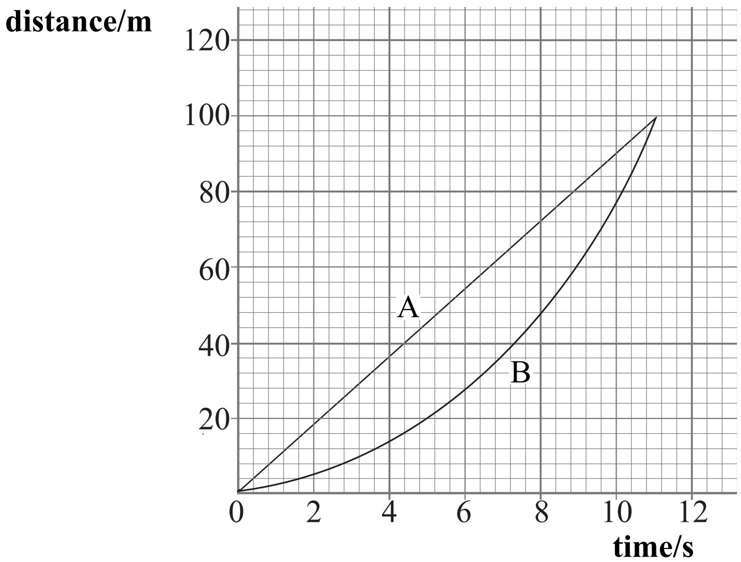
$G = -\frac{R_f}{R_1}$ inverting

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

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

Answer **all** questions.

1 The distance-time graphs for two runners, A and B, in a 100 m race are shown.



(a) Explain how the graph shows that athlete B accelerates throughout the race.

....

....

(1 mark)

(b) Estimate the maximum distance between the athletes.

....

(1 mark)

(c) Calculate the speed of athlete A during the race.

....

(1 mark)

(d) The acceleration of athlete B is uniform for the duration of the race.

(i) State what is meant by uniform acceleration.

....

(ii) Calculate the acceleration of athlete B.

....

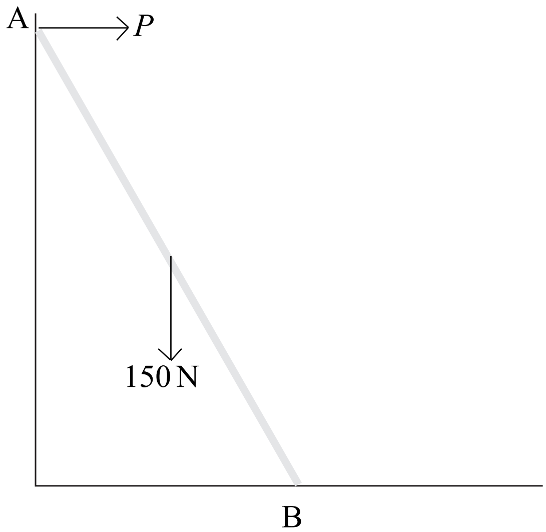
....

(3 marks)

6

2 **Figure 1** shows two of the forces acting on a uniform ladder resting against a smooth vertical wall.

Figure 1



The ladder is 6.0 m long and has a weight of 150 N. The horizontal force, *P*, exerted on the ladder by the wall is 43 N. Force *Q* (not shown) is the force the ground exerts on the ladder at B.

(a) Explain why the force, *Q* must have

(i) a vertical component,

....

....

(ii) a horizontal component.

....

....

(2 marks)

(b) Draw an arrow on the diagram to represent the force *Q*.

(1 mark)

(c) State the

(i) horizontal component of *Q*, ...

(ii) vertical component of *Q*. ....

(2 marks)

(d) State and explain the effect on force *Q* if a person stands on the bottom of the ladder and the direction of P is unchanged.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

....

....

....

....

(3 marks)

8

Turn over for the next question

3 A cylinder of fixed volume 8.2×10^{-3} m^3 contains gas at a temperature of 295 K and a pressure of 4.2×10^5 Pa.

(a) Calculate

(i) the amount of gas in the cylinder in moles,

....

....

(ii) the average kinetic energy of the gas molecules.

....

....

(3 marks)

(b) The temperature of the gas in the cylinder is decreased.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

(i) How does this change affect the motion of the gas molecules?

....

....

....

(ii) State and explain, using the kinetic theory, the effect this has on the pressure of the gas.

....

....

....

(4 marks)

LEAVE MARGIN BLANK

(c) Another cylinder of the same volume contains a gas at the same temperature and pressure as the original gas but whose molecules have a greater mass. Explain why the amount of energy required to raise the temperature of both gases by the same amount is identical.

....

....

....

(2 marks)

9

Turn over for the next question

4 Ice of mass 22 g at temperature –12 °C is taken from a freezer and placed in a polystyrene cup containing water at a temperature 22 °C.

specific heat capacity of ice = 2100 J kg^{-1} K^{-1}
specific latent heat of fusion of ice = 3.3×10^5 J kg^{-1}

(a) Calculate the quantity of heat needed

(i) to raise the temperature of the ice from –12 °C to 0 °C,

....

....

(ii) to change the ice to water without an increase in temperature.

....

....

(3 marks)

(b) The temperature of the water in the cup falls after the ice has been added.

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

(i) Calculate the mass of the water in the cup if the lowest temperature reached by the water is 8 °C.

....

....

....

(ii) State an assumption you have made in part (b)(i).

....

....

(4 marks)

7

LEAVE MARGIN BLANK

5 An athlete performs an experiment to measure the power developed as he runs up a flight of stairs. The athlete makes the assumption that the work done in climbing the stairs is equal to the gain in potential energy.

(i) State the measurements that would be needed to find the power developed by the athlete.

....

....

....

....

(ii) Show how the measurements would be used to calculate the power developed as the athlete runs up the stairs.

....

....

....

....

....

(iii) Explain why the power calculated by the athlete is likely to be less than the power actually developed.

....

....

....

(8 marks)

8

6 (a) State the principle of moments.

....

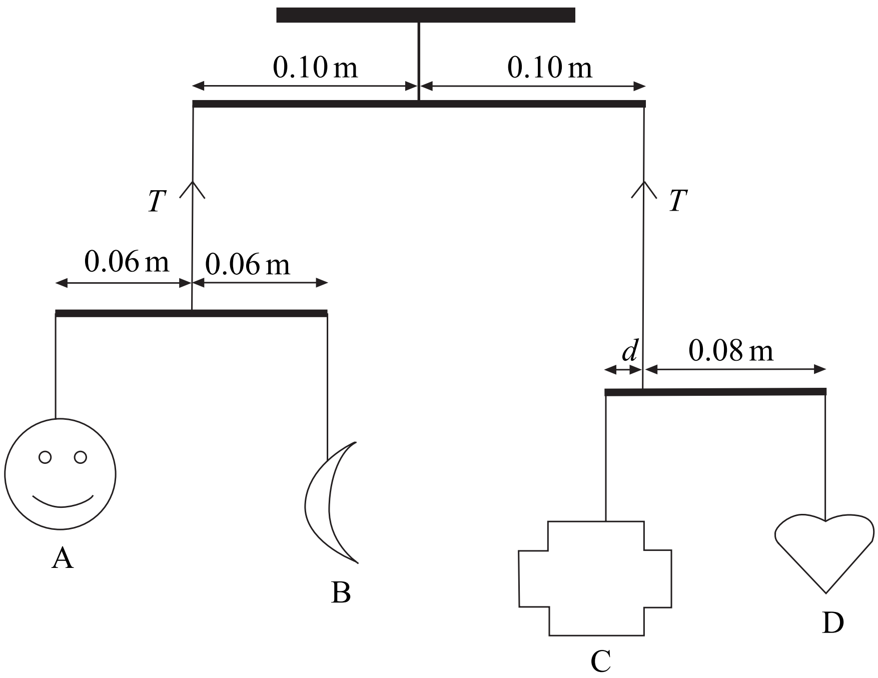
....

....

(2 marks)

Figure 2 shows a child's mobile in equilibrium.

Figure 2



A piece of cotton thread is attached to the rod supporting objects A and B and another piece of cotton thread supports the rod holding objects C and D. The tension in the cotton threads is T and all the rods are horizontal.

(b) (i) Complete the following table assuming the weights of the rods are negligible.

weight of object A /N	**weight of object B /N**	**weight of object C /N**	**weight of object D /N**
0.40			0.10

LEAVE MARGIN BLANK

(ii) Calculate the distance, *d*.

....

....

(iii) Calculate the magnitude of *T*.

....

(5 marks)

(c) Object A becomes detached and falls to the ground. State and explain the initial effect on

(i) the rod holding objects A and B,

....

....

(ii) the rod holding objects C and D,

....

....

(iii) the rod closest to the top of the mobile.

....

....

(3 marks)

10

Quality of Written Communication (*2marks*)

2

END OF QUESTIONS

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