Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
2014

Physics

Assessment Unit A2 2

assessing

Fields and their Applications

[AY221]

AY221

MONDAY 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 **4(c)(ii)**.
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 7 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	
7	
Total Marks	

Examiner Only	
Marks	Remark

1 **(a)** Define gravitational field strength.

____

____

____ [1]

(b) **(i)** The Moon has a radius of 1.74×10^6 m and a mass of 7.35×10^{22} kg. Calculate the gravitational field strength on the surface of the Moon.

Gravitational field strength = ___________ $N\,kg^{-1}$ [3]

(ii) The Moon moves in a circular orbit of mean radius of 3.84×10^8 m around the Earth. The mass of the Earth is 5.98×10^{24} kg. Show that the force on the Moon due to the Earth is 1.99×10^{20} N.

[3]

(iii) Calculate the period of the Moon's orbit around the Earth in days.

Period = ___________ days [3]

(c) The Earth has many artificial satellites with geostationary orbits. Explain fully what the term "geostationary" means.

____

____

____ [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

2 (a) (i) State one similarity and one difference **in the force** produced by electric and gravitational fields.

Similarity ____

____

Difference ____

____ [2]

(ii) Write down the equation used to calculate the magnitude of the force that exists between two point charges. Identify all the symbols used and state the name of the law that this equation represents.

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____

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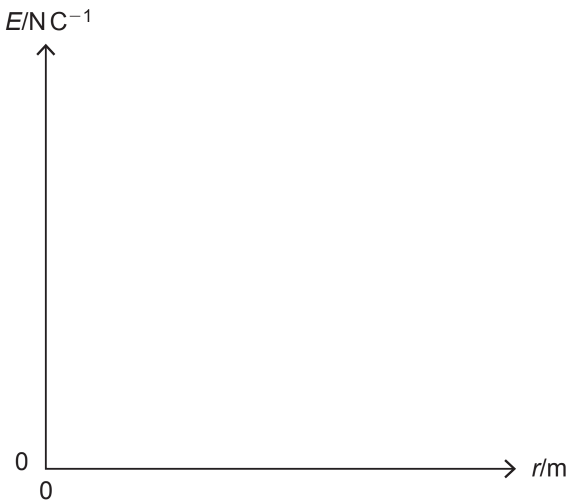
____ [3]

(b) (i) On **Fig. 2.1**, sketch a graph showing how the electric field strength *E* due to a point charge varies with the distance *r* from the charge.



[1]

Fig. 2.1

A point charge of $-3\,\mu C$ is placed 20 mm from a point charge of $+4\,\mu C$, see **Fig. 2.2**.

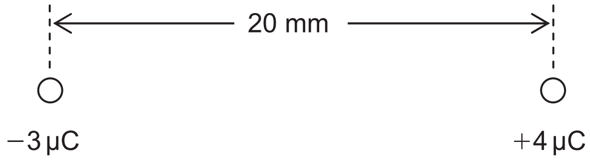


Fig. 2.2

(ii) Calculate the magnitude and direction of the resultant electric field strength at point A midway between the two charges.

Electric field strength = ____________ $N\,C^{-1}$ [3]

Direction = ____ [1]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

3 **(a)** A capacitor of capacitance 330 μF is charged from a 40 V power supply.

(i) How much charge is stored by the capacitor?

Charge = ____________ C [2]

(ii) What would be the maximum energy stored by this capacitor?

Energy = ____________ J [2]

(b) **Fig. 3.1** shows a network of capacitors each of capacitance 330 μF. Calculate the capacitance between A and B.

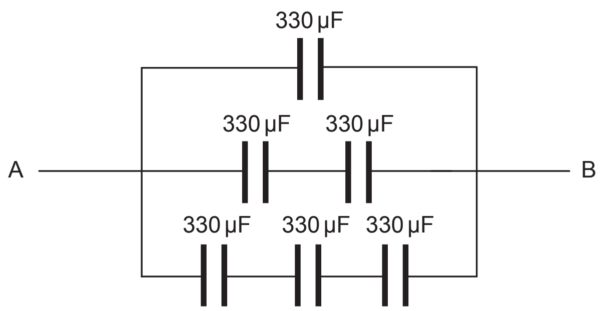


Fig. 3.1

Capacitance = ____________ μF [2]

(c) **Fig. 3.2** shows a circuit containing a capacitor of capacitance C, a resistor of resistance R, a supply voltage V_s and two switches S_1 and S_2.

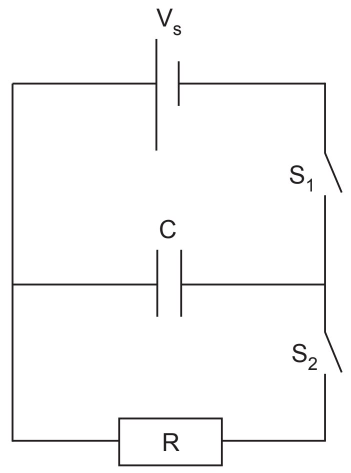


Fig. 3.2

When switch S_1 is closed the capacitor is charged by the battery.

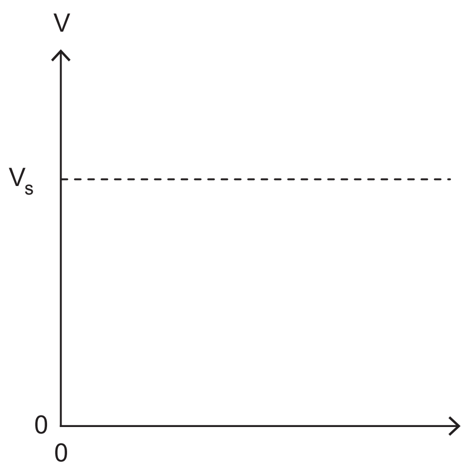
(i) Explain how the capacitor is charged in terms of the movement of charge.

____

____

____ [3]

(ii) On **Fig. 3.3** sketch a graph to show how the potential difference V across the capacitor plates varies with time *t* during the charging process. Switch S_1 is closed at time $t = 0$.



[1]

Fig. 3.3

Examiner Only	
Marks	Remark

The capacitor is charged to a maximum potential difference and switch S_1 is then opened. When switch S_2 is closed the capacitor discharges through the resistor R and the potential difference V_C across the capacitor C decreases with time *t*.

(iii) What effect does the resistor have on the discharge of the capacitor?

____

____ [1]

(iv) Define the time constant τ of the circuit in terms of the variation of the potential difference across the capacitor with time as it discharges.

____

____ [1]

(d) A 470 μF capacitor is charged to a potential difference of 200 V. The capacitor is discharged through a resistor R. After 12 s, the potential difference across the capacitor has fallen to 74 V. Calculate the resistance of resistor R in kΩ.

Resistance = ____________ kΩ [3]

Examiner Only	
Marks	Remark

4 Your answer to part (c)(ii) of this question should be in continuous prose. You will be assessed on the quality of your written communication.

(a) Define the weber.

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____ [2]

(b) **Fig. 4.1** shows a current carrying wire between two magnetic poles. The direction of the current in the wire is out of the page.

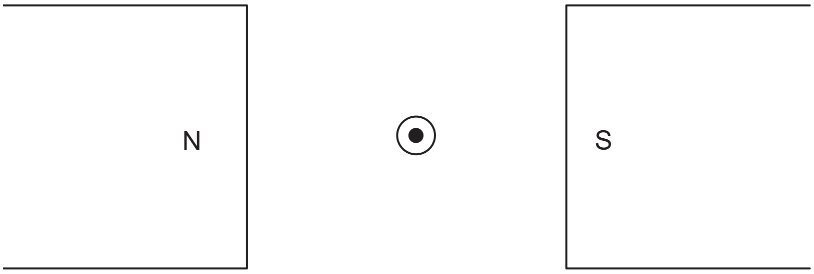

Fig. 4.1

(i) State the direction of the force on the current carrying wire.

____ [1]

(ii) The wire carries a current of 3.0 A. The length of the wire in the field is 5.0 cm and it experiences a force of 0.03 N. Calculate the strength of the magnetic field in millitesla.

Magnetic field strength = ___________ mT [3]

(c) (i) State Lenz's Law of electromagnetic induction.

____

____ [1]

(ii) State what happens as the N pole of the bar magnet approaches the coil, as shown in **Fig. 4.2** and explain how this is consistent with Lenz's Law.

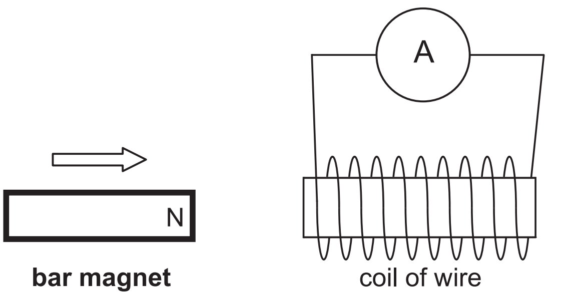

Fig. 4.2

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____ [3]

Quality of written communication [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(d) A flat circular multi-turn coil with a total resistance of 20 Ω has 50 turns and an area of 80 cm^2. The coil is placed perpendicular to a uniform magnetic field of 0.3 T.

(i) Calculate the **total** flux linkage through the multi-turn coil.

Flux linkage = ___________ Wb [3]

(ii) Calculate the induced e.m.f. if the magnetic field is reduced to zero in 50 ms.

Induced e.m.f. = ___________ V [2]

(iii) Calculate the induced current.

Induced current = ___________ A [1]

5 (a) A cathode ray oscilloscope (CRO) is used extensively by physicists to display electrical signals. Outline the basic structure of the CRO.

____

____

____

____ [4]

(b) A beam of electrons in an evacuated tube enters the uniform electric field provided by a potential difference of 600 V applied across two parallel plates 50 mm apart. The beam is deflected by the electric field until a uniform magnetic field of 0.72 mT perpendicular to the beam is applied to cancel the deflection and straighten the beam. Calculate the speed of the beam in the field.

Velocity of beam of electrons = ___________ $m\,s^{-1}$ [5]

Examiner Only	
Marks	Remark

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(Questions continue overleaf)

6 A linear particle accelerator is a type of particle accelerator that increases the speed of subatomic particles. **Fig. 6.1** illustrates the main features of a linear accelerator.

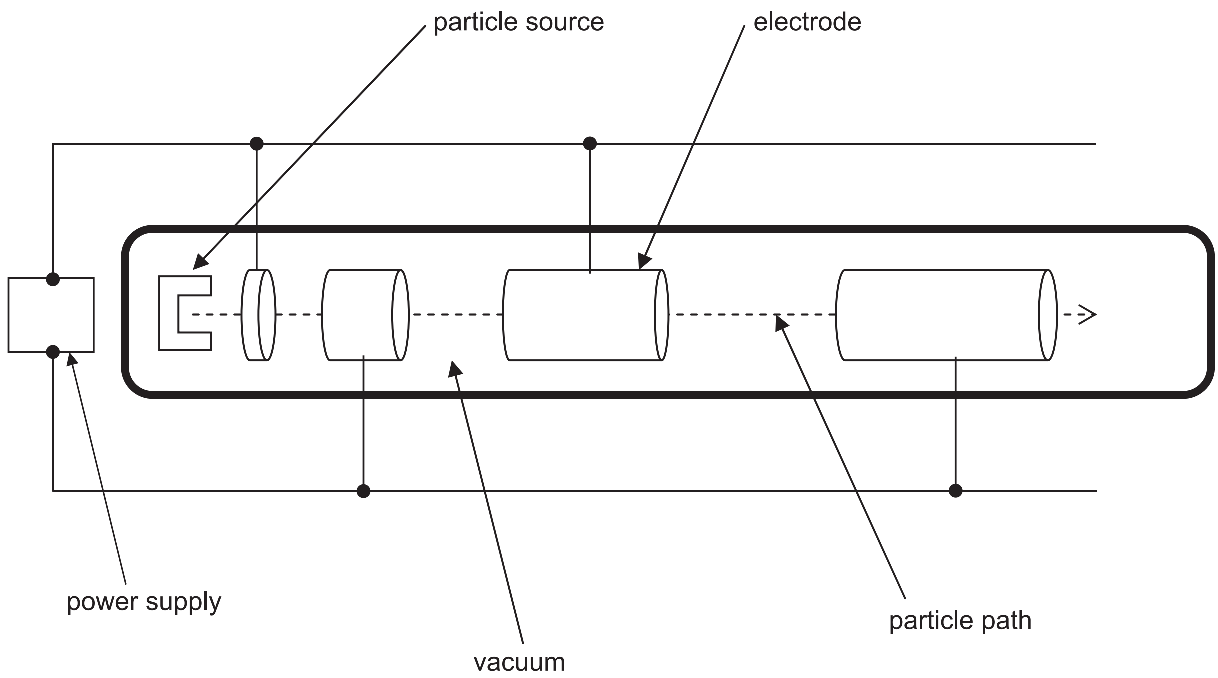

Fig. 6.1

Examiner Only	
Marks	Remark

(a) Why is it necessary for the chamber to be a vacuum?

____

____ [1]

Examiner Only

Marks	Remark

(b) Describe and explain how the speed of a subatomic particle is increased by a linear particle accelerator.

____

____

____

____

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____ [5]

(c) Leptons and hadrons are two groups of subatomic particles.

(i) State two differences between leptons and hadrons.

____

____

____ [2]

(ii) Hadrons can be subdivided into two types. Name the two types of hadrons and give a specific example of each type.

____

____

____ [2]

Examiner Only	
Marks	Remark

7 **(a)** Stokes' Law is used in the study of the velocity of an object falling through a fluid. When a small, spherical ball bearing is released in glycerol it accelerates at first but its velocity soon reaches a steady value, known as the terminal velocity. **Fig. 7.1** shows the forces acting on the ball bearing as it falls. Viscous drag is the name given to the frictional force that exists between an object and the fluid through which it moves.

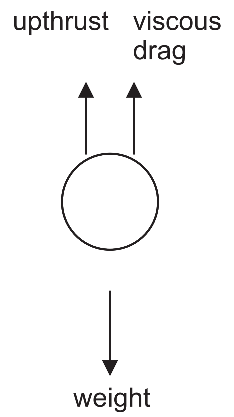

Fig. 7.1

(i) When the ball bearing drops at a constant speed, state the relationship between the three forces labelled in **Fig. 7.1**.

____

____ [1]

(ii) Stokes showed that the viscous drag F_v acting on a sphere of radius r, dropped through a fluid of viscosity η and moving with velocity v is given by **Equation 7.1**. Viscosity is the property of a fluid that measures how much it opposes the motion of an object through it.

$$F_v = 6\pi r \eta v \qquad \textbf{Equation 7.1}$$

Determine the base unit of viscosity η.

Base unit of η = ___________ [2]

Examiner Only	
Marks	Remark

(iii) The upthrust F_U is equivalent to the **weight** of fluid displaced by the ball bearing as it falls. Derive an expression for the upthrust force experienced by the ball bearing in terms of the density of the fluid ρ_f through which the ball bearing moves, the radius r of the ball bearing and such physical constants as are required.
N.B. The volume of a sphere $V = 4\pi r^3/3$

F_U = ____________ [2]

(iv) On the axes of **Fig. 7.2**, sketch two graphs:

- one to show how the velocity of an object falling from rest in a vacuum varies with time. Label this graph V.
- a second to show how the velocity of an object falling from rest in a fluid varies with time. Label this graph F.

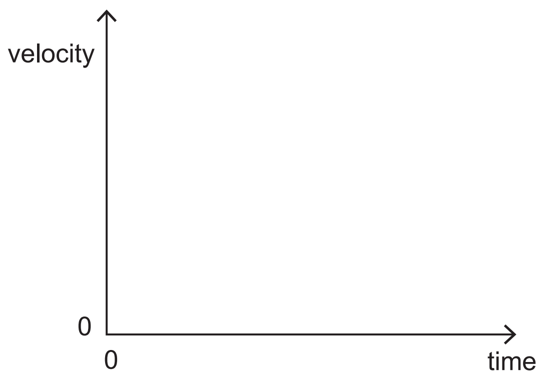

Fig. 7.2

[2]

Examiner Only	
Marks	Remark

(v) Calculate the terminal velocity of a steel ball bearing of radius 3.0 mm falling through glycerol. The density of steel is 8000 kg m^{-3} and the density of glycerol is 1300 kg m^{-3}. The viscosity of glycerol at room temperature is 1.5 S.I. units. The upthrust experienced by the ball bearing at terminal velocity is 1.44 mN.

Terminal velocity = ___________ m s^{-1} [3]

(b) A very small steel ball bearing of radius 1.2 mm and mass 5.79×10^{-5} kg attains a terminal velocity of 1400 m s^{-1} in air.

(i) Calculate the wavelength associated with the ball bearing moving at terminal velocity through the air.

Wavelength = ___________ m [2]

Examiner Only	
Marks	Remark

(ii) Discuss the usefulness of using the wave model to explain the motion of the ball bearing as it falls.

____

____

____ [1]

(iii) Use Einstein's mass–energy equivalency principle to calculate the difference between the ball bearing's mass when stationary and its mass when moving at terminal velocity and indicate whether it becomes heavier or lighter by ticking the appropriate box in the answer line.

Mass difference = ____________ kg Heavier ☐ Lighter ☐ [3]

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

AY211INS

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