Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

1420U40-1

Z22-1420U40-1

FRIDAY, 10 JUNE 2022 – AFTERNOON

PHYSICS – A2 unit 4
Fields and Options

1 hour 35 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**8**	
2.	**9**	
3.	**14**	
4.	**13**	
5.	**22**	
6.	**14**	
Total	**80**	

1420U401 01

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.
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. If you run out of space, use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.
The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in question **2**(b).

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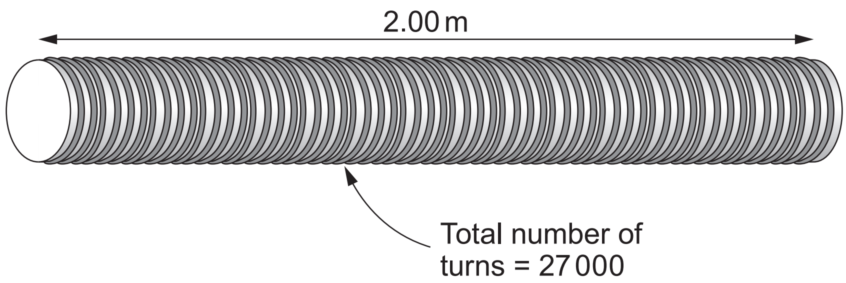
Answer **all** questions.

1. (a) (i) Lindsey calculates that a current of 3.57 A will produce a magnetic flux density of 0.121 T inside the long solenoid shown. Determine whether or not she is correct. [3]



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(ii) State how the magnetic flux density inside the solenoid can be increased greatly without changing the current or the number of turns per unit length. [1]

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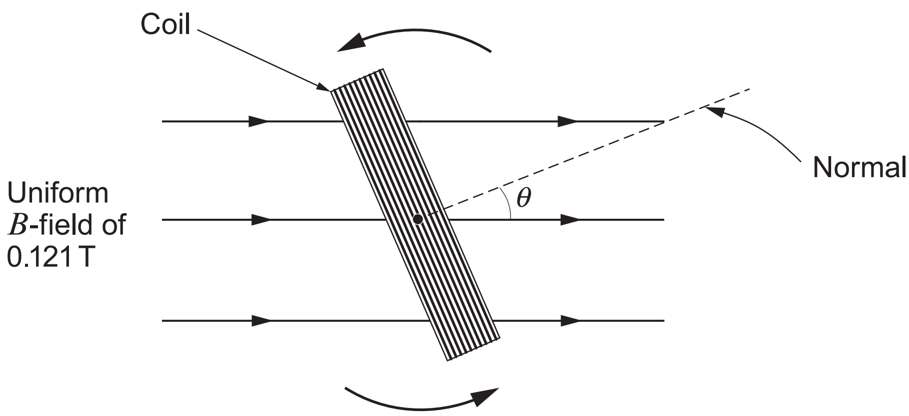
(b) A rectangular coil rotates at a constant angular velocity within a uniform magnetic field of 0.121 T. The coil has 70 turns and cross-sectional area 59 cm^2. The diagram below shows the coil, looking along the axis of rotation.



(i) Calculate the flux linkage of the coil when $\theta = 23°$. [2]

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(ii) As the coil rotates, explain what values of θ provide the maximum **and** minimum values of the induced emf. [2]

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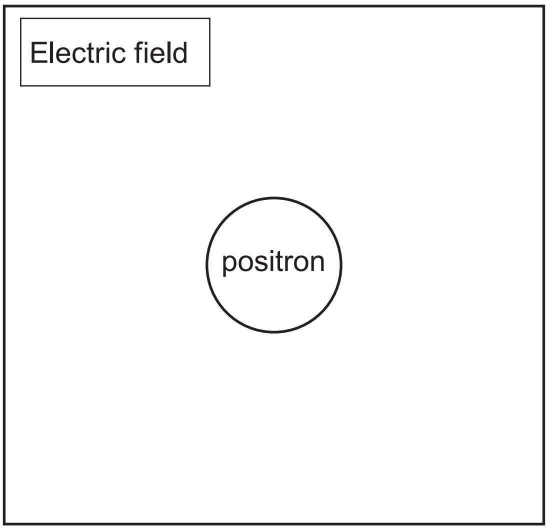
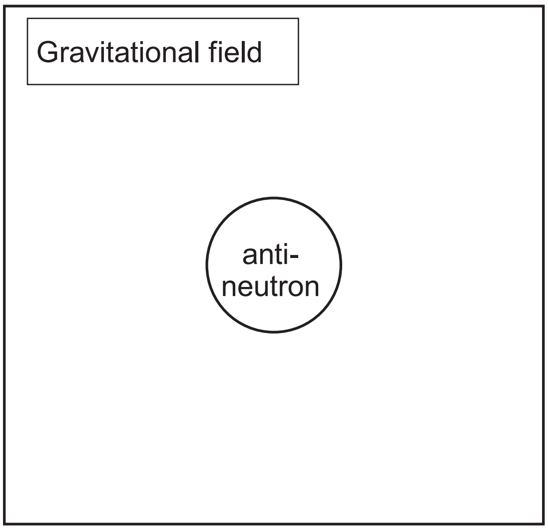
2. (a) Draw 2 equipotentials and 4 field lines for both the **electric** field of the positron and the **gravitational** field of the anti-neutron shown. [3]





(b) Describe and explain the similarities **and** differences between electric **and** gravitational fields. [6 QER]

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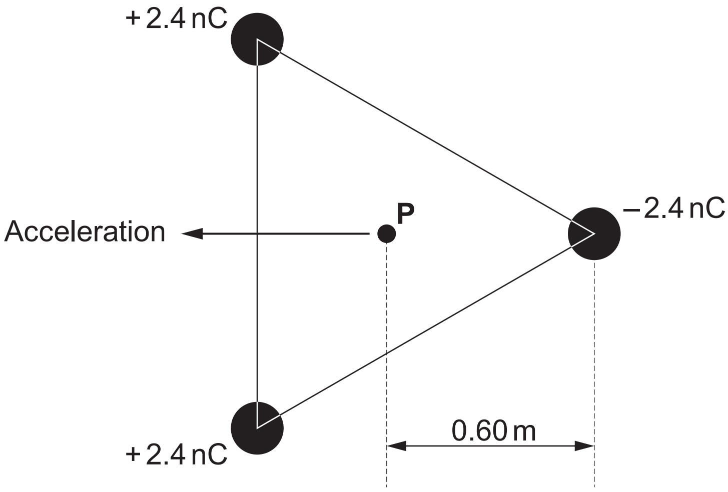
3. Three stationary charges are located at the corners of an **equilateral** triangle and an electron is located at the centre, **P**, of the triangle as shown. The electron is exactly 0.60 m from each charge.



(a) Draw arrows to show the 3 electric fields at **P** due to the 3 charges. Use these to explain why the electron will accelerate in the direction shown. [4]

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(b) Calculate the initial acceleration of the electron. [4]

(c) Show **clearly** that the initial potential energy of the electron is approximately -6×10^{-18} J. [2]

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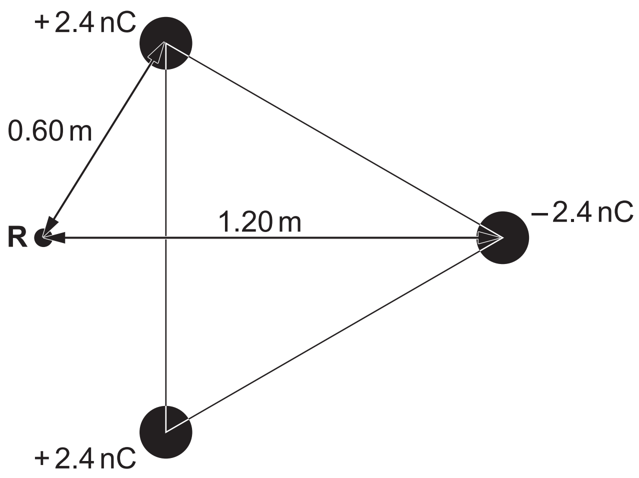
(d) Determine whether or not the electron (initially at rest) will reach point **R**, shown in the diagram below (both positive charges are 0.60 m from **R**). Explain your reasoning. [4]



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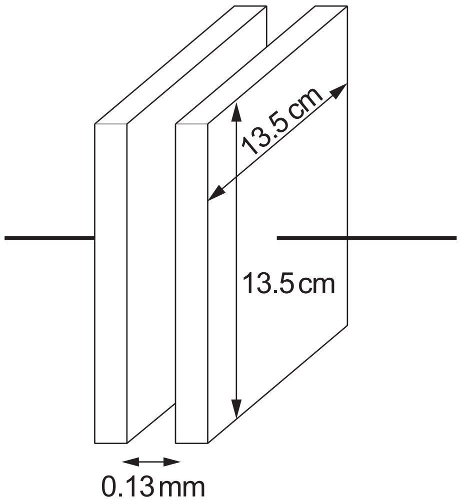
4. (a) Calculate the capacitance of the capacitor shown. [2]



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(b) (i) Calculate the pd across the terminals of a 5.0 mF capacitor when it stores 1.00 J of energy. [2]

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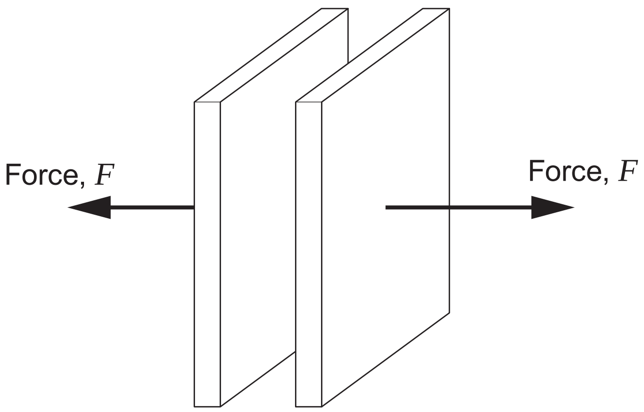
(ii) In the space provided, draw a diagram to show how you would combine three 5.0 mF capacitors to produce a capacitance of 7.5 mF. [2]

(c) The separation of the plates of a charged capacitor is increased by the application of a force, F. The capacitor is **isolated** so the charges on the plates remain unchanged.



(i) State why a force must be exerted to separate the charged plates. [1]

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(ii) Explain why the capacitor stores more **energy** when the separation of the plates is increased even though the charge remains constant. [2]

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(iii) Show that the energy stored by the capacitor is given by:

$$\text{energy stored} = \frac{1}{2}\frac{Q^2 d}{\varepsilon_0 A}$$

where Q is the charge stored, d is the separation of the plates, ε_0 is the permittivity of free space and A is the area of the plates. [2]

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(iv) Bethan states that the force, F, required to separate the plates is given by:

$$F = \frac{1}{2}\frac{Q^2}{\varepsilon_0 A}$$

Determine whether Bethan is correct to arrive at this conclusion. [2]

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5. (a) (i) Derive the expression for the critical density of a flat universe. [4]

$$\rho_c = \frac{3H_0^{\,2}}{8\pi G}$$

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(ii) Use this equation to show that the critical density of the universe corresponds to approximately 5 hydrogen atoms per m^3. [2]

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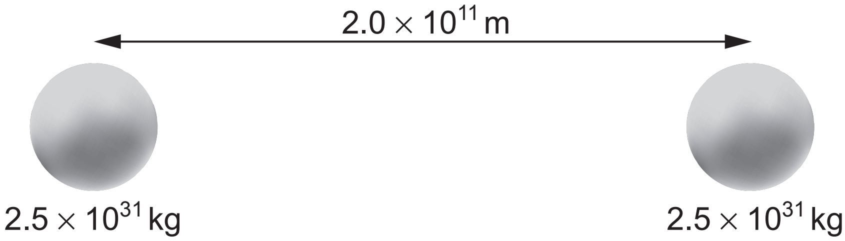
(b) A two-star system has two stars of equal mass as shown.



(i) State or calculate the position of the centre of mass of the two-star system. [1]

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(ii) Calculate the period of orbit of the stars about their centre of mass. [2]

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(iii) Calculate the maximum red shift (or blue shift) of the hydrogen 434 nm line due to the orbital motion of the stars. [3]

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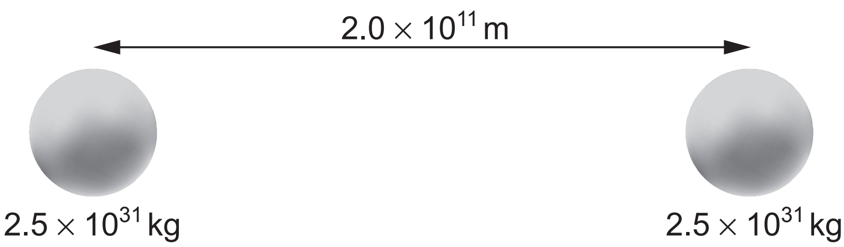
(c) The centre of mass of this two-star system is also the point where the resultant gravitational field strength is zero. Explain why these points only coincide when the stars have identical masses. [2]



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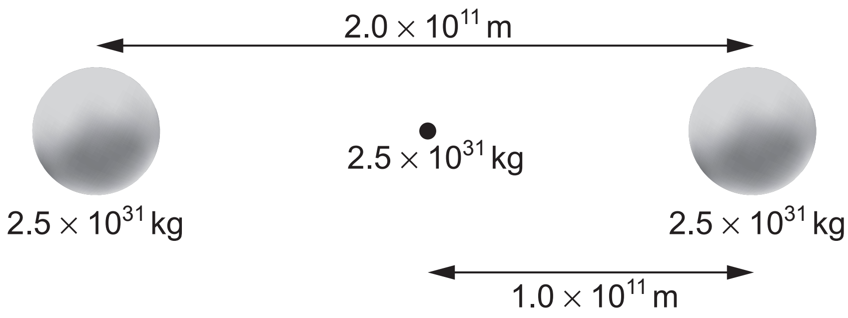
(d) A different star system consists of three stars all of equal mass. Two stars orbit around a stationary black hole and the black hole is always halfway between the two stars as shown.



(i) Explain why the resultant force on the black hole is always zero. [1]

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(ii) Explain why the gravitational force acting on either of the orbiting stars is five times greater in this three-star system than the two-star system of part (b). [2]

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(iii) Joseff claims that the stars in the three-star system will provide a red shift that is five times larger than that of the two-star system of part (b). Evaluate whether or not he is correct. [3]

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(e) A recent theoretical publication suggests that the decay of the Higgs Boson will give direct evidence for dark matter. Suggest what needs to be done for this theory to be generally accepted by scientists in the future. [2]

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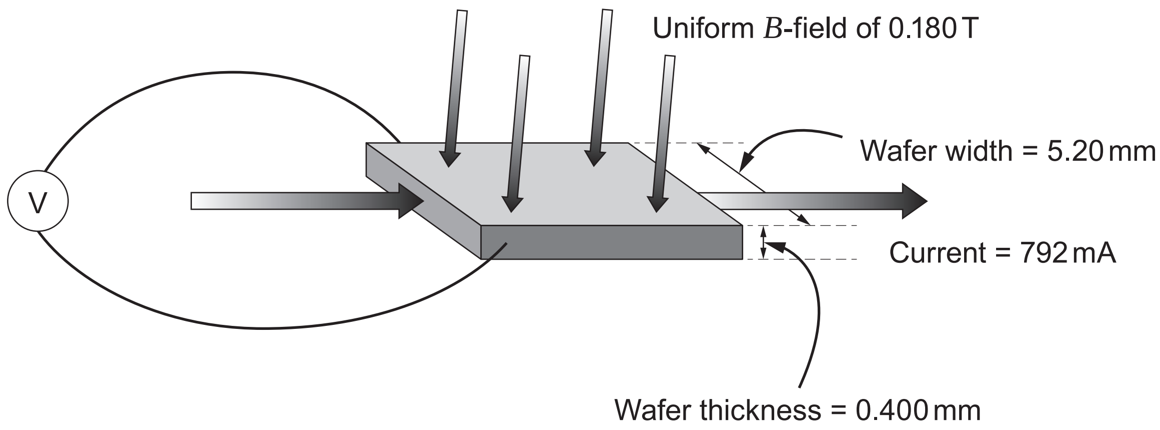
6. (a) Catrin carries out a Hall effect experiment to find out the number of free electrons per unit volume in a certain metal. She places a wafer of the metal in a known magnetic field and passes a current through it (see diagram).



(i) By considering the forces acting on free electrons passing through the wafer, explain why a Hall voltage is measured on the voltmeter shown. [4]

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(ii) By equating the magnetic and electrical forces, show that the Hall voltage, V_H, is given by:

$$V_H = Bvd$$

where B is the magnetic flux density, d is the width of the wafer and v is the drift velocity. [3]

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(iii) Catrin states that her measured Hall voltage of 68.0 nV is consistent with a drift velocity of approximately $0.07\,\text{mm}\,\text{s}^{-1}$. Determine whether, or not, she is correct. [2]

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(iv) Calculate the number of free electrons per unit volume for the metal. [3]

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(b) After repeating the same experiment on a different metal, Catrin obtains a value of $(5.85 \pm 0.19) \times 10^{28}\,\text{m}^{-3}$, for the number of free electrons per unit volume. She is given a table of values in order to determine which metal has been used in the experiment.

Element	Free electron density / $10^{22}\,\text{cm}^{-3}$
Aluminium	18.1
Barium	3.15
Copper	8.47
Gold	5.90
Iron	17.0
Silver	5.86

Explain which metal(s) she should conclude has been used in the experiment. [2]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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