Rewarding Learning

ADVANCED
General Certificate of Education
2015

Centre Number

Candidate Number

Physics

Assessment Unit A2 2
assessing
Fields and their Applications

AY221

[AY221]

THURSDAY 4 JUNE, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **3**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question 8 contributes to the synoptic assessment required of the specification. Candidates should allow approximately 15 minutes to complete this question.

For Examiner's use only		
Question Number	Marks	Remark
1		
2		
3		
4		
5		
6		
7		
8		
Total Marks		

Examiner Only	
Marks	Remark

1 **(a)** The planet Mars has a mean radius of 3.39×10^6 m and a mass of 6.42×10^{23} kg. Calculate the gravitational field strength on the surface of Mars.

Gravitational field strength on Mars = ___________ N kg^{-1} [3]

(b) **(i)** Show that Kepler's third law (t^2 proportional to r^3) is consistent with Newton's law of universal gravitation; r is the radius of orbit and t is the period of the orbit.

[2]

(ii) Mars has two small moons, Phobos and Deimos. Phobos has a period of 7.67 hours and an orbital radius around Mars of 9.38×10^6 m. Deimos has a period of 30.3 hours.

Calculate the orbital radius of Deimos.

Radius = ___________ m [3]

Examiner Only	
Marks	Remark

(iii) Calculate the force of attraction which Mars exerts on the moon Phobos, which has a mass of 1.07×10^{16} kg.

Force = ___________ N [2]

2 A small charged metal sphere **A** is suspended by an insulated thread. The charge on **A** is −4.0 nC. **Fig. 2.1** shows this sphere which is deflected by another charged sphere **B** attached to the end of an insulated rod. The thread makes an angle of 30° with the vertical.

Examiner Only	
Marks	Remark

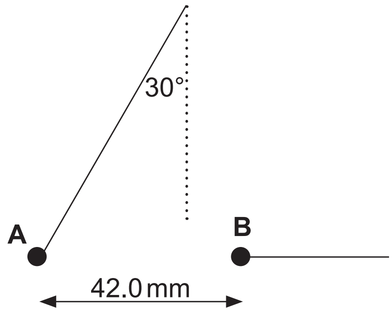

Fig. 2.1

The charge on sphere **B** is −7.0 nC. The centres of the two spheres are 42.0 mm apart.

(i) Calculate the magnitude and direction of the electric field strength at a point midway between the charges.

Electric field strength = ___________ $N\ C^{-1}$

Direction = ___________________ [4]

(ii) Calculate the magnitude of the force acting on each sphere.

Force = ___________ N [2]

(iii) Find the tension T in the thread.

Tension = ____________ N [2]

(iv) Hence find the weight of the sphere **A**.

Weight = ____________ N [2]

Examiner Only	
Marks	Remark

In this question you will be assessed on the quality of your written communication.

Examiner Only	
Marks	Remark

3 **(a)** Show clearly that the product of capacitance and resistance (CR) has the S.I. unit "second".

[2]

(b) **(i)** Draw a diagram of a circuit from which the time constant of a resistor–capacitor network can be determined. The capacitor is initially **uncharged**.

[2]

(ii) Describe how the circuit may be used to obtain results from which the time constant may be determined.

____

____

____

____

____ [2]

(iii) Explain how the results from **(b)(ii)** may be analysed graphically to obtain an accurate value for the time constant.

____

____

____

____

____ [2]

Quality of written communication [2]

Examiner Only	
Marks	Remark

(c) (i) Calculate the charge stored in a 300 μF capacitor when it is connected to a 600 V supply.

Charge = ____________ C [2]

The 300 μF charged capacitor is then connected to an uncharged capacitor of capacitance 500 μF as shown in **Fig. 3.1**.

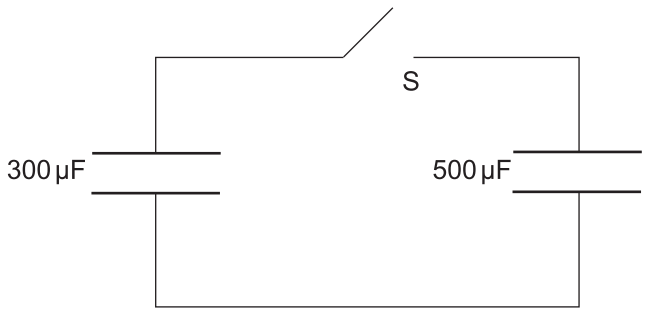

Fig. 3.1

The switch S is then closed.

(ii) Calculate the potential difference across the capacitors.

Potential difference = ____________ V [3]

Examiner Only	
Marks	Remark

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(Questions continue overleaf)

4 **(a)** A solenoid X is connected to a 50 Hz alternating voltage supply. A second solenoid Y is positioned 10 cm from the first where the maximum flux density is 1.6 mT. See **Fig. 4.1**.

Examiner Only	
Marks	Remark

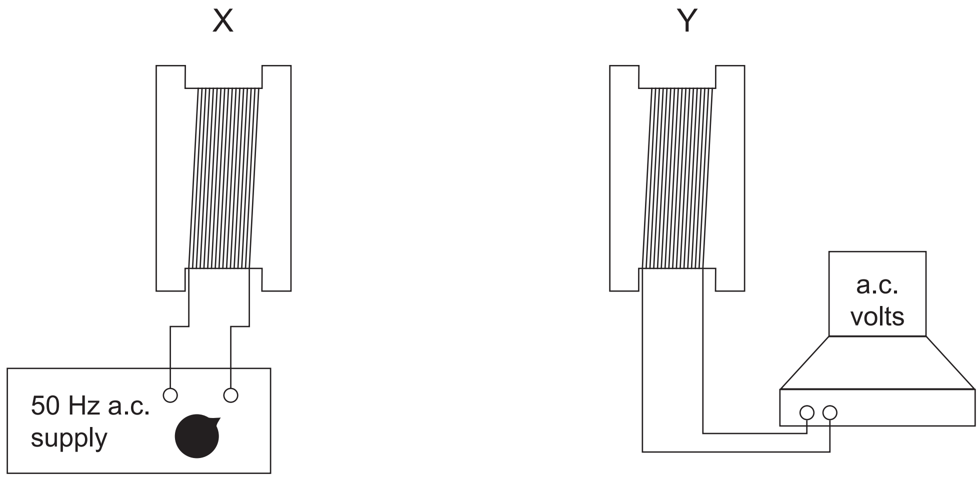

Fig. 4.1

(i) Calculate the electromotive force (EMF) induced in solenoid Y if it has an area of cross section of 0.0048 m^2 and contains 200 turns.

EMF = ___________ V [3]

(ii) Comment on the direction of the magnetic field due to the supply of current in solenoid X and the direction of the magnetic field induced in solenoid Y at any instant in time. Explain your comment.

____

____

____ [2]

An iron core is inserted between solenoid X and solenoid Y, as shown in **Fig. 4.2**.

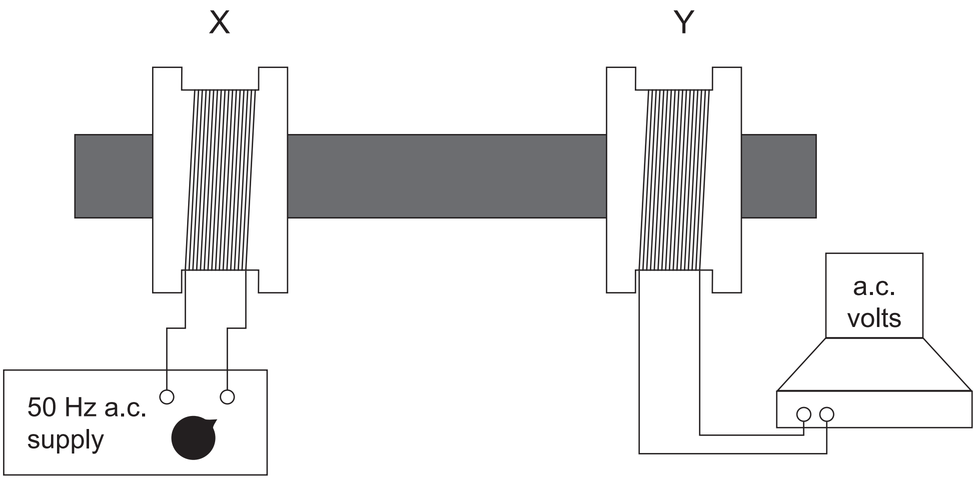

Fig. 4.2

(iii) Describe and explain the effect of inserting the iron core.

____

____

____

____

____ [2]

(b) In some types of commercial transformer the iron core forms a continuous loop. What additional design feature is incorporated into the core structure? Explain the reason for this additional design feature.

____

____

____

____ [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

5 **(i)** Show that when electrons in a vacuum are accelerated from rest through a potential difference of 200 V, they acquire a velocity of $8.4 \times 10^6\,\text{m s}^{-1}$.

[2]

These electrons now enter a deflection system midway between two parallel metal plates 30 mm apart as illustrated in **Fig. 5.1**. Each plate has a length of 40 mm.

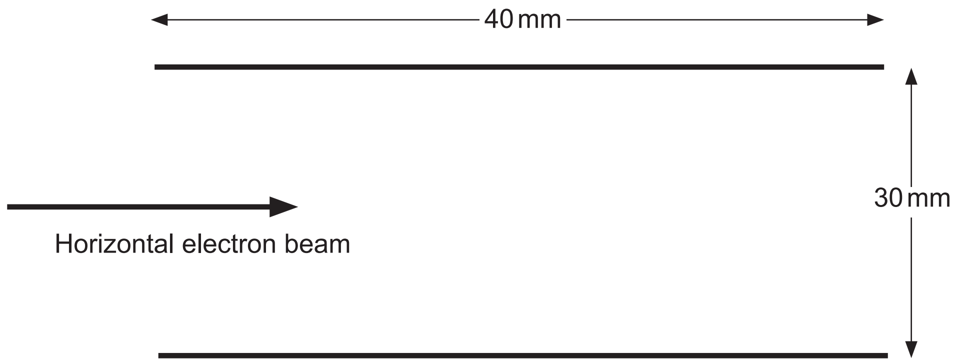

Fig. 5.1

(ii) Calculate the time it would take an electron moving with a horizontal velocity of $8.4 \times 10^6\,\text{m s}^{-1}$ to travel through this deflection system. State your answer in nanoseconds.

Time = ____________ ns [2]

(iii) A voltage of 50 V is now applied across the plates, the top plate being positively charged. On **Fig. 5.1** draw the electric field lines between the plates and show the path the electrons travel. [2]

(iv) 1. Calculate the vertical force on the electrons produced by this electric field.

Force = ___________ N [2]

2. Find the vertical displacement of an electron where it reaches the right hand end of the deflection system.

Displacement = ___________ mm [3]

(v) It is possible to cancel out this displacement by applying a magnetic field. State clearly the direction of the magnetic field.

____

____

____ [2]

6 Cyclotrons can be used to accelerate protons. A cyclotron consists of two hollow semicircular metal dees in a vacuum with uniform magnetic field of 0.7 T applied perpendicular to the dees, as shown in **Fig. 6.1**.

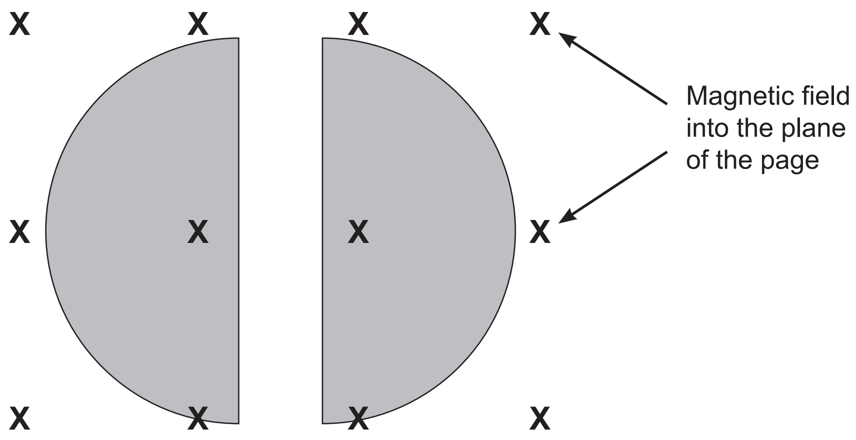

Fig. 6.1

(a) (i) Why is it necessary to have a vacuum in the cyclotron?

____

____ [1]

(ii) Why do the protons move with a constant speed **inside** each dee?

____

____ [1]

Examiner Only	
Marks	Remark

(iii) Calculate the radius of the circular path of the protons when they have a velocity of $2.0 \times 10^5 \text{ m s}^{-1}$ in one of the dees.

Radius = ___________ m [3]

(b) Each time the protons cross the gap between the dees, they are accelerated by a potential difference of 500 V. Calculate the energy they acquire after crossing the gap 120 times.

Energy acquired = ___________ J [3]

Examiner Only	
Marks	Remark

7 (a) (i) Explain what is meant by a fundamental particle.

____

____ [1]

(ii) Give one example of a fundamental particle other than a type of quark.

____ [1]

(b) (i) In **Table 7.1** enter the names of two particles that are classified as baryons and insert:

- their quark structure
- the quark charges
- the particle charge.

Table 7.1

Particle	Structure	Quark charges	Particle charge

[4]

(ii) Which, if any, of the quantities charge, baryon number and lepton number must be conserved for any reaction to be possible?

____ [1]

(c) (i) Write an equation for beta decay in terms of quarks.

[1]

(ii) What is the name of the force responsible for this process?

____ [1]

Examiner Only

Marks	Remark

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(Questions continue overleaf)

Examiner Only	
Marks	Remark

8 Power from wind turbines

(a) Wind with an air density ρ and speed v blows towards a wind turbine of effective area A.

(i) Show that the mass of air delivered to the turbine each second is $\rho A v$.

[1]

(ii) It is the kinetic energy of the wind that drives the turbine. Hence show that a power of $\frac{1}{2}\rho A v^3$ is delivered to the turbine.

[1]

(iii) If the wind speed increases by 2% estimate the percentage increase in power available from the turbine.

Percentage increase = ___________ % [1]

Examiner Only

Marks	Remark

(b) Control signals are transmitted to the turbines by an optical fibre of length 20.0 km.

The frequency of the laser light used is 2.29×10^{14} Hz.

(i) 1. Calculate the wavelength of this light.

Wavelength ___________ m [1]

2. To which region of the electromagnetic spectrum does this radiation belong?

____ [1]

(ii) Calculate the **minimum time** it would take for a signal of this light to reach a turbine if the speed of light in the fibre was $2.4 \times 10^8 \text{ m s}^{-1}$.

Time = __________________ s [1]

(c) The electrical power generated by the turbine is transmitted along a multistrand aluminium and steel overhead cable of length 20 km.

(i) Suggest why a multistrand aluminium and steel cable is used instead of a solid aluminium cable of the same resistance with no steel.

____

____ [2]

The multistrand aluminium and steel cable consists of eight strands of steel surrounding the aluminium core as shown in **Fig. 8.1**.

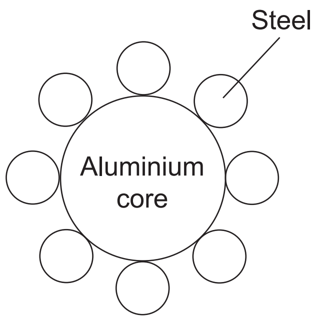

Fig. 8.1

The aluminium core has a diameter 0.22 m and the resistivity of aluminium is $2.7 \times 10^{-8}\,\Omega\,m$.

Each steel strand has diameter 0.06 m and resistivity $1.5 \times 10^{-7}\,\Omega\,m$.

(ii) Calculate the resistance of 20 km of the multistrand cable.

Resistance = ____________ Ω [6]

Examiner Only	
Marks	Remark

(iii) Calculate the power loss in this cable if the current is 2000 A.

Power loss = ___________ kW [2]

Examiner Only	
Marks	Remark

THIS IS THE END OF THE QUESTION PAPER

180200

GCE Physics

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{F^{-1}\,m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
(unified) atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall on the Earth's surface	$g = 9.81\,\mathrm{m\,s^{-2}}$
electron volt	$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

The following equations may be useful in answering some of the questions in the examination:

Mechanics

Conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$	for a constant force
Hooke's Law	$F = kx$ (spring constant k)	

Simple harmonic motion

Displacement	$x = A \cos \omega t$

Sound

Sound intensity level/dB	$= 10 \lg_{10} \frac{I}{I_0}$

Waves

Two-source interference	$\lambda = \frac{ay}{d}$

Thermal physics

Average kinetic energy of a molecule	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
Kinetic theory	$pV = \frac{1}{3}Nm\langle c^2\rangle$
Thermal energy	$Q = mc\Delta\theta$

Capacitors

Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
Capacitors in parallel	$C = C_1 + C_2 + C_3$
Time constant	$\tau = RC$

Light

Lens formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification $m = \frac{v}{u}$

Electricity

Terminal potential difference $V = E - Ir$ (e.m.f. E; Internal Resistance r)

Potential divider $V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$

Particles and photons

Radioactive decay $A = \lambda N$

$A = A_0 e^{-\lambda t}$

Half-life $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

de Broglie equation $\lambda = \frac{h}{p}$

The nucleus

Nuclear radius $r = r_0 A^{\frac{1}{3}}$