Surname			Other	Names			
Centre Number	r			Cand	lidate Number		
Candidate Sign	ature						

General Certificate of Education June 2008 Advanced Level Examination

PHYSICS (SPECIFICATION B) Unit 5 Fields and their Applications

PHB5

Tuesday 17 June 2008 1.30 pm to 3.30 pm

For this paper you must have:

- a calculator
- a ruler

• a loose insert containing formulae sheets and a comprehension passage to be used for Questions 6, 7, 8, 9, 10, and 11.

Time allowed: 2 hours

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer all questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- The passage for answering Questions 6, 7, 8, 9, 10 and 11 is provided on the loose insert. Read the passage before answering the questions.

Information

- The maximum mark for this paper is 100. Four of these marks will be awarded for the Quality of Written Communication.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- You are reminded of the need for good English and clear presentation in your answers. Questions 4(c) and 8 should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.
- The Formulae Sheet is provided on the loose insert to this paper.

F	or Exam	iner's Us	e		
Question	Mark	Question	Mark		
1		9			
2		10			
3		11			
4					
5					
6					
7					
8	8				
Total (Column 1)					
Total (Column 2)					
TOTAL					
Examiner's Initials					



QUALIFICATIONS ALLIANCE

For Examiner's Use

other such

1 (a) Show that the speed of Pluto in orbit is about $4.7 \,\mathrm{km \, s^{-1}}$. Assume that the orbit is circular.

(3 marks)

 (b) The escape velocity is the velocity of an object at the surface of a planet that would allow it to be removed completely from the planet's gravitational field. Calculate the escape velocity for an object on the surface of Pluto.

(3 marks)

1	(c)	Pluto's atmosphere is mostly methane and nitrogen. The surface temperature is -220 °C and the atmospheric pressure is 0.30 Pa.
1	(c)	(i) Calculate the number of moles of gas per m^3 in the atmosphere of Pluto. universal molar gas constant = 8.3 $Jmol^{-1}K^{-1}$
1	(c)	(ii) Suggest why this value is so low.
		Turn over for the post question
		i ut ii over for the next question

2 Radiocarbon dating is an effective tool in dating ancient wooden objects. The method uses radioactive carbon-14 $\binom{14}{6}$ C) which decays to nitrogen (N) by the emission of a β^{-} particle. It has been estimated that the Earth and its atmosphere contain about 2.5×10^{30} atoms of radioactive carbon-14 which is assumed to remain fairly constant.

half-life of carbon-14 = 5700 years Avogadro constant = $6.0 \times 10^{23} \text{mol}^{-1}$ 1 year = $3.2 \times 10^7 \text{ s}$

2 (a) (i) Calculate the total activity of all the carbon-14 in the Earth and its atmosphere.

2 (a) (ii) Calculate the mass of carbon-14 that is formed in the upper atmosphere each second to replace the carbon-14 that decays.

(5 marks)

2 (b) Write down the complete nuclear equation for the decay of carbon-14.

(3 marks)



- 2 (c) A sample of wood from a tree recently chopped down has an activity of 0.75 Bq. The activity of a sample of wood of equal mass from an old wooden boat has an activity of 0.52 Bq.
- 2 (c) (i) Calculate the approximate age of the boat. Give your answer in years.

2 (c) (ii) The carbon-14 content of the atmosphere may be higher now than when the boat was made. State and explain the effect this would have on the estimated age of the boat.

Turn over for the next question





3	(b)	(ii) V v F	When the alpha particle was a long way from the gold nucleus, its kinetic energy was 7.2×10^{-13} J. Calculate the speed of the alpha particle as it moves through boint P .
3	(b)	(iii) S	Show on Figure 1, the path that the same alpha particle would follow if the gold
		r	nucleus had a higher proton number. (7 marks)
3	(c)	State the ignored	he effect of the collision on the gold nucleus and why this effect could be d in part (b)(ii).
			(3 marks)

4 The table shows the masses of some particles and nuclei.

particle	mass/10 ⁻²⁷ kg
$^{1}_{1}p$	1.674
1_0 n	1.675
²³⁵ ₉₂ U	390.406
$^{90}_{36}$ Kr	149.357
$^{144}_{56}\mathrm{Ba}$	239.056

1 MeV	=	1.6×10^{-13} J
speed of electromagnetic radiation	=	$3.0 \times 10^8 \mathrm{ms}^{-1}$
Avogadro constant	=	$6.0 \times 10^{23} \text{mol}^{-1}$

4 (a) The following reaction occurs in a nuclear reactor.

 ${}^{235}_{92}U \ + \ {}^{1}_{0}n \ \ \rightarrow \ {}^{90}_{36}Kr \ \ + \ {}^{144}_{56}Ba \ \ + \ {}^{1}_{0}n$

Calculate the mass change when 0.50kg of uranium-235 undergoes fission by this reaction.

(3 marks)

4 (b) (i) Calculate the binding energy of a uranium-235 nucleus. Give your answer in J.

4	(b)	(ii) Calculate the binding energy per nucleon. Give your answer in MeV.	
		(6 marks)
4	(c)	Describe	
		 how energy is extracted from a hot nuclear reactor core to produce electricity how the power output of the reactor is controlled. 	
		Two of the 8 marks are available are for the quality of your written communication.	
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		(8 marks	;)
			/



5 Figure 2 shows the side view of the principal components of a magneto-hydrodynamic propulsion system for a boat. Figure 3 shows the cross-section through the system looking towards the water intake end. The system is fitted to the bottom of the boat as shown in Figure 4.



(4 marks)

5 (b) (i) Calculate the electric field strength in the region between the electrodes.

5 (b) (ii) The resistivity of sea water is $0.20 \Omega m$. Show that the current in the sea water is about 860 A.

(6 marks)

- 5 (c) The boat has four such systems to produce motion giving a top speed of $7.5 \,\mathrm{m\,s}^{-1}$.
- 5 (c) (i) Calculate the maximum thrust produced.

5 (c) (ii) Calculate the total power developed by the propulsion system when moving at top speed.

Question 5 continues on the next page



The passage on the insert is for answering Questions 6 to 11. Read the passage before answering Questions 6 to 11. 6 Figure 5 shows part of a magnetron. Figure 5 positive anode • cathode (a) Define the direction of an electric field. 6 _____ (1 mark) (b) Draw on Figure 5, the *radial electric field*. Show the direction of the electric field. 6 (2 marks) Turn over for the next question

(i) Show that when the electrons reach the anode their velocity is about $4 \times 10^7 \,\mathrm{m\,s}^{-1}$. 7 (a) Assume that the electrons leave the cathode with no kinetic energy. 7 (ii) Calculate the magnetic flux density of the field that makes the electrons move in (a) a circular path of radius 30 mm in the magnetron. (6 marks) 7 (b) A designer suggests increasing the inside radius of the anode but keeping the magnetic field strength at the same magnitude. State and explain how the accelerating voltage would have to change if the new arrangement is to work. (3 marks) www.theallpapers.com

8	Explain what is meant by 'transformer action' (line 17).
	Two of the 6 marks are available for the quality of your written communication.
	(6 marks)
9	Calculate the number of photons emitted each second by the magnetron in the microwave oven (lines 19 - 21).
	(2 marks)
	Turn over for the next question
	Furn over for the next question

10 The standing wave (line 25) could be set up when waves are reflected from the wall opposite the magnetron.

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10 (a) (i) Calculate the wavelength of the microwaves in the oven.

10 (a) (ii) Draw on Figure 6, a standing wave that could be set up along XY for a microwave oven with a width of 366 mm. Assume that there is a node at Y.





11	(a)	Microwaves are dangerous. State two design features that prevent microwaves escaping from the oven.
		First feature
		Second feature
		(2 marks)
11	(b)	Suggest how energy is transferred to cook the inside of large items of food and why there is less need for 'waiting time' when heating liquids.
		(2 marks)
		END OF QUESTIONS

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PHYSICS (SPECIFICATION B) Unit 5 Fields and their Applications

Formulae Sheet

Foundation Physics Mechanics Formulae moment of force = Fd v = u + at $s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(u + v)t$ for a spring, $F = k\Delta l$ energy stored in a spring $= \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$ $T = \frac{1}{f}$ Foundation Physics Electricity Formulae I = nAvqterminal p.d. = E - Irin series circuit, $R = R_1 + R_2 + R_3 +$

in parallel circuit, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$ output voltage across $R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times$ input voltage

Waves and Nuclear Physics Formulae

PHB5

fringe spacing
$$= \frac{\lambda D}{d}$$

single slit diffraction minimum sin $\theta = \frac{\lambda}{b}$

diffraction grating $n\lambda = d\sin\theta$

Doppler shift $\frac{\Delta f}{f} = \frac{v}{c}$ for $v \ll c$

Hubble law v = Hd

radioactive decay $A = \lambda N$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
ū	$-\frac{2}{3}e$	$-\frac{1}{3}$
d	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Dortiala	Le	pton numbe	r L
Particle	L_e	L_{μ}	$L_{ au}$
e -	1		
e +	-1		
v_{e}	1		
\overline{v}_{e}	-1		
μ-		1	
μ^+		-1	
v_{μ}		1	
$\overline{v}_{\!\mu}$		-1	
τ-			1
au +			-1
$v_{ au}$			1
$\overline{v}_{ au}$			-1

Geometrical and Trigonometrical Relationships





This insert page should **not** be sent to the examiner

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Microwave Ovens

The passage printed on pages 2 and 3 of this loose insert is for answering Questions 6, 7, 8, 9, 10 and 11.

Microwave ovens are now used in many homes and restaurants. The microwaves in an oven are produced by a magnetron such as that shown schematically in **Figure A**.



The heated cathode, **C**, is at the centre of the anode which is a ring of metal a few mm thick. This ring has a number of circular holes cut in it with small gaps as shown in **Figure A**. These holes are called cavities.

Electrons produced at the cathode **C** are accelerated towards the positive anode in the radial electric field produced by a potential difference of 4000 V. At the same time a magnetic field, perpendicular to the diagram in **Figure A**, causes the electrons to move in a spiral path which increases in radius as they move outwards. When the electrons reach the anode they are moving in a circular path of radius 30 mm. The arrangement causes the electrons to move in 'bunches' 10 and, as each bunch passes a cavity gap, energy is transferred to the cavity. This action makes electrons in the anode oscillate around each cavity setting up alternating magnetic fields in the cavities. **Figure B** shows the direction of the oscillations for one of the cavities.



5

Figure A

The energy stored in a cavity alternates between the magnetic field in the cavity and the electric field in the capacitor formed at the gap. The total energy builds up as each cavity resonates. The resonant frequency of the magnetron is determined by the radius of the cavity and the dimensions of the gap.

The energy is extracted due to 'transformer action' in a coupling coil in one of the cavities. This coil behaves like the secondary of a transformer and is shown in **Figure A** and **Figure B**. The coil is connected to a short aerial which transmits microwaves through a waveguide into the oven. The microwaves in an oven have a frequency of about 2450 MHz. A typical oven has an input power of 1500 W of which 1100 W is converted to microwave energy. Some energy is used to rotate the food on a turntable and some is lost in heating internal parts of the oven and the surroundings.

Figure C shows a cross-section through a microwave oven.



The inside of the oven is lined with metal which reflects the waves and the microwave photons transfer energy to the water in the food being cooked. The design of the oven has to take account of the fact that standing waves can be set up inside the oven which could mean that some parts of the food being cooked would receive no energy at all. The rotating turntable can minimise this effect. Microwaves are dangerous and can also affect radio and TV reception so designers have to ensure that the intensity of any escaping microwaves is at a safe level.

Microwaves photons pass on energy to water molecules. This increases the temperature of the water in the food which results in the food being cooked. Microwave intensity decreases exponentially with distance travelled in the food so that only the outer parts of the food are cooked directly by the microwaves. Heat transferred from the outer parts cooks the inner region so that the procedure requires some 'waiting time' during cooking and before serving to ensure that cooking is complete although this is less necessary when heating liquids.

Data required when answering questions

Planck constant	$= 6.7 \times 10^{-34} \mathrm{Js}$
speed of electromagnetic radiation	$= 3.0 \times 10^8 \mathrm{m s^{-1}}$
electron charge	$= -1.6 \times 10^{-19} \text{C}$
electron mass	$= 9.1 \times 10^{-31} \text{kg}$

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Circular Motion and Oscillations

$$v = r\omega$$

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

$$x = A \cos 2\pi f t$$
maximum $a = (2\pi f)^{2}A$
maximum $v = 2\pi f A$
for a mass-spring system, $T = 2\pi \sqrt{\frac{m}{k}}$
for a simple pendulum, $T = 2\pi \sqrt{\frac{l}{g}}$

Fields and their Applications

uniform electric field strength, $E = \frac{V}{d} = \frac{F}{Q}$ for a radial field, $E = \frac{kQ}{r^2}$ $k = \frac{1}{4\pi\varepsilon_0}$ $g = \frac{F}{m}$ $g = \frac{GM}{r^2}$ for point masses, $\Delta E_{\rm p} = GM_1M_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ for point charges, $\Delta E_{\rm p} = kQ_1Q_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

for a straight wire, F = BIl

for a moving charge,
$$F = BQv$$

$$\phi = BA$$

induced emf = $\frac{\Delta(N\phi)}{t}$
 $E = mc^{2}$

Temperature and Molecular Kinetic Theory

$$T/K = \frac{(pV)_{T}}{(pV)_{tr}} \times 273.16$$

$$pV = \frac{1}{3} Nm \langle c^{2} \rangle$$
energy of a molecule = $\frac{3}{2} kT$

Heating and Working

$$\Delta U = Q + W$$
$$Q = mc\Delta\theta$$
$$Q = ml$$
$$P = Fv$$

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

work done on gas
$$= p \Delta V$$

work done on a solid
$$= \frac{1}{2} F\Delta l$$

stress $= \frac{F}{A}$
strain $= \frac{\Delta l}{l}$
Young modulus $= \frac{\text{stress}}{l}$

strain

Capacitance and Exponential Change

in series,
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

in parallel, $C = C_1 + C_2$
energy stored by capacitor $= \frac{1}{2}QV$
parallel plate capacitance, $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$
 $Q = Q_0 e^{-t/RC}$
time constant $= RC$
time to halve $= 0.69 RC$
 $N = N_0 e^{-\lambda t}$
 $A = A_0 e^{-\lambda t}$
half-life, $t_{\frac{1}{2}} = \frac{0.69}{\lambda}$

Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

$$hf = \Phi + E_{k(max)}$$

$$hf = E_2 - E_1$$

$$\lambda = \frac{h}{mv}$$