New Specification

Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
2010

Physics

Assessment Unit A2 2

Fields and their Applications

[AY221]

AY221

WEDNESDAY 9 JUNE, MORNING

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 **5(a)**.
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 9 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
1	
2	
3	
4	
5	
6	
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8	
9	
Total Marks	

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Examiner Only	
Marks	Remark

1 **(a)** State Newton's law of universal gravitation.

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____ [2]

(b) The International Space Station of mass m_s, orbits the Earth at a height h above the Earth's surface. Take the Earth's mass as m_e and radius r_e.

(i) State an equation for the gravitational force F which exists between the International Space Station and the Earth.

[1]

(ii) Calculate the value of the Earth's gravitational field strength g at a height 350 km above the Earth's surface. Take the mass of the Earth to be 6.0×10^{24} kg and the mean radius of the Earth to be 6400 km.

g = __________ N kg^{-1} [3]

(iii) Explain why an astronaut in the International Space Station experiences apparent **weightlessness**, even though the Earth's gravitational field acts on him.

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____ [3]

2 **(a)** State Coulomb's Law for the force F between two point charges.

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_______________________________________ [2]

(b) A point charge q_1 of charge 5 μC is suspended by a thread of length 0.60 m from a point A and hangs in position B as shown in **Fig 2.1.**

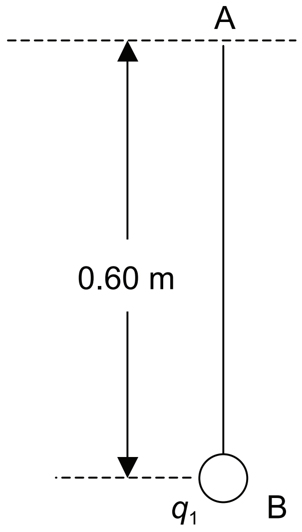

Fig. 2.1

A second point charge q_2 of charge –3 μC is brought to, and held at, point D. Point D is a horizontal distance of 0.6 m and a vertical distance of 0.3 m below position A, as shown in **Fig. 2.2**.

Point charge q_1 will move under the influence of the second charge q_2 to a new equilibrium position at point C as shown in **Fig. 2.2**.

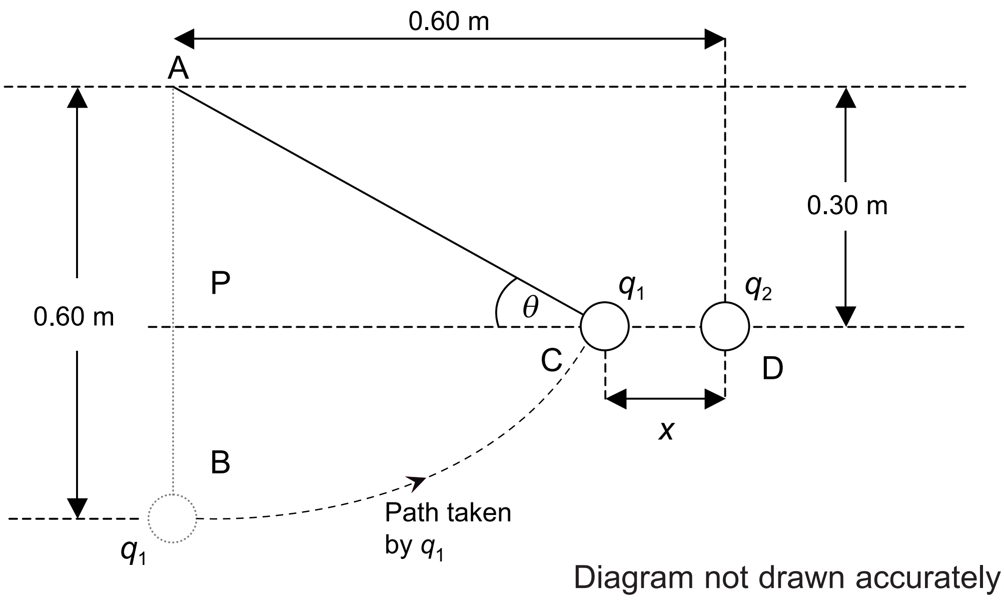

Diagram not drawn accurately

Fig. 2.2

Examiner Only
Marks Remark

(i) Complete the force diagram (free-body diagram) in **Fig. 2.3** for the point charge in the equilibrium position C by drawing another arrow. What is the name of the force represented by the arrow you have drawn?

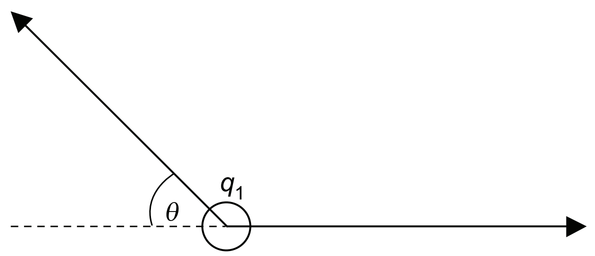

Fig. 2.3 [1]

Examiner Only	
Marks	Remark

(ii) Show that the distance x from C to D, as labelled in **Fig. 2.2**, is 0.08 m.

[2]

(iii) Calculate the electrostatic force acting on charge q_1 due to charge q_2 when q_1 is in position C.

Force = ________________ N [2]

(iv) 1. The thread hangs at an angle θ to the horizontal, see **Fig. 2.2**. Show that $\theta = 30°$.

[1]

2. Hence, calculate the tension in the string.

Tension = ________________ N [2]

3 **Fig 3.1** shows a circuit which can be used to charge a capacitor C of capacitance 6 μF.

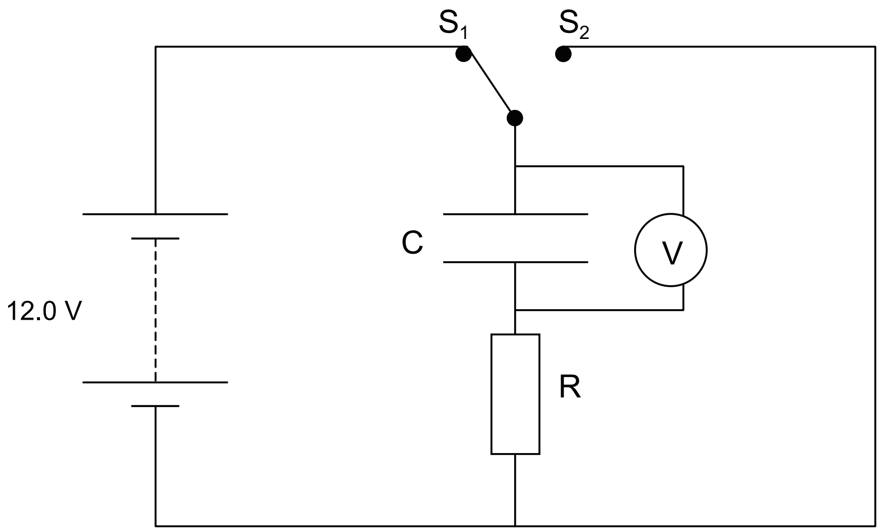

Fig. 3.1

The switch S_1 is closed at time $t = 0$.

(a) On **Fig 3.2**, show how the voltage, *V*, recorded by the voltmeter varies with time *t* during the charging of the capacitor. Label the final value for *V* on the *y*-axis.

Fig. 3.2 [2]

(b) Explain how the **movement of charge carriers** in the circuit, after the switch is closed, can explain the shape of the graph you have drawn in **Fig. 3.2**.

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____ [3]

(c) The switch is now moved to position S_2 and the capacitor discharges through resistor *R*. After 48 seconds, the voltage has fallen from 12.0 V to 1.64 V. Use these data to calculate the size of resistance *R*.

R = ________ MΩ [4]

Examiner Only	
Marks	Remark

4 (a) (i) State Faraday's law of electromagnetic induction.

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____ [2]

(ii) Describe an experiment in which Faraday's law of electromagnetic induction can be demonstrated. Your answer should include

1. a labelled diagram of the apparatus
2. an explanation as to how the results or observations demonstrate Faraday's law.

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____ [5]

Examiner Only	
Marks	Remark

(b) A loop of wire is placed in the magnetic field produced by an electromagnet. The loop of wire has a resistance of 2.6 Ω and an area of 4.0×10^{-3} m^2.

The electromagnet, when switched on, takes 0.8 s to reach its maximum flux density of 600 μT.

Assuming all the field links with the loop, and the loop's area is perpendicular to the field, calculate the average current that flows in the wire in the 0.8 s after the electromagnet is switched on.

Current = ___________ A [3]

Examiner Only	
Marks	Remark

5 **Fig. 5.1** shows a diagram of a transformer.

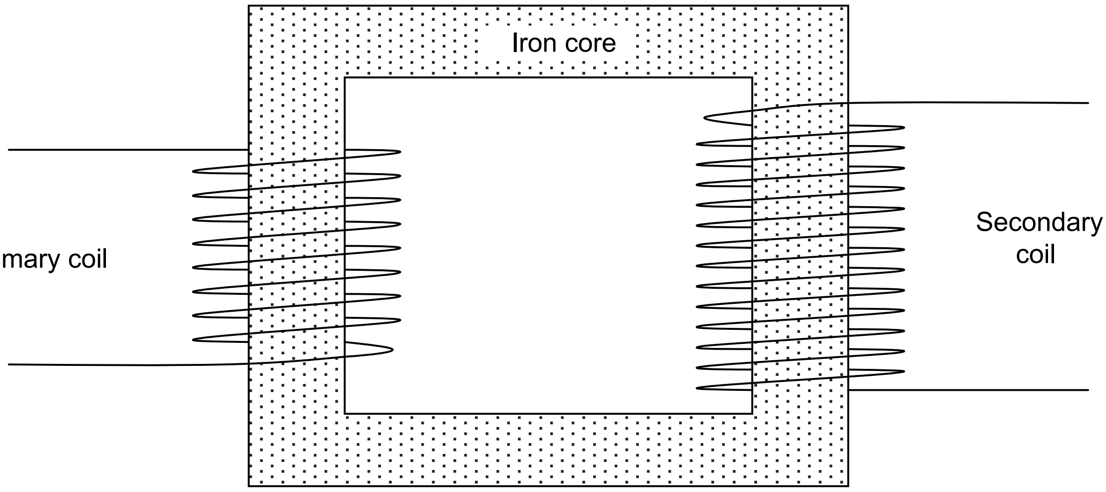

Fig. 5.1

(a) Describe how the transformer works.

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____

____

____ [3]

Quality of written communication [2]

(b) A transformer steps down voltage from 240 V to 19 V. The maximum current drawn from the transformer is 3.3 A. Assuming the transformer is 100% efficient, calculate the current drawn from the supply.

Current = ______________ A [2]

Examiner Only	
Marks	Remark

(c) In practice, a transformer is not 100% efficient. Describe how the current drawn from the supply, in **(b)**, would need to be changed, if at all, if the current drawn from the transformer is to remain 3.3 A.

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____ [1]

(d) State one source of energy loss in a transformer and explain how it can be reduced.

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____ [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

6 A beam of helium ions of mass m, charge q and travelling at a speed of v, enters a region EFGH at right angles as shown in **Fig. 6.1**. The region EFGH is a square of side 8 cm and a uniform magnetic field of flux density B acts vertically out of the plane of the page throughout this region.

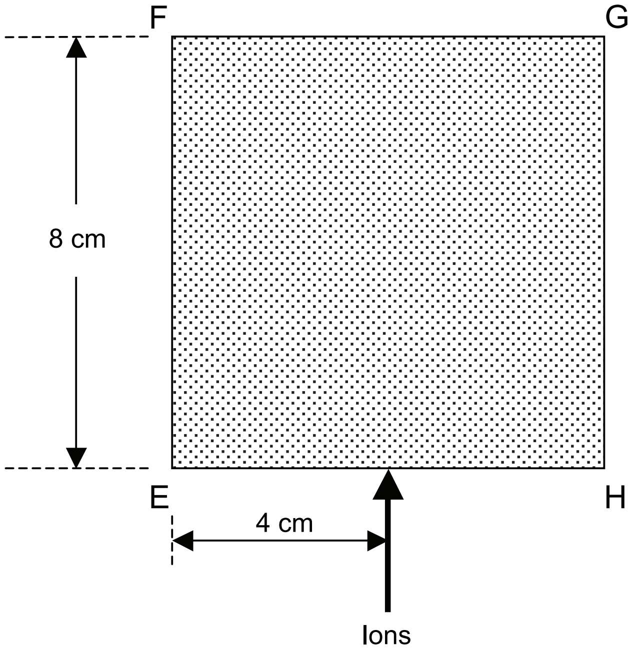

Fig. 6.1

(a) (i) Explain why the helium ions follow a circular path when in the region EFGH.

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____ [2]

(ii) Show that the radius r of the path taken by the ions while in the region EFGH is given by $r = \dfrac{mv}{Bq}$.

[2]

Examiner Only	
Marks	Remark

(iii) If the ions have a mass of 6.6×10^{-27} kg, a charge of 3.2×10^{-19} C and are travelling at a speed of 1.55×10^{6} m s^{-1}, calculate the radius of the path of the ions if the magnetic field has a flux density of 0.80 T. Give your answer to the nearest cm.

r = ____________ cm [2]

(iv) On **Fig. 6.1**, sketch the path taken by the ions within region EFGH and show the direction they travel when they leave the region EFGH. Label this path P. [2]

(b) The value of the magnetic flux density is increased to 1.60 T.

(i) Sketch the new path taken by the ions. Label this path Q. [1]

(ii) Explain why the ions take this new path.

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____ [1]

Examiner Only	
Marks	Remark

7 **(a)** Explain what is meant by antimatter.

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____ [2]

(b) At the CERN laboratory, antiprotons have been formed using protons accelerated in a synchrotron. The protons are smashed into an iridium rod. The antiprotons produced are separated off using magnets in a vacuum.

(i) Draw and label a diagram to show the structure of a synchrotron.

[2]

(ii) Explain how the synchrotron causes a proton to achieve the kinetic energy needed to form antiprotons during the collision with the iridium.

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____ [2]

(c) The annihilation of a positron occurs when it meets an electron. This is represented by the equation

$$^{0}_{+1}e + ^{0}_{-1}e \Rightarrow 2\gamma$$

where γ is a photon.

(i) Explain why two photons are produced.

____

____ [1]

(ii) Calculate the energy E of each photon produced.

E = ____________ J [2]

Examiner Only	
Marks	Remark

8 (a) (i) Some physicists consider the gauge bosons to be fundamental particles. How do we define a fundamental particle?

____

____ [1]

(ii) Give one example of a fundamental particle other than a gauge boson.

______________ [1]

(b) (i) Two electrons approaching each other do not collide, but exert forces on one another without coming into contact. Explain the role of the GAUGE BOSON in this interaction.

____

____ [2]

(ii) Complete **Table 8.1** by naming the appropriate gauge boson for each of the fundamental forces.

Table 8.1

Force	**Gauge Boson**
Strong	
Electromagnetic	
Weak	
Gravitational	

[2]

(c) (i) Name the two types of particle that are classified as hadrons.

1. ____________________

2. ____________________ [1]

(ii) In what way are these hadrons different?

____

____

____ [1]

Examiner Only
Marks | Remark

Examiner Only	
Marks	Remark

9 **(a)** **(i)** When a golf ball is hit by the head of a golf club, kinetic energy is transferred from the golf club head to the ball on impact. Assuming that all the kinetic energy is transferred from the club head to the ball and that the club head is brought to rest when it hits the ball, determine the velocity of the ball after impact. The mass of the golf ball is 46 g and that of the golf club head is 190 g. The velocity of the club head immediately before impact is 44.7 $m\,s^{-1}$.

Velocity = ______________ $m\,s^{-1}$ [3]

(ii) In practice, measurements using high speed cameras have shown that the ball velocity in this situation is 63.5 $m\,s^{-1}$. Explain why there is such a difference between the theoretical value obtained in **(a)(i)** and the practical value obtained through high speed photography.

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____ [2]

(b) The Coefficient of Restitution (CoR), as defined below in Equation 9.1, provides a numerical measure of the club head–ball interaction.

$$\text{CoR} = \frac{\text{(velocity of ball after impact)}}{\text{(velocity of club head before impact)}}$$ **Equation 9.1**

(i) Calculate the CoR for this situation. Use the measured value for velocity from **(a)(ii)**.

CoR = ______________ [1]

(ii) Explain why a high CoR is desirable.

____

____

____ [1]

(c) The CoR of the club head is related to its **natural frequency of vibration**. Explain the meaning of the term in bold.

____

____

____ [1]

Examiner Only

Marks	Remark

(d) It is found that the lower the natural frequency of vibration, the higher the CoR. The natural frequency of vibration of the head is given by the relationship

$$\text{Natural frequency} = \frac{(\text{thickness})^3 \times \text{Young Modulus}}{\text{Area} \times \text{hardness}}$$

(i) **Table 9.1** below shows the relationship between hardness and the Young Modulus for four materials whose club heads are of the same thickness and area. Which material would give the highest CoR?

Table 9.1

Material	Hardness/units	Young Modulus/units
A	14.7	1.36
B	10.5	8.44
C	67.8	2.77
D	56.6	7.34

Material ___________ [1]

(ii) Explain your choice.

____

____

____ [1]

Examiner Only	
Marks	Remark

(e) The golf ball is struck and leaves the tee with a velocity of 63.5 m s^{-1} at an angle of 30^o to the horizontal. Calculate the horizontal distance travelled by the golf ball when it first hits the ground.

Distance = ______________ m [5]

THIS IS THE END OF THE QUESTION PAPER

GCE Physics

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

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

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

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