

Fields Past Paper Questions

Q1. A spacecraft of mass m is at the mid-point between the centres of a planet of mass M_1 and its moon of mass M_2 . If the distance between the spacecraft and the centre of the planet is d , what is the magnitude of the resultant gravitational force on the spacecraft?

A $\frac{Gm(M_1 - M_2)}{d}$

B $\frac{Gm(M_1 + M_2)}{d^2}$

C $\frac{Gm(M_1 - M_2)}{d^2}$

D $\frac{Gm(M_1 + M_2)}{d}$

(Total 1 mark)

Q2. Which one of the following statements about gravitational potential is correct?

- A** gravitational potential can have a positive value
- B** the gravitational potential at the surface of the Earth is zero
- C** the gravitational potential gradient at a point has the same numerical value as the gravitational field strength at that point
- D** the unit of gravitational potential is N kg^{-1}

(Total 1 mark)

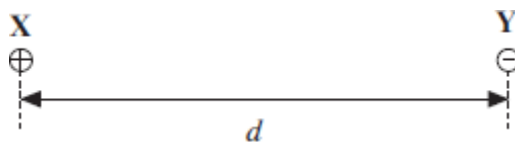
Q3. Which one of the following statements is correct?

The force between two charged particles

- A** is always attractive
- B** can be measured in $\text{C}^2 \text{F}^{-1} \text{m}^{-1}$
- C** is directly proportional to the distance between them
- D** is independent of the magnitude of the charges

(Total 1 mark)

Q4. Two point charges, X and Y, exert a force F on each other when they are at a distance d apart.



When the distance between them is 20 mm, the force they exert on each other is $0.5 F$.

What is the distance d ?

- A 7 mm
- B 14 mm
- C 15 mm
- D 28 mm

(Total 1 mark)

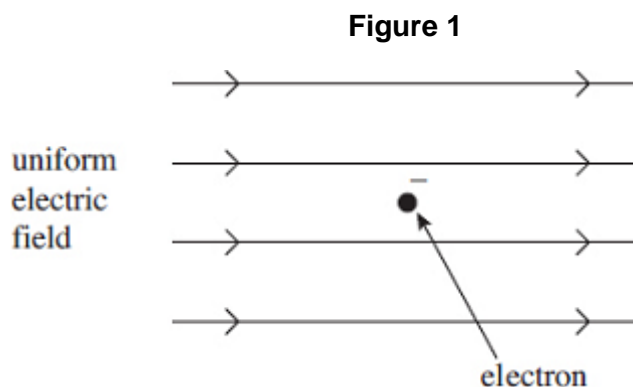
Q5. Which one of the following statements is correct?

When a negative ion is projected into an electric field

- A the field can change the magnitude of the velocity but not its direction
- B the field can change the direction of the velocity but not its magnitude
- C the field can change both the magnitude and the direction of the velocity
- D the ion will accelerate in the direction of the field

(Total 1 mark)

Q6. (a) **Figure 1** shows an electron at a point in a uniform electric field at an instant when it is stationary.



- (i) Draw an arrow on **Figure 1** to show the direction of the electrostatic force that acts on the stationary electron.

(1)

- (ii) State and explain what, if anything, will happen to the magnitude of the electrostatic force acting on the electron as it starts to move in this field.

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(2)

- (b) **Figure 2a** shows a stationary electron in a non-uniform electric field. **Figure 2b** shows a stationary proton, placed in exactly the same position in the same electric field as the electron in **Figure 2a**.

Figure 2a

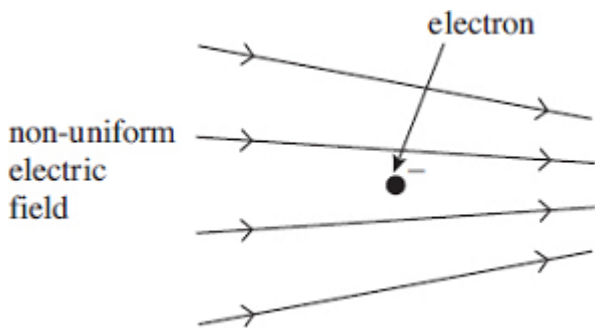
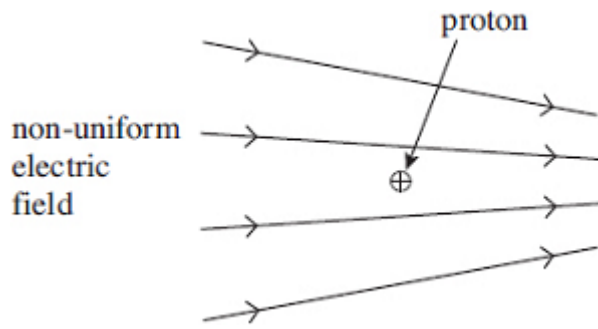


Figure 2b



- (i) State and explain how the electrostatic force on the proton in **Figure 2b** compares with that on the electron in **Figure 2a**.

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(2)

- (ii) Each of the particles starts to move from the positions shown in **Figure 2a** and **Figure 2b**. State and explain how the magnitude of the **initial** acceleration of the proton compares with that of the electron.

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(2)

- (iii) Describe and explain what will happen to the acceleration of each of these particles as they continue to move in the electric field.

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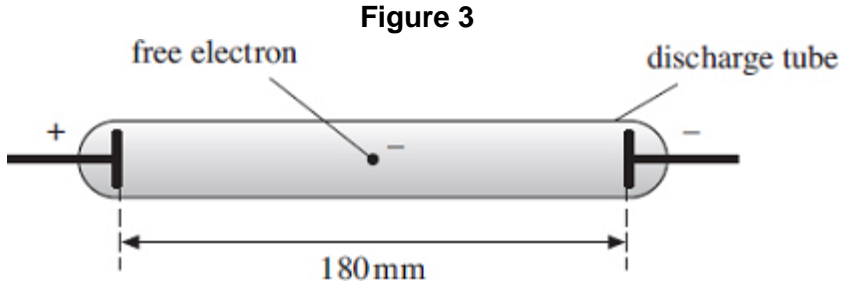
(2)

(c) The line spectrum of neon gas contains a prominent red line of wavelength 650 nm.

- (i) Show that the energy required to excite neon atoms so that they emit light of this wavelength is about 2 eV.

(3)

(ii) An illuminated shop sign includes a neon discharge tube, as shown in **Figure 3**. A pd of 4500 V is applied across the electrodes, which are 180 mm apart.



Assuming that the electric field inside the tube is uniform, calculate the minimum distance that a free electron would have to move from rest in order to excite the red spectral line in part (c).

answer = m

(3)
(Total 15 marks)

- Q7.** (a) Artificial satellites are used to monitor weather conditions on Earth, for surveillance and for communications. Such satellites may be placed in a *geo-synchronous* orbit or in a low polar orbit.

Describe the properties of the geo-synchronous orbit and the advantages it offers when a satellite is used for communications.

You may be awarded marks for the quality of written communication in your answer.

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(3)

- (b) A satellite of mass m travels at angular speed ω in a circular orbit at a height h above the surface of a planet of mass M and radius R .

- (i) Using these symbols, give an equation that relates the gravitational force on the satellite to the centripetal force.

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- (ii) Use your equation from part (b)(i) to show that the orbital period, T , of the satellite is given by

$$T^2 = \frac{4\pi^2 (R + h)^3}{GM}$$

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- (iii) Explain why the period of a satellite in orbit around the Earth cannot be less than 85 minutes. Your answer should include a calculation to justify this value.

$$\begin{aligned} \text{mass of the Earth} &= 6.00 \times 10^{24} \text{ kg} \\ \text{kg radius of the Earth} &= 6.40 \times 10^6 \text{ m} \end{aligned}$$

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(6)

- (c) Describe and explain what happens to the speed of a satellite when it moves to an orbit that is closer to the Earth.

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(2)

(Total 11 marks)

- Q8.(a)** State, in words, Newton's law of gravitation.

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(3)

- (b) By considering the centripetal force which acts on a planet in a circular orbit, show that $T^2 \propto R^3$, where T is the time taken for one orbit around the Sun and R is the radius of the orbit.

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(3)

(c) The Earth's orbit is of mean radius 1.50×10^{11} m and the Earth's year is 365 days long.

(i) The mean radius of the orbit of Mercury is 5.79×10^{10} m. Calculate the length of Mercury's year.

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(ii) Neptune orbits the Sun once every 165 Earth years.

Calculate the ratio $\frac{\text{distance from Sun to Neptune}}{\text{distance from Sun to Earth}}$.

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(4)
(Total 10 marks)

Q9. (a) A transformer operating on a 230 V mains supply provides a 12 V output. There are 1150 turns on the primary coil.

(i) Calculate the number of turns on the secondary coil.

answer = turns

(1)

(ii) A number of identical lamps rated at 12 V, 24 W are connected in parallel across the secondary coil. The primary circuit of the transformer includes a 630 mA fuse. Calculate the maximum number of lamps that can be supplied by the transformer if its efficiency is 85%.

answer = lamps

(2)

(iii) The transformer circuit includes a fuse. Explain why this is necessary.

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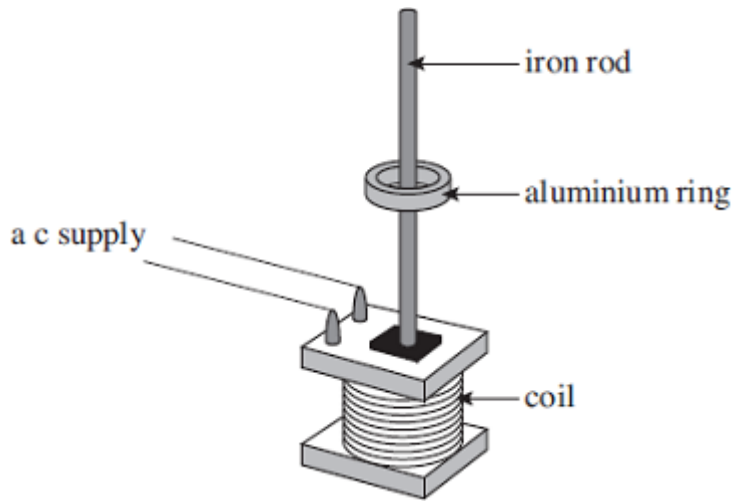
(1)

(iv) Why is the fuse placed in the primary circuit rather than in the secondary circuit?

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(1)

(b) The figure below shows an experimental arrangement that can be used to demonstrate magnetic levitation. The iron rod is fixed vertically inside a large coil of wire. When the alternating current supply to the coil is switched on, the aluminium ring moves up the rod until it reaches a stable position 'floating' above the coil.



- (i) By reference to the laws of electromagnetic induction explain
- why a current will be induced in the ring,
 - why the ring experiences a force that moves it upwards,
 - why the ring reaches a stable position.

The quality of your written communication will be assessed in your answer.

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- (ii) What would happen to the ring if the alternating current in the coil was increased without changing the frequency? Explain your answer.

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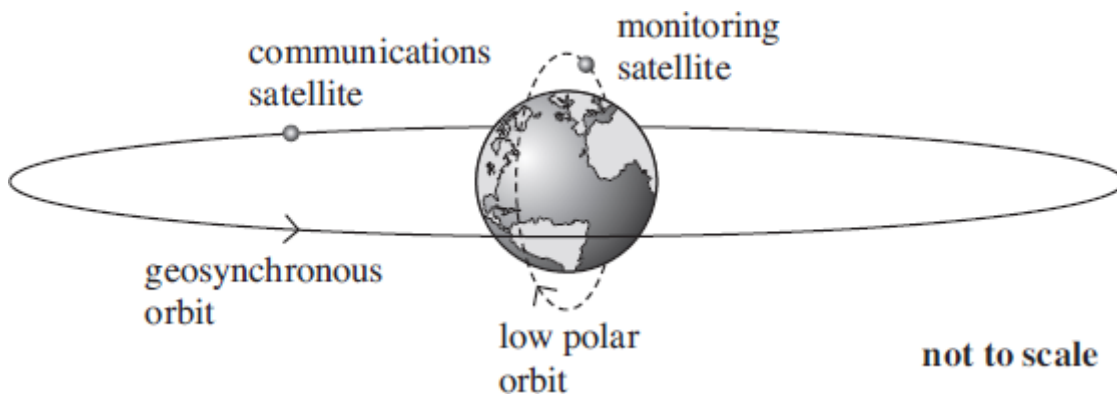
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(2)
(Total 13 marks)

Q10. The diagram below shows the orbits of two Earth satellites, a communications satellite in a geosynchronous orbit and a monitoring satellite in a low orbit that passes over the poles.



- (a) The time period, T , of any satellite in a circular orbit around a planet is proportional to $r^{3/2}$, where r is the radius of its orbit measured from the centre of the planet. For a satellite in a low orbit that passes over the poles of the Earth, T is 105 minutes when r is 7370 km.
- (i) Calculate the height above the surface of the Earth, in km, of a satellite in a geosynchronous circular orbit.
Give your answer to an appropriate number of significant figures.

height above surface km

(4)

- (ii) Calculate the centripetal force acting on the polar orbiting satellite if its mass is 650 kg.

centripetal force N

(2)

- (b) These geosynchronous and polar satellites have different applications because of their different orbits in relation to the rotation of the Earth.

Compare the principal features of the geosynchronous and polar orbits and explain the consequences for possible uses of satellites in these orbits.

In your answer you should explain why:

- a low polar orbit is suitable for a satellite used to monitor conditions on the Earth.
- a geosynchronous circular orbit above the Equator is especially suitable for a satellite used in communications.

The quality of your written communication will be assessed in your answer.

(6)

(Total 12 marks)

Q11. The Large Hadron Collider (LHC) uses magnetic fields to confine fast-moving charged particles travelling repeatedly around a circular path. The LHC is installed in an underground circular tunnel of circumference 27 km.

- (a) In the presence of a suitably directed uniform magnetic field, charged particles move at constant speed in a circular path of constant radius. By reference to the force acting on the particles, explain how this is achieved and why it happens.

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(4)

- (b) (i) The charged particles travelling around the LHC may be protons. Calculate the centripetal force acting on a proton when travelling in a circular path of circumference 27 km at one-tenth of the speed of light. Ignore relativistic effects.

answer = N

(3)

- (ii) Calculate the flux density of the uniform magnetic field that would be required to produce this force. State an appropriate unit.

answer = unit

(3)

- (c) The speed of the protons gradually increases as their energy is increased by the LHC. State and explain how the magnetic field in the LHC must change as the speed of the protons is increased.

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(2)

(Total 12 marks)

M1.C

[1]

M2.C

[1]

M3.B

[1]

M4.B

[1]

M5.C

[1]

M6. (a) (i) horizontal arrow to the left ✓

1

(ii) the electrostatic force is unchanged ✓

2

because electric field strength is constant ✓

(b) (i) forces are equal in magnitude but opposite in direction ✓

(E is the same for both and) Q has same magnitude but opposite sign ✓

2

(ii) acceleration of proton is (much) smaller (than acceleration of electron) ✓

because mass of proton is (much) greater (than mass of electron) ✓

2

(iii) acceleration of proton increases and acceleration of electron decreases ✓

correct reference to changing strength of electric field (for either or both) ✓

2

(c) (i) energy of photon $E \left(= \frac{hc}{\lambda} \right) = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{650 \times 10^{-9}} \checkmark$
 $= 3.06 \times 10^{-19} \text{ (J)} \checkmark$

$$\text{energy required} = \frac{3.06 \times 10^{-19}}{1.60 \times 10^{-19}} = 1.91 \text{ (eV)} \checkmark$$

3

$$(ii) \text{ electric field strength } \left(\frac{V}{d} \right) = \frac{4500}{180 \times 10^{-3}} = 2.50 \times 10^4 \text{ (V m}^{-1}\text{)} \checkmark$$

$$\text{distance} = \left(\frac{V}{E} \right) = \frac{1.91}{2.50 \times 10^4} \left[\text{or} = \left(\frac{W}{F} \right) \left[= \frac{3.06 \times 10^{-19}}{4.0 \times 10^{-15}} \right] \right] \checkmark$$

$$= 7.64 \times 10^{-5} \text{ (m)} \checkmark$$

3

[15]

M7. (a) orbits (westwards) over Equator **(1)**

maintains a fixed position relative to surface of Earth **(1)**

period is 24 hrs (1 day) or same as for Earth's rotation **(1)**

offers uninterrupted communication between transmitter and receiver **(1)**

steerable dish not necessary **(1)**

Max 3

$$(b) (i) \quad G \frac{Mm}{(R+h)^2} = mw^2(R+h) \quad \mathbf{(1)}$$

$$\text{use of } w = \frac{2\pi}{T} \quad \mathbf{(1)}$$

$$(ii) \text{ gives } \frac{GM}{(R+h)^3} = \frac{4\pi^2}{T^2}, \text{ hence result } \mathbf{(1)}$$

(iii) limiting case is orbit at zero height i.e. $h = 0$ **(1)**

$$T^2 = \left(\frac{4\pi^2 R^3}{GM} \right) = \frac{4\pi^2 \times (6.4 \times 10^6)^3}{6.67 \times 10^{-11} \times 6.0 \times 10^{24}} \quad \mathbf{(1)}$$

$$T = 5090 \text{ s (1) (= 85 min)}$$

6

(c) speed increases (1)

loses potential energy but gains kinetic energy (1)

$$\text{[or because } v^2 \propto \frac{1}{r} \text{ from } \frac{GMm}{r^2} = \frac{mv^2}{r} \text{]}$$

[or because satellite must travel faster to stop it falling inwards when gravitational force increases]

2

[11]

M8.(a) attractive **force** between point masses (1)
 proportional to (product of) the masses (1)
 inversely proportional to square of separation/distance apart (1)

3

$$(b) \quad m\omega^2 R = (-) \frac{GMm}{R^2} \left(\text{or} = \frac{mv^2}{R} \right) \quad (1)$$

$$\text{(use of } T = \frac{2\pi}{\omega} \text{ gives) } \frac{4\pi^2}{T^2} = \frac{GM}{R^3} \quad (1)$$

G and M are constants, hence $T^2 \propto R^3$ (1)

3

$$(c) \quad (i) \quad \text{(use of } T^2 \propto R^3 \text{ gives) } \frac{365^2}{(1.50 \times 10^{11})^3} = \frac{T_m^2}{(5.79 \times 10^{10})^3} \quad (1)$$

$$T_m = 87(.5) \text{ days (1)}$$

$$(ii) \quad \frac{1^2}{(1.50 \times 10^{11})^3} = \frac{165^2}{R_N^3} \quad (1) \text{ (gives } R_N = 4.52 \times 10^{12} \text{ m)}$$

$$\text{ratio} = \frac{4.51 \times 10^{12}}{1.50 \times 10^{11}} = 30(.1) \quad (1)$$

4

[10]

M9. (a) (i) use of $\frac{N_s}{N_p} = \frac{V_s}{V_p}$ gives $N_s = \frac{12 \times 1150}{230} = 60$ (turns) ✓

1

(ii) max output power = $0.85 \times 0.630 \times 230$ ✓ (= 123 W)

max number of lamps $\left(= \frac{123}{24} \right) = 5$ ✓ (no mark for non-integer answer)

[or efficiency = $\frac{I_s V_s}{I_p V_p}$ gives $0.85 = \frac{I_s \times 12}{0.630 \times 230}$ ✓ (and max $I_s = 10.3$ (A))

max number of lamps $\left(= \frac{10.3}{2.0} \right) = 5$ ✓]

2

(iii) fuse prevents transformer from overheating [or prevents transformer from supplying excessive currents] ✓

1

(iv) (all of) transformer is disconnected from supply when fuse fails [or fuse in secondary circuit would leave primary circuit live] ✓

1

(b) (i) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High level (good to excellent) 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate states that the ac in the coil produces a constantly changing magnetic field that passes through the ring, causing an emf to be induced according to Faraday's law.

The candidate recognises that the induced emf will cause a current to flow in the ring, that the current is likely be large because the coil acts as a single conductor with low resistance, and that this current also produces a magnetic field.

The candidate appreciates that Lenz's law indicates that the direction of the induced current is such as to produce a magnetic field that will oppose the existing field, and that the two fields will interact.

The candidate refers to the force that acts on a current-carrying conductor when it is in a magnetic field and that this force lifts the ring upwards (into an area where the magnetic field is weaker) until the upwards magnetic force is equal to the downwards weight of the ring.

Intermediate level (modest to adequate) 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate is familiar with either or both Faraday's and Lenz's laws but only applies one of them to explain what happens in this demonstration. There are correct references to the two forces that act on the ring, and a reasonable explanation of why the ring reaches a stable position.

Low level (poor to limited) 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate refers much more superficially to either Faraday's or Lenz's law (or to both of them) but shows some understanding of why the forces acting on the ring cause it to reach equilibrium.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

Faraday's law

- An emf is induced whenever there is a change in the magnetic flux passing through a conductor.
- The magnitude of the emf is proportional to the rate of change of magnetic flux linkage.
- The induced emf will cause a current to flow in any complete circuit, such as a single conducting ring.
- Because the ring is made from aluminium, which is a good conductor, a large initial current will be induced in it.

Lenz's law

- The induced current flows in such a direction as to oppose the increase in magnetic flux when the current is switched on in the coil.
- The current produces a magnetic field in the opposite direction to that produced by the coil.
- These two (alternating) fields interact like the fields between two facing like magnetic poles, giving repulsion.

Forces

- The ring is a current-carrying conductor in a magnetic field, and consequently it experiences a force.
- This magnetic force acts upwards, in the opposite direction to the weight of the ring.
- As the ring rises, the magnetic field to which it is exposed becomes weaker as it moves away from the coil.
- This reduces the induced current, reducing also the magnetic force on the ring.
- The ring reaches a stable height when the magnetic force has decreased to the point where it is equal to the weight of the ring.

6

(ii) ring would 'float' higher [**or** be expelled upwards] ✓

because (initial) current or emf (induced) *in ring* is greater ✓

or ring moves into weaker field until magnetic force balances weight
[**or** (initially) magnetic force exceeds weight] ✓

2

$$\text{M10.(a) (i) } \left(T \propto r^{3/2} \text{ or } \frac{T_E}{T_P} = \left(\frac{r_E}{r_P} \right)^{3/2} \text{ gives} \right) \frac{60 \times 24}{105} = \left(\frac{r_E}{7370} \right)^{3/2} \checkmark$$

$$\text{from which } \frac{r_E}{7370} = \left(\frac{60 \times 24}{105} \right)^{2/3} = 5.73$$

$$\text{and } r_E (= 5.73 \times 7370) = 42\,200 \text{ (km)} \checkmark$$

height above surface = $42\,200 - 6370 = 35\,800$ or $35\,900$ (km) \checkmark
 answer to **3SF** only \checkmark

Full solution derived from Newton's law of gravitation is acceptable for all 4 marks.

[or Newton's law approach for 1st two marks:

$$\left(\frac{GMm}{r^2} = m\omega^2 r \text{ and } \omega = \frac{2\pi}{T} \right) \text{ give } r^3 \left(= \frac{GMT^2}{4\pi^2} \right)$$

$$\therefore r_E^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2}{4\pi^2} \checkmark \quad (= 7.54 \times 10^{22})$$

$$\text{from which } r_E = 42\,200 \text{ (km)} \checkmark]$$

*For 3rd mark, final answer **must** be expressed in km. **3SF** mark is independent.*

4

$$\text{(ii) centripetal force } (= m\omega^2 r) = \frac{650 \times 4\pi^2 \times 7.37 \times 10^6}{(105 \times 60)^2} \checkmark$$

$$= 4800 \text{ (4760) (N)} \checkmark$$

*If **both** T and r values for the **geosynchronous** satellite are substituted, award 0 marks for (ii).*

$$\text{[or centripetal force } \left(= \frac{mv^2}{r} \right) \text{ and } v = \frac{2\pi r}{T} = \frac{2\pi \times 7.37 \times 10^6}{105 \times 60}$$

$$\text{gives } v = 7350 \text{ (m s}^{-1}\text{) and centripetal force} = \frac{650 \times 7350^2}{7.37 \times 10^6} \checkmark$$

$$= 4800 \text{ (4760) (N)} \checkmark]$$

[or centripetal force $\left(= \frac{GMm}{r^2} \right) = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 650}{(7.37 \times 10^6)^2}$ ✓

= 4800 (4770) (N) ✓]

If only one correct T or r value for the **polar** satellite is substituted, mark (ii) to max 1.

2

- (b) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Four aspects must be considered in a high level answer:-

Features of polar orbit.

Features of geosynchronous orbit.

Why polar orbit is suitable for monitoring.

Why geosynchronous orbit is suitable for communication.

The candidate gives a comprehensive comparison of the principal features of the satellite orbits and explains the consequences for the uses of the two types of satellites. There are clear statements showing good understanding of why the polar satellite is suitable for monitoring, and of why the geosynchronous satellite is useful for communications.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate's comparison of the principal features of the orbits is less complete and the consequences for the uses of satellites in them are less well understood. The candidate has an acceptable appreciation of why the polar satellite is suitable for monitoring, and of why the geosynchronous satellite is useful for communications.

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate has a much weaker knowledge of the principal features of the orbits and very limited knowledge of consequences for the uses of satellites in them. Understanding of why the polar satellite is suitable for monitoring, and why the geosynchronous satellite is suitable for communications, is limited or absent.

The explanation expected in a competent answer should include a coherent selection of the following points.

Low polar orbit

- Orbital period is a few hours
- Earth rotates relative to the orbit

- Many orbits with different radii and periods are possible
- Orbit height is less than geosynchronous satellite
- Speed is greater than that of geosynchronous satellite
- Satellite scans the whole surface of the Earth
- Applications: surveillance of conditions / installations on Earth, mapping, weather observations, environmental monitoring
- Gives access to every point on Earth's surface every day
- Can collect data from regions inaccessible to man
- Contact with transmitting / receiving aerial is intermittent
- Aerial is likely to need a tracking facility
- Lower signal strength required than that for geosynchronous satellite

Geosynchronous orbit above Equator

- Orbital period matches Earth's rotational period exactly
- Satellite maintains same position relative to Earth
- Only one particular orbit radius is possible
- Travels west to east above Equator (in same direction as Earth's rotation)
- Orbit height is greater than polar orbit satellite
- Speed is less than that of polar orbiting satellite
- Scans a restricted (and fixed) area of the Earth's surface only
- Applications: telecommunications generally, cable and satellite TV, radio, digital information, etc.
- Satellite is in continuous contact with transmitting / receiving aerial
- Aerial can be in a fixed position
- Higher signal strength required than that for polar satellite

max 6
[12]

M11. (a) (magnetic) field is applied perpendicular to path

or direction or velocity of charged particles ✓

(magnetic) force acts perpendicular to path

or direction or velocity of charged particles ✓

force depends on speed of particle or on B [or $F \propto v$ or $F = BQv$ explained] ✓

force provides (centripetal) acceleration towards centre of circle

[or (magnetic) force is a centripetal force] ✓

$$BQv = \frac{mv^2}{r} \text{ or } r = \frac{mv}{BQ} \text{ shows that } r \text{ is constant when } B \text{ and } v \text{ are constant } \checkmark$$

4

(b) (i) radius r of path = $\frac{\text{circumference}}{2\pi} = \frac{27 \times 10^3}{2\pi} = 4.30 \times 10^3 \text{ (m)}$
(allow 4.3km) ✓

centripetal force $\left(= \frac{mv^2}{r} \right) = \frac{1.67 \times 10^{-27} \times (3.00 \times 10^7)^2}{4.30 \times 10^3} \checkmark = 3.50 \times 10^{-16} \text{ (N)} \checkmark$

3

(ii) magnetic flux density $B \left(= \frac{F}{Qv} \right) = \frac{3.50 \times 10^{-16}}{1.60 \times 10^{-19} \times 3.00 \times 10^7} \checkmark$
 $= 7.29 \times 10^{-5} \checkmark \text{ T } \checkmark$

3

(c) magnetic field must be increased \checkmark

to increase (centripetal) force **or** in order to keep r constant \checkmark

[**or** otherwise protons would attempt to travel in a path of larger radius]

[**or**, referring to $r = \frac{mv}{BQ}$, B must increase when v increases to keep r constant]

2

[12]

M12. The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate gives a comprehensive account of the similarities and differences between gravitational and electric fields, referring to both radial and uniform fields. There are clear statements showing good to excellent understanding of the forces between masses/charges, gravitational and electric field strengths, and gravitational and electric potentials and of how aspects of them differ for gravitational and electric effects.

*A **High Level** answer must refer to at least **two valid** similarities and at least **two valid** differences, and must also contain information about **both** radial and uniform fields.*

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate's comparisons are less complete but good understanding is shown of the factors affecting the respective forces and of the definitions of field strength and potential. There may be limited reference to radial and uniform fields. Similarities between gravitational and electric effects are better known than differences.

*An **Intermediate** Level answer must refer to at least **two valid** similarities and at least **one valid** difference, and must also consider **either** radial or uniform fields, or both.*

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate has a much weaker ability to convey the similarities and differences between gravitational and electric fields. There is likely to be little or no reference to radial and uniform fields. Factors affecting the respective forces are known, but understanding of field strength is likely to be weaker and understanding of potential may be poor or absent.

*A **Low Level** answer must refer to at least **one valid** similarity but may not identify any **valid** differences.*

The explanation expected in a competent answer should include a coherent selection of the following points.

(D) = valid difference.

Good candidates are likely to mention other valid differences e.g. electrostatic forces depend on the medium whereas gravitational forces don't, possibility of shielding an electric field but impossibility of shielding a gravitational field.

Forces

- In a radial field, both gravitational and electric involve an inverse square relationship.
- In both cases the force is proportional to a product (masses / charges).
- In both cases a spherical body may be considered to act as a point mass or charge placed at the centre of the sphere.
- In a uniform field the force is constant at all points.
- Gravitational forces are always an attraction whilst electric forces may be attraction or repulsion. **(D)**
- Gravitational forces are usually much smaller than electric forces (unless very large masses are involved). **(D)**

Field Strengths

- Both are defined as a *force per unit* mass or charge.
- In both cases the field strength in a radial field is proportional to $1/r^2$
- In both cases the field strength in a radial field is proportional to the magnitude of the mass or charge that produces it.
- In a uniform field the field has the same magnitude and same direction at all points.
- A gravitational field is always directed towards the mass producing it whereas an electric field is directed towards a negative charge but away from a positive charge. **(D)**
- A mass of 1 kg is small in terms of the gravitational field it produces but a charge of 1 C would produce a very strong electric field. **(D)**

Potentials

- Definitions of both involve work done in moving a mass or charge from infinity to a point.
- Both definitions involve the work done *per unit* mass or charge.
- Both types of potential are proportional to $1/r$ in a radial field.
- Both types of potential are proportional to the mass or charge producing them.
- In a uniform field the potential varies linearly with distance.
- The work done in moving a mass or charge across a potential difference is calculated by multiplying the mass or charge by the potential difference.
- Gravitational potential is always a negative quantity but electric potential is negative for negative charges and positive for positive charges. **(D)**

(max 6)