

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
 June 2004
 Advanced Subsidiary Examination



PA02

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

Monday 14 June 2004 Afternoon Session

<p>In addition to this paper you will require:</p> <ul style="list-style-type: none"> • a calculator; • a pencil and a ruler.
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For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1)	→		
Total (Column 2)	→		
TOTAL			
Examiner's Initials			

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 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 50.
- Mark allocations are shown in brackets.
- The paper carries 30% of the total marks for Physics Advanced Subsidiary and carries 15% 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.

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	a	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	$\omega_2 = \omega_1 + at$		$\theta \approx \frac{\lambda}{D}$	
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} at^2$		$1/n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$		$1/n_2 = \frac{n_2}{n_1}$	
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				$\text{work done per cycle} = \text{area of loop}$		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	
<i>Class</i>	<i>Name</i>	<i>Symbol</i>	<i>Rest energy</i>	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$		$R_T = R_1 + R_2 + R_3 + \dots$	
			/MeV	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$		$P = I^2 R$	
photon	photon	γ	0	$\text{friction power} = \text{indicated power} - \text{brake power}$		$E = \frac{F}{Q} = \frac{V}{d}$	
lepton	neutrino	ν_e	0	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$		$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$	
		ν_μ	0	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$		$E = \frac{1}{2} QV$	
mesons	electron	e^\pm	0.510999			$F = BI$	
	muon	μ^\pm	105.659			$F = BQv$	
	pion	π^\pm	139.576			$Q = Q_0 e^{-l/RC}$	
	kaon	K^\pm	493.821			$\Phi = BA$	
baryons	proton	p	938.257				
	neutron	n	939.551				
Properties of quarks							
<i>Type</i>	<i>Charge</i>	<i>Baryon number</i>	<i>Strangeness</i>				
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 = $\frac{4}{3}\pi r^3$							

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

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

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

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

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

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

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

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

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

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

TURN OVER FOR THE FIRST QUESTION

Turn over ▶

Answer **all** questions.

- 1 The aeroplane shown in **Figure 1** is travelling horizontally at 95 m s^{-1} . It has to drop a crate of emergency supplies.
The air resistance acting on the crate may be neglected.

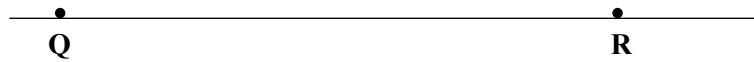
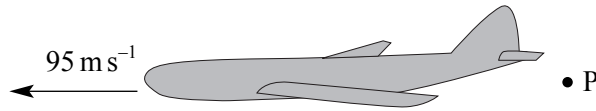


Figure 1

- (a) (i) The crate is released from the aircraft at point **P** and lands at point **Q**. Sketch the path followed by the crate between **P** and **Q** as seen from the ground.
- (ii) Explain why the horizontal component of the crate's velocity remains constant while it is moving through the air.

.....

.....

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(3 marks)

- (b) (i) To avoid damage to the crate, the maximum vertical component of the crate's velocity on landing should be 32 m s^{-1} . Show that the maximum height from which the crate can be dropped is approximately 52 m.

.....

.....

.....

- (ii) Calculate the time taken for the crate to reach the ground if the crate is dropped from a height of 52 m.

.....

.....

(iii) If **R** is a point on the ground directly below **P**, calculate the horizontal distance **QR**.

.....
.....
(6 marks)

(c) In practice air resistance is **not** negligible. State and explain the effect this has on the maximum height from which the crate can be dropped.

.....
.....
(2 marks)

11

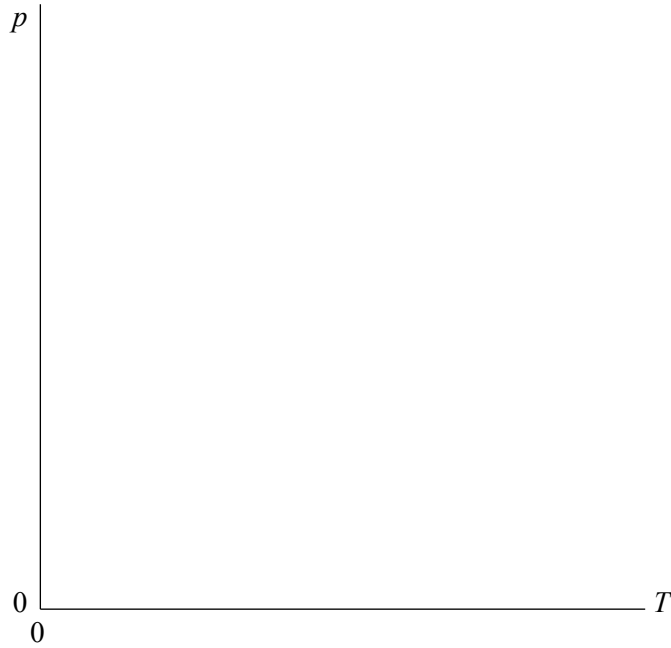
TURN OVER FOR THE NEXT QUESTION

Turn over ▶

2 (a) State the equation of state for an ideal gas.

.....
(1 mark)

(b) A fixed mass of an ideal gas is heated while its volume is kept constant. Sketch a graph on the axes below to show how the pressure, p , of the gas varies with the absolute temperature, T , of the gas.



(2 marks)

(c) Explain in terms of molecular motion, why the pressure of the gas in part (b) varies with the absolute temperature.

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

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(4 marks)

(d) Calculate the average kinetic energy of the gas molecules at a temperature of 300 K.

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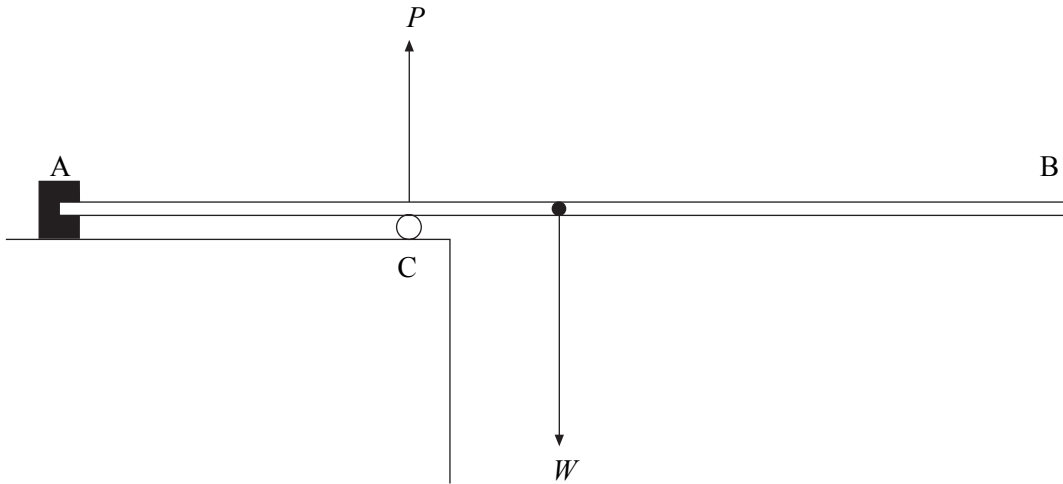
(2 marks)

3 (a) Define the moment of a force.

.....

(2 marks)

(b) The diagram shows a uniform diving board of weight, W , that is fixed at A. The diving board is supported by a cylinder at C, that exerts an upward force, P , on the board.



(i) By considering moments about A, explain why the force P must be greater than the weight of the board, W .

.....

(ii) State and explain what would be the effect on the force P of a girl walking along the board from A to B.

.....

(4 marks)

4 A skydiver of mass 70 kg, jumps from a stationary balloon and reaches a speed of 45 m s^{-1} after falling a distance of 150 m.

(a) Calculate the skydiver's

(i) loss of gravitational potential energy,

.....
.....

(ii) gain in kinetic energy.

.....
.....

(4 marks)

(b) The difference between the loss of gravitational potential energy and the gain in kinetic energy is equal to the work done against air resistance. Use this fact to calculate

(i) the work done against air resistance,

.....
.....

(ii) the average force due to air resistance acting on the skydiver.

.....
.....
.....

(3 marks)

7

- 5 (a) A 2.0 kW heater is used to heat a room from 5 °C to 20 °C. The mass of air in the room is 30 kg. Under these conditions the specific heat capacity of air = 1000 J kg⁻¹K⁻¹.

Calculate

- (i) the gain in thermal energy of the air,

.....
.....

- (ii) the minimum time required to heat the room.

.....
.....
.....

(4 marks)

- (b) State and explain **one** reason why the actual time taken to heat the room is longer than the value calculated in part (a)(ii).

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.....
.....
.....

(2 marks)

6

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

6 A golf club undergoes an *inelastic* collision with a golf ball and gives it an initial velocity of 60 m s^{-1} . The ball is in contact with the club for 15 ms and the mass of the ball is $4.5 \times 10^{-2} \text{ kg}$.

(a) Explain what is meant by an inelastic collision.

.....

(1 mark)

(b) Calculate

(i) the change in momentum of the ball,

.....

(ii) the average force the club exerts on the ball.

.....

.....

(4 marks)

(c) (i) State the value of the force exerted by the ball on the club and give its direction.

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.....

(ii) Explain how your answer to part (i) follows from an appropriate law of motion.

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

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(4 marks)

QUALITY OF WRITTEN COMMUNICATION (2 marks)

END OF QUESTIONS

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