Candidate Name	Centre Number	Candidate Number

WELSH JOINT EDUCATION COMMITTEE
General Certificate of Education
Advanced

CYD-BWYLLGOR ADDYSG CYMRU
Tystysgrif Addysg Gyffredinol
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545/01

PHYSICS

ASSESSMENT UNIT PH5: FIELDS, FORCES AND NUCLEI

A.M. THURSDAY, 15 June 2006

(1 hour 30 minutes)

ADDITIONAL MATERIALS

In addition to this paper, you may require a calculator.

INSTRUCTIONS TO CANDIDATES

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

You are advised to spend not more than 45 minutes on questions 1 to 5.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 90.

The number of marks is given in brackets at the end of each question or part question.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

Your attention is drawn to the information "Mathematical Data and Relationships" on the back page of this paper.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

For Examiner's use only.	
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Fundamental Constants

Avogadro constant	N_A	=	$6{\cdot}0 \times 10^{23}$ mol^{-1}
Fundamental electronic charge	e	=	$1{\cdot}6 \times 10^{-19}$ C
Mass of an electron	m_e	=	$9{\cdot}1 \times 10^{-31}$ kg
Mass of a proton	m_p	=	$1{\cdot}67 \times 10^{-27}$ kg
Molar gas constant	R	=	$8{\cdot}3$ J mol^{-1} K^{-1}
Acceleration due to gravity at sea level	g	=	$9{\cdot}8$ m s^{-2}
[Gravitational field strength at sea level	g	=	$9{\cdot}8$ N kg^{-1}]
Universal constant of gravitation	G	=	$6{\cdot}7 \times 10^{-11}$ N m^2 kg^{-2}
Planck constant	h	=	$6{\cdot}6 \times 10^{-34}$ J s
Unified mass unit	1 u	=	$1{\cdot}66 \times 10^{-27}$ kg
Boltzmann constant	k	=	$1{\cdot}38 \times 10^{-23}$ J K^{-1}
Speed of light *in vacuo*	c	=	$3{\cdot}0 \times 10^{8}$ m s^{-1}
Permittivity of free space	ε_o	=	$8{\cdot}9 \times 10^{-12}$ F m^{-1}
Permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}

1. In the past, watches used radioactive isotopes as energy sources to ensure that the dials and hands on the watch faces were always 'luminous'. Ideally, a pure alpha particle emitter was mixed with paint to produce this effect.

(a) Explain why the wearer of this type of 'luminous' watch should be completely safe from radioactive emission from the watch face. [2]

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(b) The total initial activity of this 'ideal' radioactive watch was 26×10^6 Bq and each of the alpha particles had energy 5·5 MeV. Calculate the total initial output power of the alpha particles. [2]

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(c) The half-life of the radioactive isotope in the paint is 68 years. Calculate the decay constant of the radioactive isotope. [2]

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(d) Calculate the activity of the watch after 40 years. [2]

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(e) A Geiger counter recorded the activity of this watch over 40 years and found that the activity **measured just outside the watch** was gradually increasing. Suggest briefly how this might be possible (remember that nuclei produced from alpha decay are not usually stable). [2]

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2. *(a)* The nucleus $^{56}_{26}Fe$ is considered to be the most stable nucleus of all. Calculate the binding energy per nucleon for this nucleus from the following data. [3]

Mass of $^{56}_{26}Fe$ nucleus = 55·920 67u, Mass of a proton = 1·007 28u,
Mass of a neutron = 1·008 66u, 1u ≡ 931 MeV

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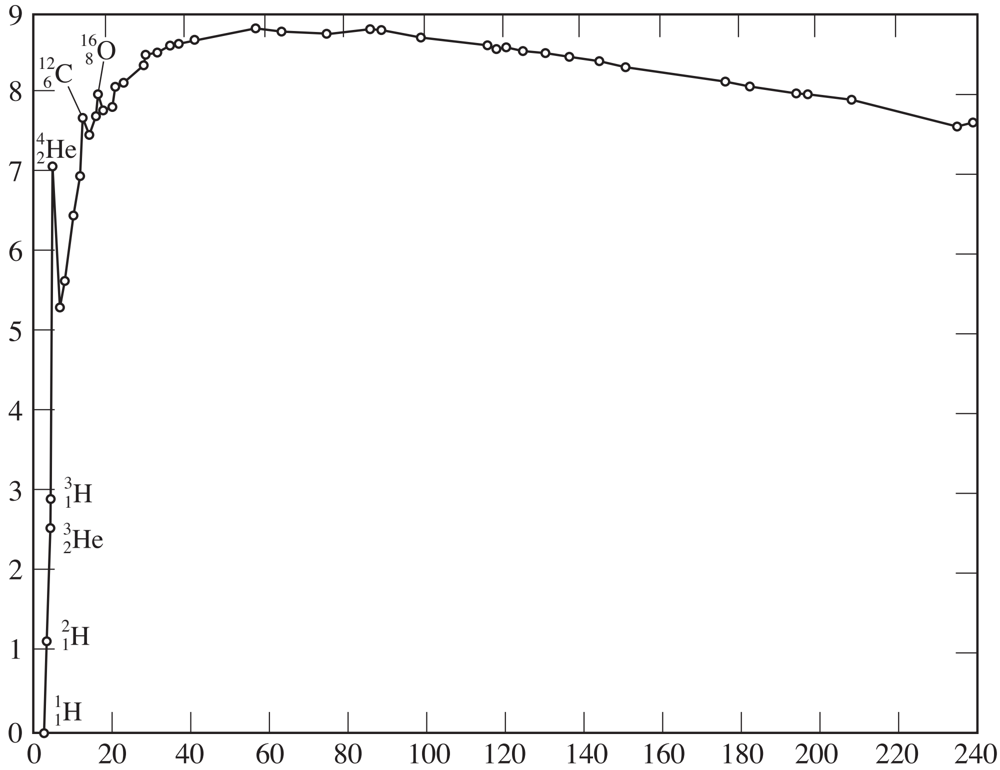
(b) (i) Label the axes of the graph relating to nuclear stability shown below. [2]



(ii) Explain very briefly why $^{1}_{1}H$ has a value of 0 on the *y-axis*. [1]

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(iii) Indicate, on the graph opposite, the region where elements are most likely to undergo nuclear fission. [1]

(iv) Describe briefly the process by which a sustainable fission chain reaction is produced. [3]

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3. *(a)* P and Q are points in an electric field.

(i) Calculate the work done when a +0·42 μC point charge moves from P to Q. [4]

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(ii) Explain briefly what the kinetic energy of the + 0.42 μC point charge would be if it were allowed to move freely from rest at P to Q. [2]

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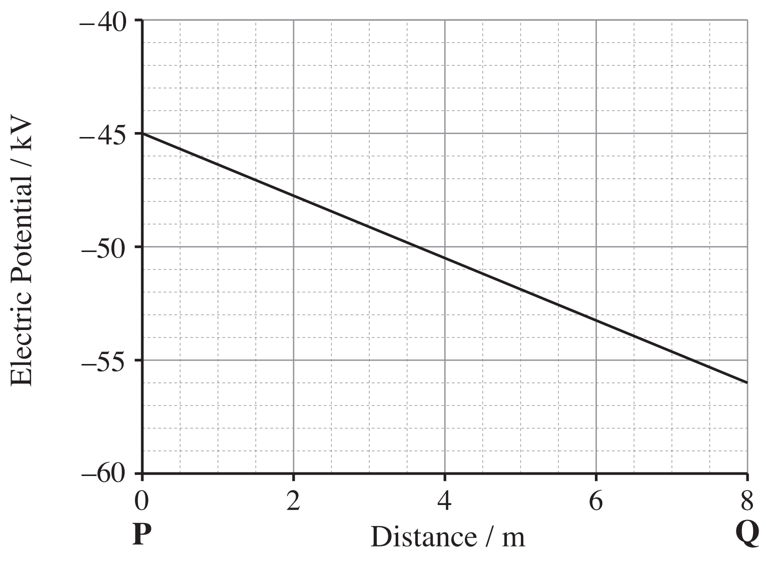
(b) A graph of electric potential against distance between P and Q is shown below.



(i) Calculate the electric field strength between P and Q. [2]

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(ii) State, giving a reason, the direction of this electric field. [2]

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4. *(a)* State Faraday's Law of electromagnetic induction. [2]

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The uniform magnetic flux density inside a long solenoid (ignoring any end effects) is

$$B = \mu_o nI$$

This expression, combined with Faraday's Law, leads to the following expression for the induced emf, E, in a long solenoid with a total number of turns, N.

$$E = -NA\mu_o n \times \text{ rate of change of current}$$

(b) Show that the self inductance, L, of the solenoid can be written as

$$L = \mu_o n^2 V$$

where V is the volume of the space inside the long solenoid. [4]

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(c) The current flowing through a long solenoid is changed uniformly from 7·3 A to 0·0 A in 0·053 s. The e.m.f. induced in the solenoid is 15 V.

(i) Show that the self inductance of the solenoid is around 0·1 H. [2]

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(ii) If the long solenoid has 2500 turns per metre, calculate its volume. [2]

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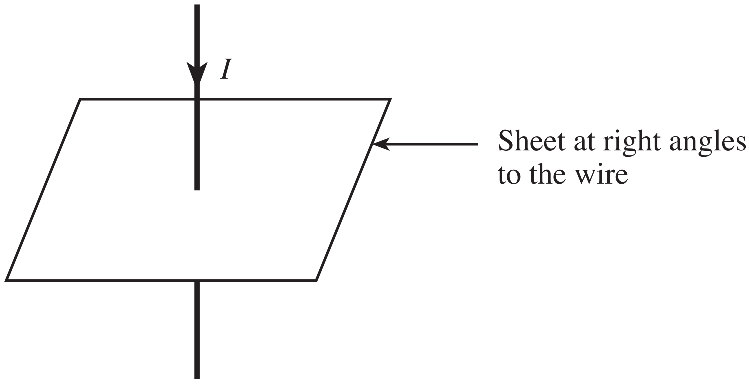
5. *(a)* (i) Part of a long wire carrying a current is shown below. Sketch some magnetic field lines due to this current-carrying wire. [1]



(ii) The current flowing through the wire is 38 A. Calculate the magnetic flux density a perpendicular distance 10 cm from the wire. The magnetic flux density due to a long straight wire is given by $B = \frac{\mu_0 I}{2\pi a}$. [2]

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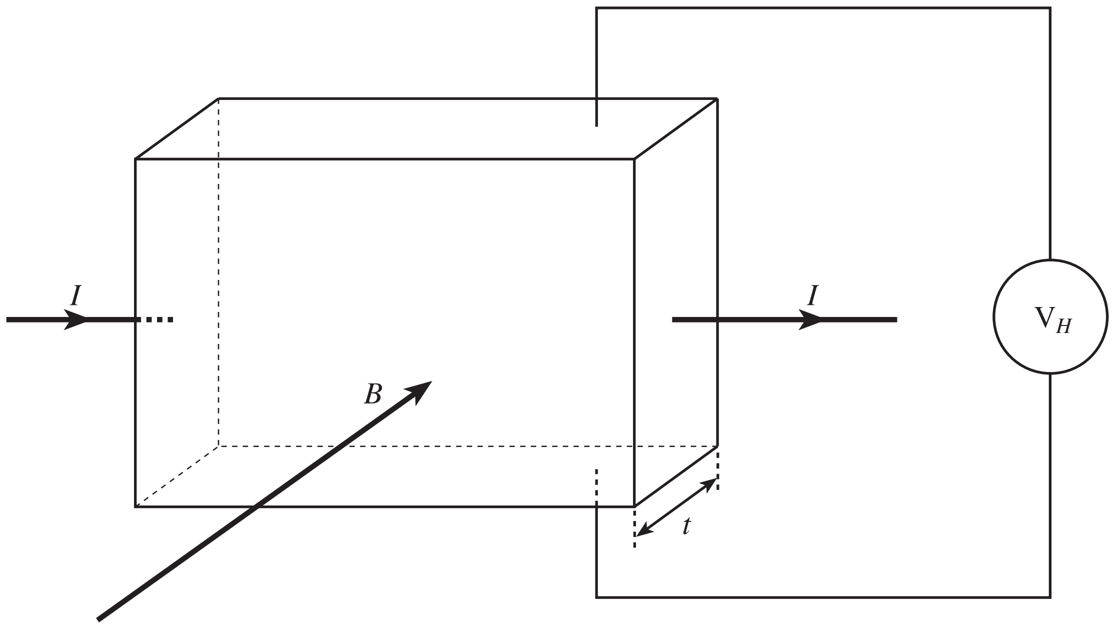
(b) Derive the expression for the Hall voltage $V_H = \frac{BI}{tnq}$. Refer to the diagram below. [5]

(n is the number of charge carriers per m^3).



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(c) A Hall probe is placed at a perpendicular distance of 10 cm from the wire in part *(a)*. For the probe, t = 0·10 cm, it has 2·5 × 10^{20} free electrons per m^3, has a current of 0·35A flowing through it and the Hall voltage is 6·3 × 10^{-4} V.

Calculate the magnetic flux density as measured by the Hall probe. [2]

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6. *(a)* Explain briefly the process by which electromagnetic waves are scattered by electrons and explain why these scattered waves are coherent with the incident wave. [4]

(b) (i) Show that the momentum, p, of a particle of mass m is related to its kinetic energy, E_k, by the relationship [2]

$$p^2 = 2mE_k$$

(ii) Use the above relationship to calculate the accelerating potential required for electrons to have a de Broglie wavelength of $4{\cdot}5 \times 10^{-11}$ m. [5]

(iii) Explain briefly why $4{\cdot}5 \times 10^{-11}$ m is an appropriate wavelength to probe crystal structures. [2]

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(c) Various experiments using electrons accelerated to high energies suggest that atomic nuclei are spherical. Calculate the average density of a $^{12}_{6}C$ nucleus given that its radius is approximately $2{\cdot}5 \times 10^{-15}$ m. [3]

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(d) Results from inelastic electron scattering at even higher energies suggest that particles such as the neutron, previously thought to be fundamental, are in fact composed of three basic particles known as **quarks**. The charges of two kinds of quark, the **UP** and the **DOWN**, are shown in the following table.

Quark	**Charge / e**
UP	$+\frac{2}{3}$
DOWN	$-\frac{1}{3}$

(i) The quark structure of the neutron is UP DOWN DOWN i.e. one UP quark and two DOWN quarks. Show that this is consistent with the properties of the neutron. [2]

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(ii) Identify a particle which has the quark structure UP UP DOWN. Explain your reasoning. [2]

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7. *(a)* (i) By equating the gravitational force to the force needed to maintain an object in a circular orbit, show that the velocity, v, of a satellite in orbit around the Earth (mass M_E) is related to the radius, r, of its orbit by the relationship below. [3]

$$v^2 = \frac{GM_E}{r}$$

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(ii) Show that the orbital radius of a satellite orbiting the Earth is related to its period of orbit, T, by the following relationship. [4]

$$r^3 = \frac{GM_E T^2}{4\pi^2}$$

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(iii) From the equation in (ii), calculate the orbital radius of a satellite whose orbital period, T, is 1 day. ($M_E = 5{\cdot}98 \times 10^{24}$ kg). [3]

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(iv) Although there are an infinite number of orbits around the Earth with this radius there is only one geostationary orbit (sometimes called the Clark belt). Explain briefly why there can be only one geostationary orbit. [2]

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(b) (i) Show that the difference in gravitational potential between a point on the surface of the Earth (R_E = 6400 km) and a point at a distance of 42 000 km from the centre of the Earth is 53·1 MJ kg^{-1}. [2]

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(ii) Calculate the change in gravitational potential energy when a 500 kg satellite is moved from the surface of the Earth to a radius of 42 000 km. [1]

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(c) (i) Using the expression in part *(a)*(i), calculate the kinetic energy of a 500 kg satellite in orbit at a radius of 42 000 km. [2]

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(ii) Neglecting the initial kinetic energy of the satellite on the Earth's surface and air resistance, calculate the total energy required to place the 500 kg satellite in orbit at a radius of 42 000 km. [2]

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(iii) Other than air resistance, give one reason why, in reality, it would take more energy than your answer to *(c)*(ii) for a real rocket to carry the satellite to its orbit. [1]

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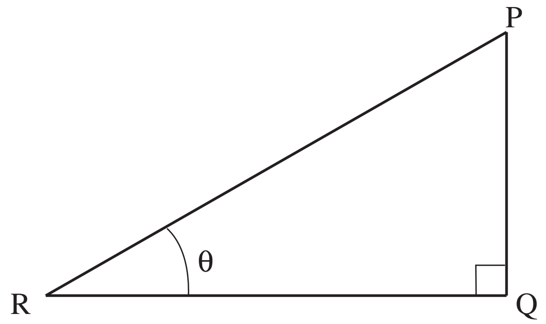
Mathematical Data and Relationships

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P

Geometry and trigonometry



$$\sin\theta = \frac{PQ}{PR}, \quad \cos\theta = \frac{QR}{PR}, \quad \tan\theta = \frac{PQ}{QR}, \quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$PR^2 = PQ^2 + QR^2$$

Areas and Volumes

Area of a circle $= \pi r^2 = \dfrac{\pi d^2}{4}$

Area of a triangle = ½ base × height

Solid	Surface area	Volume
rectangular block	$2(lh + hb + lb)$	lbh
cylinder	$2\pi r(r + h)$	$\pi r^2 h$
sphere	$4\pi r^2$	$\frac{4}{3}\pi r^3$

Logarithms

[Unless otherwise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log\left(\dfrac{a}{b}\right) = \log a - \log b$

$\log(x^n) = n\log x$

$\log(kx^n) = \log k + n\log x$

$\log_e(e^{kx}) = \ln(e^{kx}) = kx$

$\log_e 2 = \ln 2 = 0{\cdot}693$