Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2005
Advanced Level Examination

PHYSICS (SPECIFICATION A) PA10
Unit 10 The Synoptic Unit

Monday 27 June 2005 Afternoon 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			
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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.

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

$v = u + at$

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

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

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

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

$P = Fv$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

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 $= \frac{\textit{tensile stress}}{\textit{tensile strain}} = \frac{F}{A}\frac{l}{e}$

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

LEAVE MARGIN BLANK

Answer **all** questions.

1 A winch in a boatyard uses a 230 V electric motor to raise objects from a boat onto the quayside, as shown in **Figure 1**.

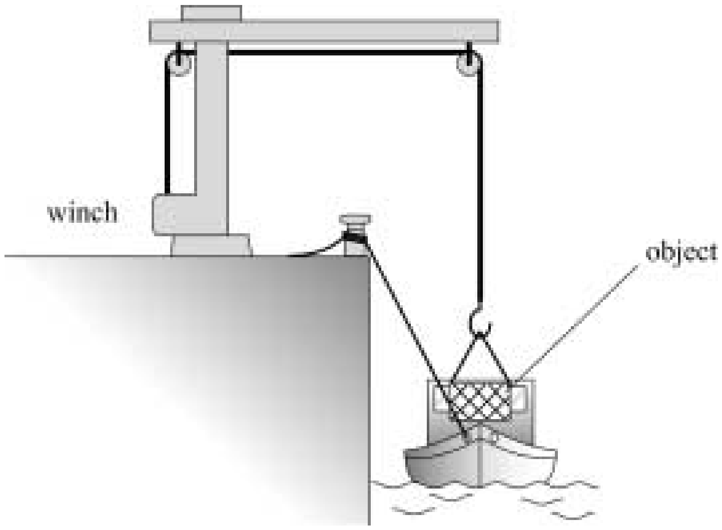

Figure 1

(a) The winch takes 22 s to raise an object of mass 160 kg through a height of 5.0 m. The motor current during this time is 14 A. Calculate the efficiency of the winch.

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(3 marks)

LEAVE MARGIN BLANK

(b) (i) The steel cable that is used to raise the 160 kg object has a cross-sectional area of $1.8 \times 10^{-4}\,m^2$. Calculate the strain in the cable when it raises the object at constant speed.

the Young modulus for steel = 2.1×10^{11} Pa

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(ii) The length of steel cable from the object to the winch is 14 m when the object is on the boat. Calculate the extension of the cable when it supports the object.

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(5 marks)

8

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

LEAVE MARGIN BLANK

2 (a) Suggest **two** reasons why an α particle causes more ionisation than a β particle of the same initial kinetic energy.

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

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(2 marks)

(b) A radioactive source has an activity of 3.2×10^9 Bq and emits α particles, each with kinetic energy of 5.2 MeV. The source is enclosed in a small aluminium container of mass 2.0×10^{-4} kg which absorbs the radiation completely.

(i) Calculate the energy, in J, absorbed from the source each second by the aluminium container.

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(ii) Estimate the temperature rise of the aluminium container in **1 minute**, assuming no energy is lost from the aluminium.

specific heat capacity of aluminium = $900\ \mathrm{J\,kg^{-1}\,K^{-1}}$

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(5 marks)

7

3 A wind turbine, as shown in **Figure 2**, has blades of length 22 m. When the wind speed is $15\,\text{m}\,\text{s}^{-1}$ its output power is 1.5 MW.

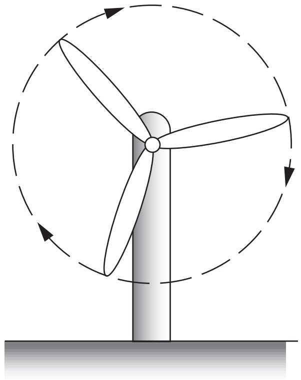

Figure 2

(i) The volume of air passing through the blades each second can be calculated by considering a cylinder of radius equal to the length of the blade. Show that $2.3 \times 10^4\,\text{m}^3$ of air passes through the blades each second.

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(ii) Calculate the mass of air that passes through the blades each second.

density of air = $1.2\,\text{kg}\,\text{m}^{-3}$

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(iii) Calculate the kinetic energy of the air reaching the blades each second.

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(iv) Assuming that the power output of the turbine is proportional to the kinetic energy of the air reaching the blades each second, discuss the effect on the power output if the wind speed decreased by half.

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(7 marks)

7

4 A steel wire of diameter 0.24 mm is stretched between two fixed points 0.71 m apart. A U-shaped magnet is placed at the centre of the wire so that the wire passes between its poles, as shown in **Figure 3**.

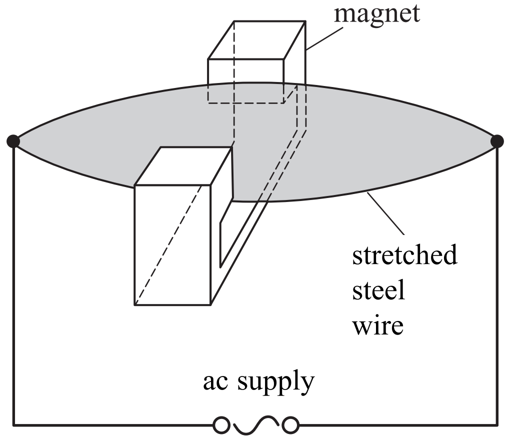

Figure 3

(a) (i) Explain why the wire vibrates when an alternating current is passed through it.

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

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(ii) Explain why the wire vibrates strongly in its fundamental mode when the frequency of the alternating current is 290 Hz.

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(iii) Show that the speed of the waves on the wire is 410 m s^{-1}.

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(6 marks)

(b) The speed, c, of waves on a wire of mass per unit length, μ, is related to the tension, T, in the wire by

$$c = \sqrt{\frac{T}{\mu}}.$$

(i) The wire in **Figure 3** is at a tension of 60 N. Calculate its mass per unit length.

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(ii) Hence calculate the density of the metal.

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(5 marks)

$\overline{}$ *11*

TURN OVER FOR THE NEXT QUESTION

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5 Whilst investigating the oscillations of a helical spring, a student carried out measurements when various masses were suspended from the spring. For each mass, the length l of the spring was measured and 50 vertical oscillations were timed. The results are shown in the table.

length l/mm	time for 50 oscillations/s	time period T/s	T^2/s^2
316	12.5	0.25	0.063
333	17.5		
349	22.0		
364	25.5		
381	28.5		
397	31.0		

(a) Complete the table. *(2 marks)*

(b) The time period for vertical oscillations is given by

$$T = 2\pi\sqrt{\frac{m}{k}},$$

where m is the mass suspended and k is the spring constant.

(i) Assuming that the spring obeys Hooke's law, show that

$$T^2 = 4\pi^2\frac{(l - l_0)}{g},$$

where l_0 is the length of the unloaded spring.

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(ii) Plot a graph of T^2 against l.

QUESTION 5 CONTINUES ON PAGE 14

Turn over

(iii) Use the graph to determine values for g and l_0.

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(9 marks)

(c) Estimate the value of l which would give a time period of 1.00 s. State and explain **one** reason why the behaviour of the spring may cause your estimated value to be incorrect.

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(4 marks)

15

TURN OVER FOR THE NEXT QUESTION

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6 **Figure 4** shows a sonar device suspended by a cable from a helicopter. The device is used to detect submarines.

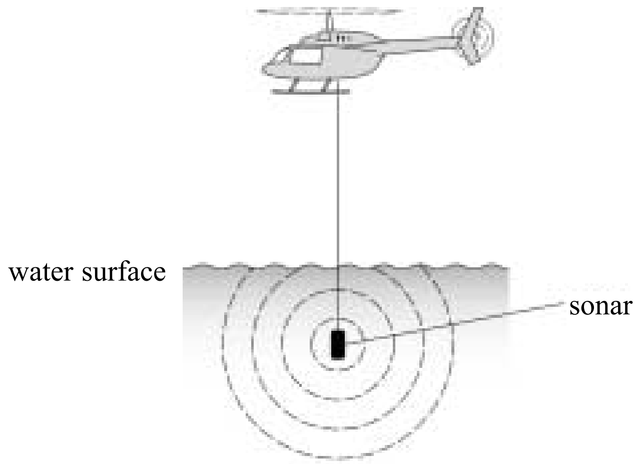

Figure 4

(a) With the device below the water surface, it emits pulses of sound at a constant rate. After each pulse is transmitted, it is used to detect pulses reflected by underwater objects.
Figure 5 shows a screen display of the reflected pulses received for each transmitted pulse.

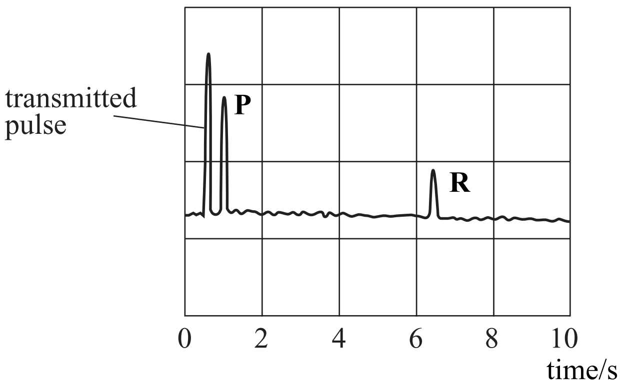

Figure 5

(i) Pulse **P** is due to partial reflection from the surface directly above the sonar. A further pulse **R** is observed. Pulse **R** is due to a reflection by a submarine. Calculate the distance from the submarine to the sonar.

speed of sound in seawater = $1500\,m\,s^{-1}$

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(ii) Discuss how the display shown in **Figure 5** would differ if the distance to the submarine had been half the value calculated in part (a) (i).

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(6 marks)

(b) **Figure 6** shows the sonar device raised out of the water to a fixed height above the surface.

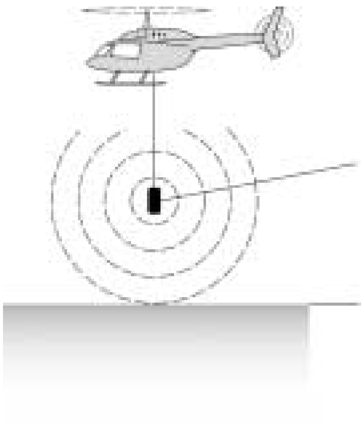

Figure 6

(i) Calculate the critical angle for sound waves in air at the surface.

speed of sound in air = $340\,\mathrm{m\,s^{-1}}$
speed of sound in the seawater = $1500\,\mathrm{m\,s^{-1}}$

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(ii) Explain why sound waves from the sonar device cannot enter the water beyond a certain distance from the device. Assume the water surface is flat.

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(4 marks)

10

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7 (a) (i) At the surface of a spherical planet of radius R, show that the gravitational potential, V_s, is related to the gravitational field of strength, g_s, by

$$V_s = -g_s R.$$

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(ii) The gravitational field strength of the Moon at its surface is $1.6\,\mathrm{N\,kg^{-1}}$. Show that the gravitational potential energy of an oxygen molecule at the surface is $-1.4 \times 10^{-19}\,\mathrm{J}$.

radius of the Moon = 1700 km
molar mass of oxygen = $0.032\,\mathrm{kg\,mol^{-1}}$

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(5 marks)

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(b) Oxygen gas at 400 K is released on the surface of the Moon.

(i) Calculate the mean kinetic energy of an oxygen gas molecule at this temperature.

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(ii) The maximum temperature of the surface of the Moon is about 400 K. Use the data opposite and the results of your calculations to explain why some of the oxygen gas released at the Moon's surface would escape into space.

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(4 marks)

9

TURN OVER FOR THE NEXT QUESTION

8 The hydrogen atom may be represented as a central proton with an electron moving in a circular orbit around it as shown in **Figure 7**. When the atom is in the ground state, the radius of the electron's orbit is 5.3×10^{-11} m.

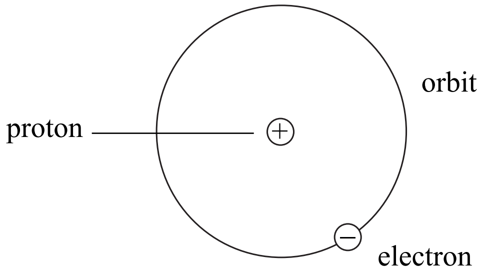

Figure 7

(a) By applying this model to the hydrogen atom in the ground state, calculate

(i) the force of electrostatic attraction between the electron and the proton,

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(ii) the speed of the electron,

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(iii) the ratio of the de Broglie wavelength of the electron to the circumference of the orbit.

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(6 marks)

(b) The total energy of the electron in a hydrogen atom may be shown to have discrete values given, in J, by

$$E = -\frac{2.2 \times 10^{-18}}{n^2},$$

where n = 1 for the ground state, n = 2 for the first excited state, and so on.

(i) Calculate the wavelength of the light emitted when the electron returns to the ground state from the first excited state.

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(ii) Explain why visible light will **not** be produced by any transition in which the electron returns to the ground state.

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(5 marks)

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11

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*

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2

END OF QUESTIONS

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