Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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

Friday 12 January 2007　　1.30 pm to 2.30 pm

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. You may wish to detach this perforated sheet at the start of the examination.
- Questions 3(c) and 6(c) 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.

PA02

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	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

$v = u + at$

$s = \left(\dfrac{u+v}{2}\right)t$

$s = ut + \dfrac{at^2}{2}$

$v^2 = u^2 + 2as$

$F = \dfrac{\Delta(mv)}{\Delta t}$

$P = Fv$

$efficiency = \dfrac{power\ output}{power\ input}$

$\omega = \dfrac{v}{r} = 2\pi f$

$a = \dfrac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2}I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

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 $\times$ fuel flow rate

indicated power as (area of $p - V$ loop) $\times$ (no. of cycles/s) $\times$ (no. of cylinders)

friction power $=$ indicated power $-$ brake power

$efficiency = \dfrac{W}{Q_{in}} = \dfrac{Q_{in} - Q_{out}}{Q_{in}}$

maximum possible $efficiency = \dfrac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

$g = \dfrac{F}{m}$

$g = -\dfrac{GM}{r^2}$

$g = -\dfrac{\Delta V}{\Delta x}$

$V = -\dfrac{GM}{r}$

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f \sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\dfrac{m}{k}}$

$T = 2\pi\sqrt{\dfrac{l}{g}}$

$\lambda = \dfrac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \dfrac{\lambda}{D}$

$_1n_2 = \dfrac{\sin\theta_1}{\sin\theta_2} = \dfrac{c_1}{c_2}$

$_1n_2 = \dfrac{n_2}{n_1}$

$\sin\theta_c = \dfrac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

$\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$

$c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

Data Sheet

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

$$\text{work done} = eV$$

$$F = 6\pi \eta r v$$

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

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

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

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

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

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

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

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

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

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}

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

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

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

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

$$v = Hd$$

$$P = \sigma A T^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

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

Answer **all** questions.

1 (a) A balloon contains 0.40 mol of helium at 300 K. Calculate

   (i) the number of helium atoms in the balloon,

   ....

   ....

   (ii) the average kinetic energy of a helium atom in the balloon,

   ....

   ....

   (iii) the total kinetic energy of the helium atoms in the balloon.

   ....
   (4 marks)

(b) The temperature of the helium in the balloon is increased.

   (i) How does this change affect the motion of the helium atoms?

   ....

   ....

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

   ....

   ....

   ....

   ....
   (4 marks)

8

Turn over ▶

2 (a) A cheetah accelerating uniformly from rest reaches a speed of $29 \, \text{m s}^{-1}$ in $2.0 \, \text{s}$ and then maintains this speed for $15 \, \text{s}$. Calculate

(i) its acceleration,

....

....

(ii) the distance it travels while accelerating,

....

....

(iii) the distance it travels while it is moving at constant speed.

....

(4 marks)

(b) The cheetah and an antelope are both at rest and $100 \, \text{m}$ apart. The cheetah starts to chase the antelope. The antelope takes $0.50 \, \text{s}$ to react. It then accelerates uniformly for $2.0 \, \text{s}$ to a speed of $25 \, \text{m s}^{-1}$ and then maintains this speed. The graph shows the speed-time graph for the cheetah.
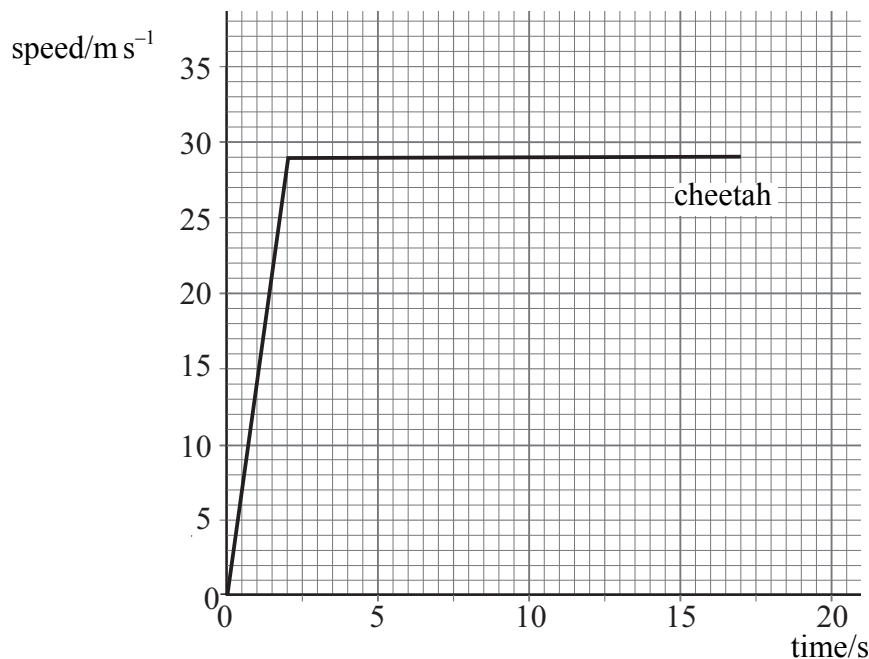
(i) Using the same axes plot the speed-time graph for the antelope during the chase.

(ii) Calculate the distance covered by the antelope in the 17 s after the cheetah started to run.

....

....

....

(iii) How far apart are the cheetah and the antelope after 17 s?

....

....
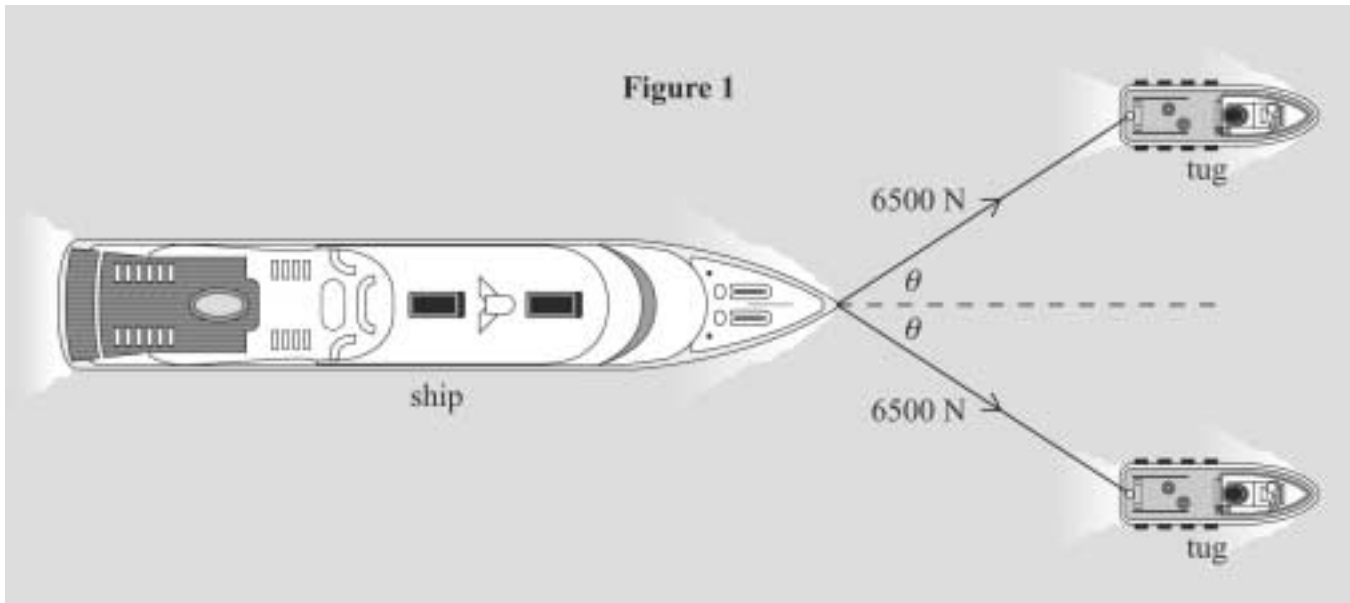
(6 marks)

10

Turn over for the next question

Turn over ▶

3 **Figure 1** shows a ship being pulled along by cables attached to two tugs.

Figure 1

(a) The tension in each cable is 6500 N and the ship is moving at a constant speed of 1.5 m s⁻¹. When θ is equal to 35°, calculate

(i) the resultant force exerted on the ship by the cables,

....

....

....

(ii) the work done by the tension in the cables in one minute.

....

....

....
(4 marks)

(b) Explain why the work done on the ship does not result in a gain in its kinetic energy.

....

....
(2 marks)

(c) State and explain the initial effect on the ship if the angle θ is reduced while the tension in the cables remains constant.

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

....

....

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....

....

(3 marks)

9

Turn over for the next question

4 (a) The intensity of solar radiation incident on a solar panel is $400 \, \text{W m}^{-2}$. The solar panel uses this radiation to heat water flowing through it. The panel has an area of $6.0 \, \text{m}^2$ and 80% of the solar radiation is absorbed by the water.

specific heat capacity of water $= 4200 \, \text{J kg}^{-1} \, \text{K}^{-1}$

Calculate

  (i) the energy received by the panel in one second,

....

  (ii) the energy absorbed by the water in one second,

....

  (iii) the temperature rise of the water if it flows through the panel at a constant rate of $3.0 \times 10^{-2} \, \text{kg s}^{-1}$.

....

....

(4 marks)

(b) The panel moves during the day so that the solar radiation always strikes its surface at right angles. State and explain the effect on the temperature rise of the water if the panel is not free to move.

....

....

....

....

(2 marks)

6

5 (a) Define the moment of a force.

....

....

....
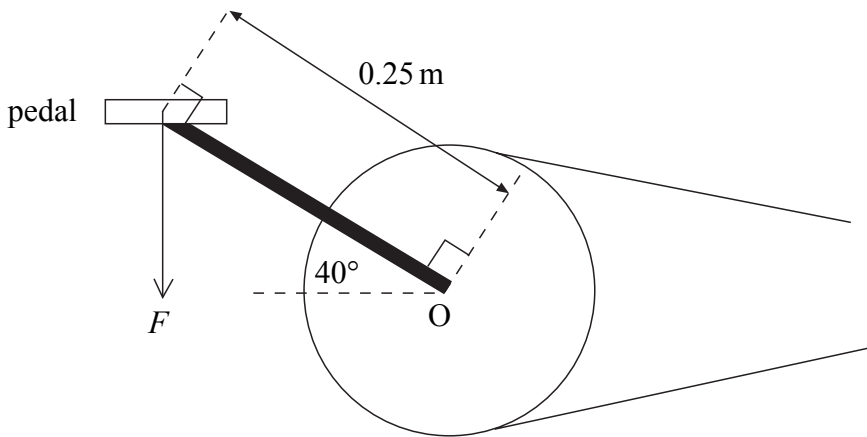*(2 marks)*

(b) **Figure 2** shows the force, *F*, acting on a bicycle pedal.

Figure 2

(i) The moment of the force about O is 46 N m in the position shown. Calculate the value of the force, *F*.

....

....
(2 marks)

(ii) Force, *F*, is constant in magnitude and direction while the pedal is moving downwards. State and explain how the moment of *F* changes as the pedal moves through 80°, from the position shown.

....

....

....
(2 marks)

6

Turn over ▶

6 **Figure 3** shows two trolleys, A and B, of equal mass, travelling towards each other at the same speed, u.

Figure 3

(a) State and explain why the initial total momentum of the trolleys is zero.

....

....

(2 marks)

(b) The trolleys collide and then move apart. If no resultant external forces are acting, explain why

(i) the velocity of trolley A must be equal and opposite to the velocity of trolley B,

....

....

....

....

(ii) the speed of each trolley will be smaller as a result of the collision.

....

....

....

....

(4 marks)

(c)   Describe how you would measure the speed of trolley A after the collision.

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

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....

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(3 marks)

9

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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