Rewarding Learning

**ADVANCED**
**General Certificate of Education**
**2022 Reserve Series**

Centre Number

Candidate Number

# Physics

Assessment Unit A2 2
*assessing*

Fields, Capacitors and Particle Physics

*APH21*

**[APH21]**

**WEDNESDAY 29 JUNE, MORNING**

**TIME**

2 hours.

**INSTRUCTIONS TO CANDIDATES**

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
**You must answer the questions in the spaces provided.**
**Do not write outside the boxed area on each page or on blank pages.**
Complete in black ink only. **Do not write with a gel pen.**
Answer **all eight** questions.

**INFORMATION FOR CANDIDATES**

The total mark for this paper is 100.
Quality of written communication will be assessed in Question **7(b)(ii)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

13604

**1 (a) (i)** State Newton's law of gravitation in words.

_______________________________________________

_______________________________________________

_______________________________________________ [3]

**(ii)** Express the units of the gravitational constant G in terms of SI base units.

SI base units of G = ______________ [2]

**(b)** The Earth may be assumed to be a uniform sphere. A uniform sphere behaves as if it were a point mass, with all its mass concentrated at the centre.

**(i)** On **Fig. 1.1**, sketch the gravitational field pattern of the Earth.

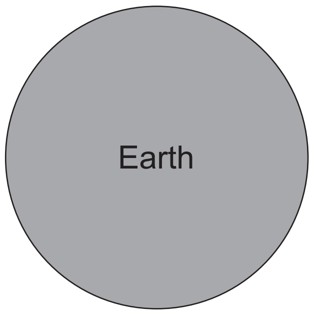


**Fig. 1.1**

[2]

**(ii)** State the equation that relates the acceleration of free fall g on the surface of the Earth to the mass of the Earth $M_E$ and the radius of the Earth $R_E$.

g = _______________ [1]

**(iii)** Given that the radius of the Earth is $6.38 \times 10^6$ m and the volume of a sphere is $\frac{4}{3}\pi r^3$, calculate a value for the mean density of the Earth.

Density = _______________ kg m$^{-3}$ [3]

2 Physicists use the concept of fields in both electric and gravitational settings.

**(a)** Complete **Table 2.1** which compares electric and gravitational fields.

**Table 2.1**

| | **Electric fields** | **Gravitational fields** |
|---|---|---|
| Physical quantity responsible | charge | |
| Type of force | attractive or repulsive | |
| Field strength unit | | N $kg^{-1}$ |

[3]

**(b)** In the nucleus of a lithium atom there are three protons. These can be considered to exist at the corners of an equilateral triangle with sides of length 2.4 fm, as shown in **Fig. 2.1**.

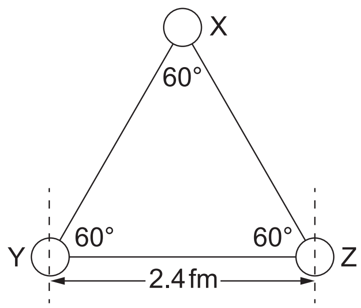


**Fig. 2.1**

**(i)** Calculate the magnitude of the electrical force that the proton at Z exerts on the proton at Y.

Force = ________________ N [4]

13604

**(ii)** On **Fig. 2.1** draw an arrow to show the direction of the resultant electrical force acting on the proton at X due to the protons at Y and Z. Label the arrow $F_E$. [1]

**(iii)** Calculate the magnitude of the total electrical force acting on the proton at X due to the protons at Y and Z.

Total electrical force = ________________ N [2]

**(c)** **(i)** On **Fig. 2.1** draw an arrow to show the direction of the resultant gravitational force acting on the proton at X due to the protons at Y and Z. Label the arrow $F_G$. [1]

**(ii)** Calculate the magnitude of the total gravitational force $F_G$ on the proton at X due to the protons at Y and Z.

$F_G$ = ________________ N [4]

**(d)** By comparing your answers to parts **(b)(iii)** and **(c)(ii)**, what can you conclude regarding the forces that must exist between protons if they are to remain stable within a nucleus?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________ [2]

**[Turn over**

**3** An uncharged capacitor of capacitance 2.2 μF, a resistor of resistance $3.5 \times 10^4\,\Omega$ and a battery of e.m.f. 7.5 V with negligible internal resistance, are connected in series, as shown in **Fig. 3.1**.

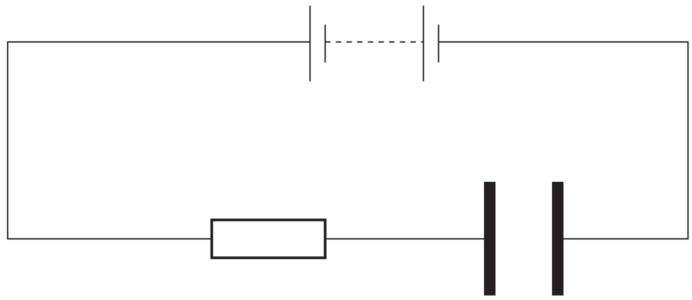

**Fig. 3.1**

**(a)** Calculate the potential difference across the resistor at the instant when the charging current in the circuit is 0.06 mA.

Potential difference = _______________ V [3]

**(b)** Deduce the potential difference across the capacitor at this instant.

Potential difference = _______________ V [2]

**(c)** Calculate the charge on the capacitor at this instant.

Charge = _______________ C [4]

13604

**(d)** Assume that the current of 0.06 mA is constant for the next 15 milliseconds. Calculate the extra charge which flows to the capacitor during this time.

Charge = _______________ C [2]

**(e)** What is the new potential difference across the capacitor after the 15 milliseconds?

Potential difference = _______________ V [2]

[Turn over

**4** A source of electrons is located in a vacuum, in a region where there is a uniform magnetic field acting. The electrons are emitted from the source with a range of speeds and move at right angles to the direction of the magnetic field.

**(a)** Explain why the electrons travel in circular paths in the magnetic field.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________ [3]

**(b)** **(i)** Show that the frequency f of the rotation of an electron is given by **Equation 4.1**.

$$f = \frac{Be}{2\pi m}$$ **Equation 4.1**

where B is the flux density of the magnetic field, e is the electronic charge, and m is the electron mass.

[4]

**(ii)** What does **Equation 4.1** tell us about the relationship between the frequency of the rotation and the radius of the circular path?

______________________________________________________________________ [1]

13604

**(iii)** When the magnetic flux density of the uniform magnetic field is $4.00 \times 10^{-4}$ T, what is the value of the frequency f?

f = ______________ Hz [2]

**(iv)** Calculate the speed of an electron travelling in this magnetic field if the radius of its path is 0.020 m.

Speed = ______________ m $s^{-1}$ [2]

**(c)** Suppose the electron source is replaced by a proton source. Compare the path taken by a proton with that of an electron travelling at the same speed.
State **one** similarity and **two** differences between the paths of the two particles.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________ [3]

**5** A square coil with 200 turns and side of length 0.12 m forms the rotor in a simple a.c. generator. The magnetic field is provided by an electromagnet which provides a constant flux density of 0.19 T through the coil. The output of the generator has a peak voltage of 240 V.

**(a)** Calculate the frequency of the generator.

Frequency = _______________ Hz [4]

**(b)** Without changing the structure of the rotor coil, what alteration must be made to the generator **and** how it is operated to give an a.c. output with the same peak value but twice the previous frequency?

_______________________________________________

_______________________________________________

_______________________________________________ [2]

BLANK PAGE

DO NOT WRITE ON THIS PAGE

(Questions continue overleaf)

**6** A set of Christmas lights has the specifications as listed:

| |
|---|
| Rated input of light chain 30 V |
| Maximum rated power 3 W |
| Bulb type 3 V, 0.01 A, 0.03 W |
| Number of bulbs 100 |
| Only use with transformer model number: YF-BS-3101 |

**(a)** **(i)** Calculate the resistance of each bulb.

Resistance = _______________ Ω [1]

**(ii)** Calculate the overall resistance of the light chain.

Resistance = _______________ Ω [2]

**(iii)** Deduce how the bulbs must be arranged in the chain from the data given and your answers to **(i)** and **(ii)**.
Show any calculations used in your deduction.

______________________________________________________________________

______________________________________________________________________ [4]

**(b)** **(i)** What type of transformer is being used when the set of lights is connected to the mains voltage of 240 V ?

______________________________________________________________________ [1]

**(ii)** What is the primary to secondary turns ratio of the transformer?

Ratio = ________________ [2]

**(iii)** Calculate the current drawn from the mains supply.
Assume the transformer to be 100% efficient.

Current = ________________ A [2]

**[Turn over**

**In (b)(ii) of this question you will be assessed on the quality of your written communication.**

**7** **(a)** **(i)** Neutrons and protons are examples of baryons. State the combination of quarks needed to form each of these baryons.

Neutron: ____________________

Proton: ____________________ [2]

**(ii)** State the relative magnitude and sign of the charge of each of the quarks you have named in your answer to **(i)**.

____________________________________________ [2]

**(b)** **(i)** Which of the two particles named in **(a)(i)** is suitable for acceleration in a synchrotron, and why is the particle chosen suitable?

____________________________________________ [1]

**(ii)** Describe the basic principles of operation of the synchrotron.

____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________ [6]

BLANK PAGE

DO NOT WRITE ON THIS PAGE

(Questions continue overleaf)

**8** Space based solar power (SBSP) is the concept of collecting solar power in outer space and transmitting it to Earth. The collecting satellite would convert solar energy into electrical energy on board, powering a microwave transmitter. On the Earth's surface, the microwaves are converted to electricity.
A single solar power station in space may cover an area of as much as $1 \times 10^7\,m^2$.

Image removed due to copyright

**(a)** **(i)** Suggest **two** benefits of space based solar energy collection over conventional solar panel use on Earth.

______________________________________________________________________

______________________________________________________________________

____________________________________________________________________ [2]

**(ii)** Suggest **one** of the key challenges to be overcome before an operational space based solar power station can become a reality.

______________________________________________________________________

____________________________________________________________________ [1]

13604

**(b)** Consider a space based solar power station satellite with solar panels that cover an area of $1 \times 10^7\,m^2$. The intensity of radiation from the Sun at the position of the satellite is $1400\,W\,m^{-2}$ and the efficiency of the solar panels in converting the light to electricity is 20%.

Calculate the maximum electrical power generated on the satellite.

Give your answer in gigawatts.

Power = _______________ GW [3]

**(c)** Assume that the radiation from the Sun can be treated as having a single wavelength of 580 nm.

**(i)** Calculate the energy of a photon of wavelength 580 nm.

Energy = _______________ J [4]

**[Turn over**

(ii) Calculate how many photons arrive on each square metre of the solar panels in one second.

Number of photons per second = _______________ [2]

(d) The satellite is placed in a geostationary orbit $3.6 \times 10^7$ m above the Earth's surface.

(i) What is the benefit of a geostationary orbit for this satellite?

_______________________________________________

_______________________________________________ [1]

(ii) Calculate how long it would take for the microwaves transmitted from the satellite to reach a point on the surface directly below the satellite.

Time = _______________ s [2]

**THIS IS THE END OF THE QUESTION PAPER**

BLANK PAGE

DO NOT WRITE ON THIS PAGE

**DO NOT WRITE ON THIS PAGE**

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

**Examiner Number**