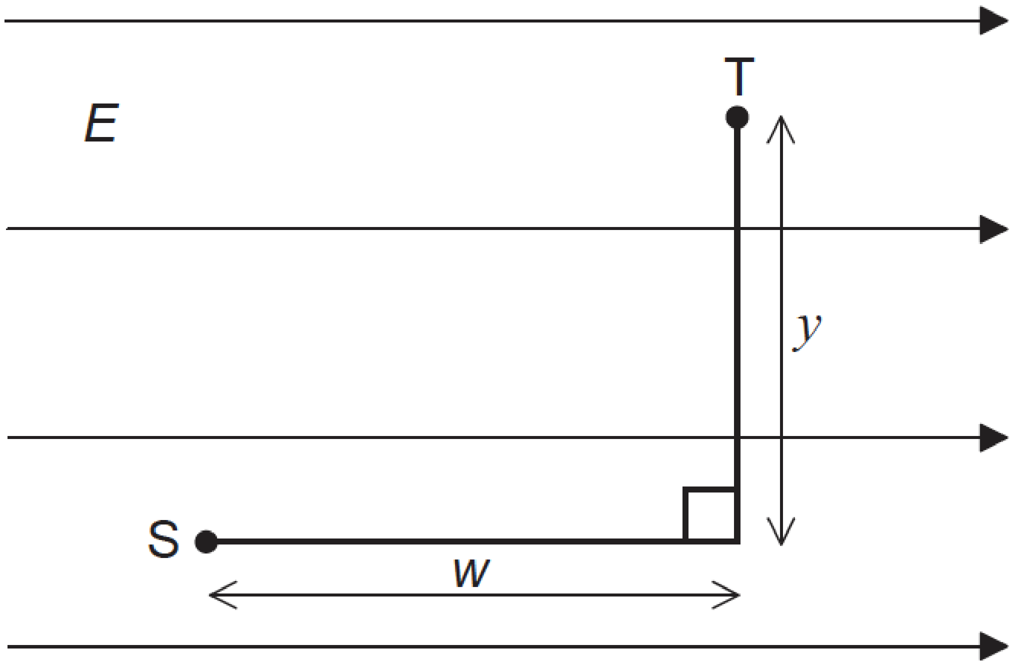
T10 *[186 marks]*

1. A particle of charge *q* is at point S in a uniform electric field of strength *E*. The particle moves a distance *w* parallel to the field lines and then a distance *y* perpendicular to the field lines to reach point T. *[1 mark]*



What is the change in electric potential energy of the charge between S and T?

A. *Eqw*

B. *Eqy*

C. *Eq* (*y* + w)

D. *Eq* $\sqrt{y^2 + w^2}$

2. A particle has charge and mass. Which types of field cause a force to be exerted on the particle when it is moving in the direction of the field? *[1 mark]*

A. Electric, gravitational and magnetic fields

B. Electric and magnetic fields only

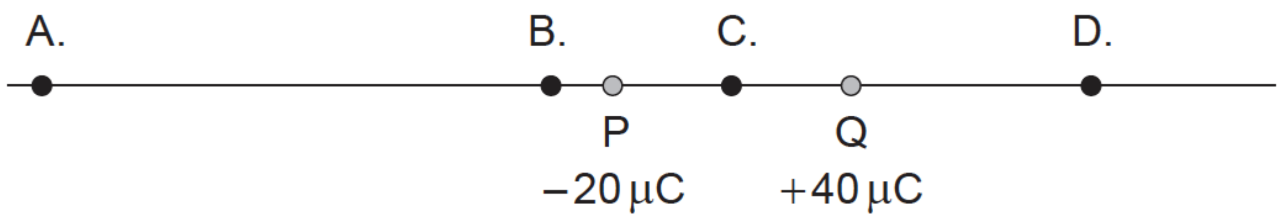
C. Gravitational and magnetic fields only

D. Electric and gravitational fields only

3. An electron is held close to the surface of a negatively charged sphere and then released. Which describes the velocity and the acceleration of the electron after it is released? *[1 mark]*

	Velocity	Acceleration
A.	decreasing	constant
B.	decreasing	decreasing
C.	increasing	constant
D.	increasing	decreasing

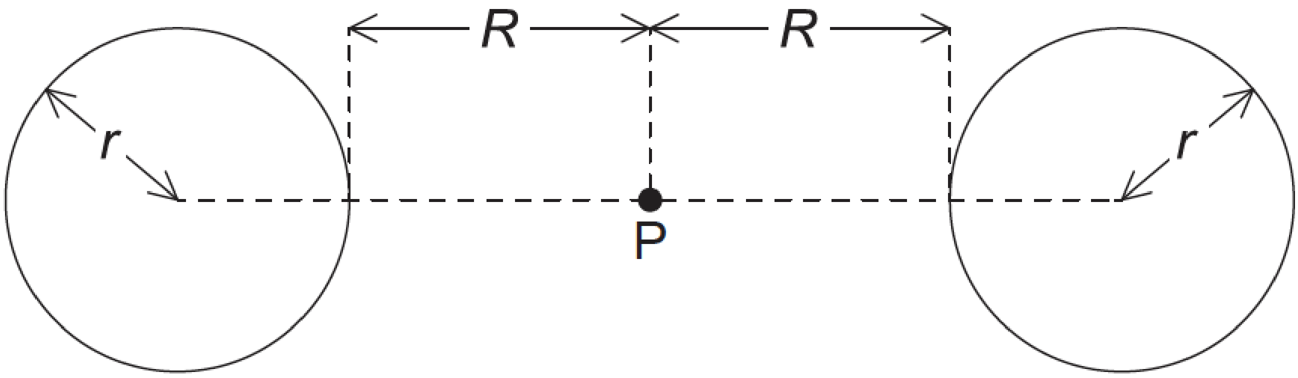
4. The diagram shows two point charges P and Q. At which position is the electric field strength equal to zero? *[1 mark]*



5. An electron is held close to the surface of a negatively charged sphere and then released. Which describes the velocity and the acceleration of the electron after it is released? *[1 mark]*

	Velocity	Acceleration
A.	decreasing	constant
B.	decreasing	decreasing
C.	increasing	constant
D.	increasing	decreasing

6. Two spherical objects of mass *M* are held a small distance apart. The radius of each object is *r*. *[1 mark]*



Point P is the midpoint between the objects and is a distance *R* from the surface of each object. What is the gravitational potential at point P?

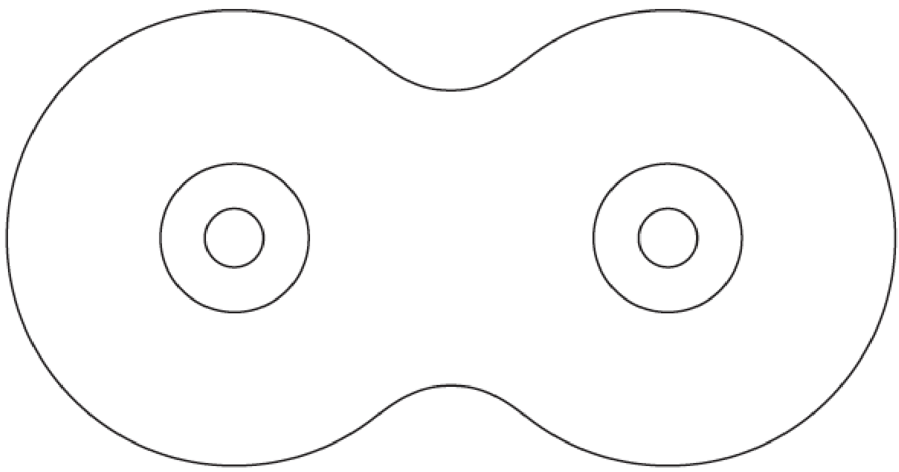
A. $-\frac{GM}{(r+R)^2}$

B. $-2\frac{GM}{r+R}$

C. $-\frac{GM}{r+R}$

D. 0

7. The diagram shows equipotential lines around two sources. *[1 mark]*



Possible sources are

I. two equal masses

II. two equal charges of same sign

III. two equal charges of opposite sign.

What is/are the possible source(s) for the equipotential lines?

A. I and II only

B. I and III only

C. II only

D. III only

This question is in two parts. **Part 1** is about momentum. **Part 2** is about electric point charges.

Part 1 Momentum

8a. State the law of conservation of linear momentum. *[2 marks]*

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8b. Two identical toy cars, A and B are dropped from the same height onto a solid floor without rebounding. Car A is unprotected whilst car B is in a box with protective packaging around the toy. Explain why car B is less likely to be damaged when dropped. *[4 marks]*

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Part 2 Electric point charges

8c. Define *electric field strength* at a point in an electric field. *[2 marks]*

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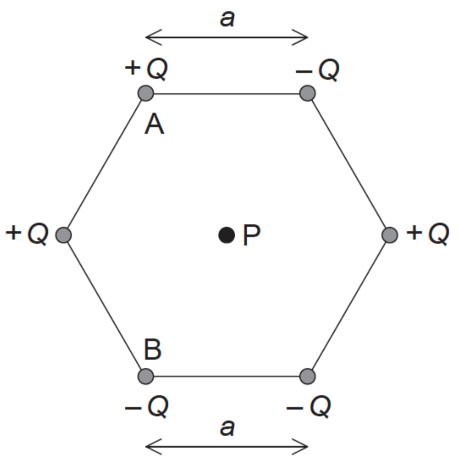
8d. Six point charges of equal magnitude *Q* are held at the corners of a hexagon with the signs of the charges as shown. Each side of the hexagon has a length *a*. *[8 marks]*



P is at the centre of the hexagon.

(i) Show, using Coulomb's law, that the magnitude of the electric field strength at point P due to **one** of the point charges is

$$\frac{kQ}{a^2}$$

(ii) On the diagram, draw arrows to represent the direction of the field at P due to point charge A (label this direction A) and point charge B (label this direction B).

(iii) The magnitude of *Q* is 3.2 μC and length *a* is 0.15 m. Determine the magnitude and the direction of the electric field strength at point P due to all six charges.

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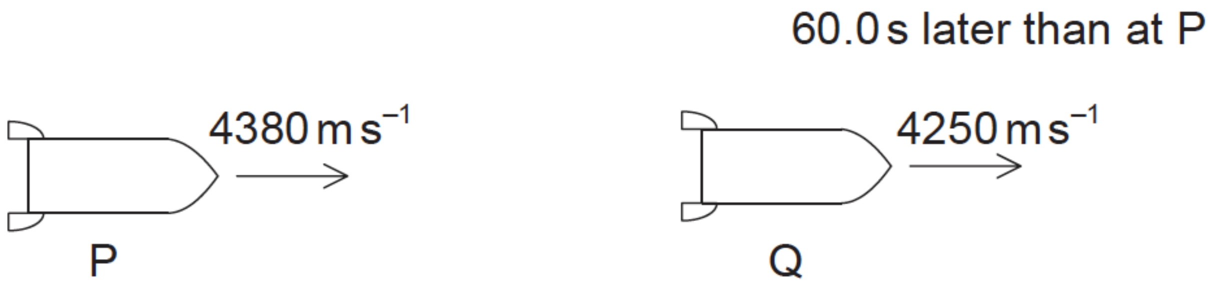
Part 2 Motion of a rocket

A rocket is moving away from a planet within the gravitational field of the planet. When the rocket is at position P a distance of 1.30×10^7m from the centre of the planet, the engine is switched off. At P, the speed of the rocket is 4.38×10^3ms^{-1}.



At a time of 60.0 s later, the rocket has reached position Q. The speed of the rocket at Q is 4.25×10^3ms^{-1}. Air resistance is negligible.

9a. Outline, with reference to the energy of the rocket, why the speed of the rocket is changing between P and Q. *[2 marks]*

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9b. Estimate the average gravitational field strength of the planet between P and Q. *[2 marks]*

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9c. A space station is in orbit at a distance *r* from the centre of the planet in (e)(i). A satellite is launched from the space station so as just to escape from the gravitational field of the planet. The launch takes place in the same direction as the velocity of the space station. Outline why the launch velocity relative to the space station can be less than your answer to (e)(i). *[1 mark]*

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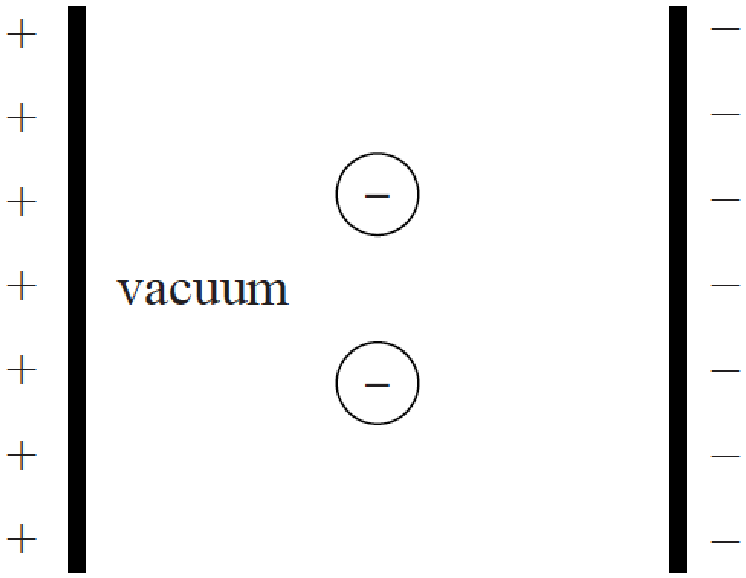
10. A field line is normal to an equipotential surface *[1 mark]*

A. for both electric and gravitational fields.
B. for electric but not gravitational fields.
C. for gravitational but not electric fields.
D. for neither electric nor gravitational fields.

11. Two negatively charged particles are released from rest half-way between two oppositely charged parallel plates in vacuum. *[1 mark]*



The particles take the same time to reach the positively charged plate. The particles must have the same

A. charge only.
B. mass only.
C. mass and charge.
D. ratio of mass to charge.

12. The gravitational field strength at a point X in a gravitational field is defined as the force *[1 mark]*

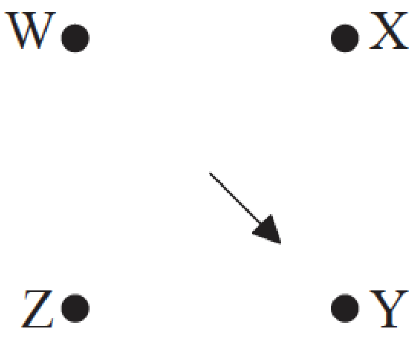
A. per unit mass on a mass placed at X.

B. on a mass placed at X.

C. per unit mass on a small point mass placed at X.

D. on a small point mass placed at X.

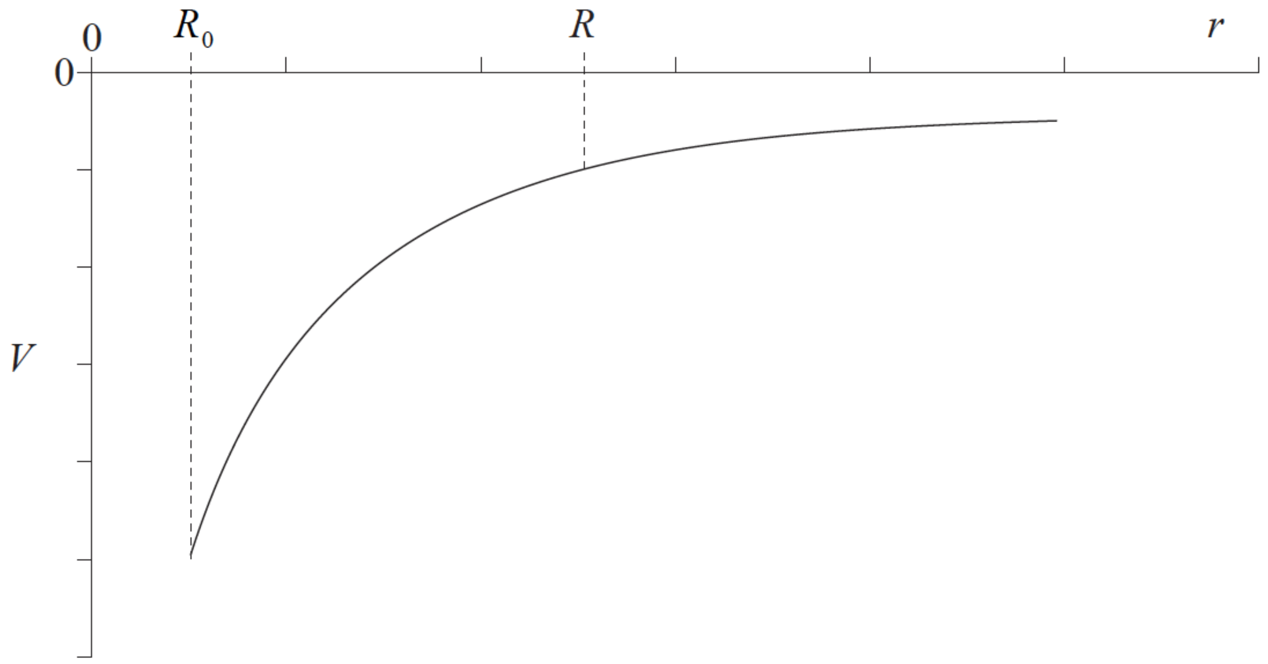
13. Four point charges of equal magnitude W, X, Y and Z are each fixed to a corner of a square. *[1 mark]*



W is a positive charge and X is a negative charge. The arrow shows the direction of the resultant electric field at the centre of the square. What are the correct signs of charge Y and of charge Z?

	Y	Z
A.	positive	positive
B.	negative	positive
C.	positive	negative
D.	negative	negative

14. The sketch graph shows how the gravitational potential V of a planet varies with distance r from the centre of the planet of radius R_0. *[1 mark]*



The magnitude of the gravitational field strength at the point $r=R$ equals the

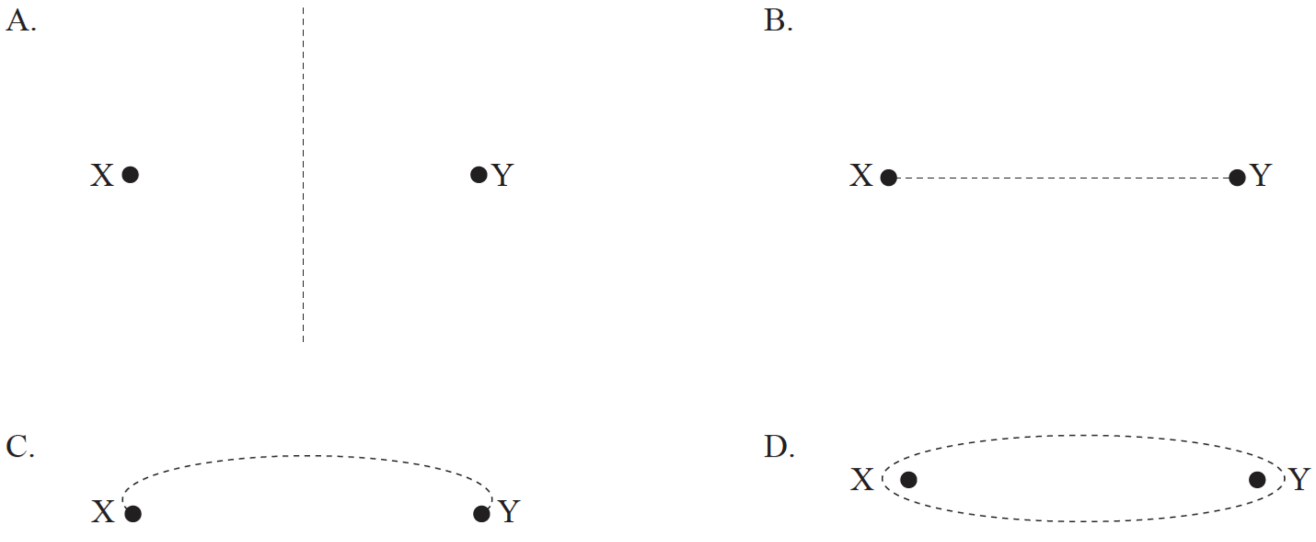
A. area between the graph and the r-axis between $r=R$ and $r=R_0$.

B. gradient of the graph at $r=R$.

C. inverse of the gradient of the graph at $r=R$.

D. value of V at $r=R$ divided by R^2.

15. Which diagram shows a correct equipotential line due to two point charges X and Y of opposite sign? *[1 mark]*



This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about orbital motion.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	7.0×10^{8} m
Surface temperature of Sun	T	5.8×10^{3} K
Distance from Sun to Earth	d	1.5×10^{11} m
Stefan-Boltzmann constant	σ	5.7×10^{-8} W m^{-2} K^{-4}

16a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

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16b. Deduce that the solar power incident per unit area at distance *d* from the Sun is given by $\frac{\sigma R^2 T^4}{d^2}$. *[2 marks]*

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16c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

16d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

16e. The average power absorbed per unit area at the Earth's surface is 240Wm^{-2}. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

16f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

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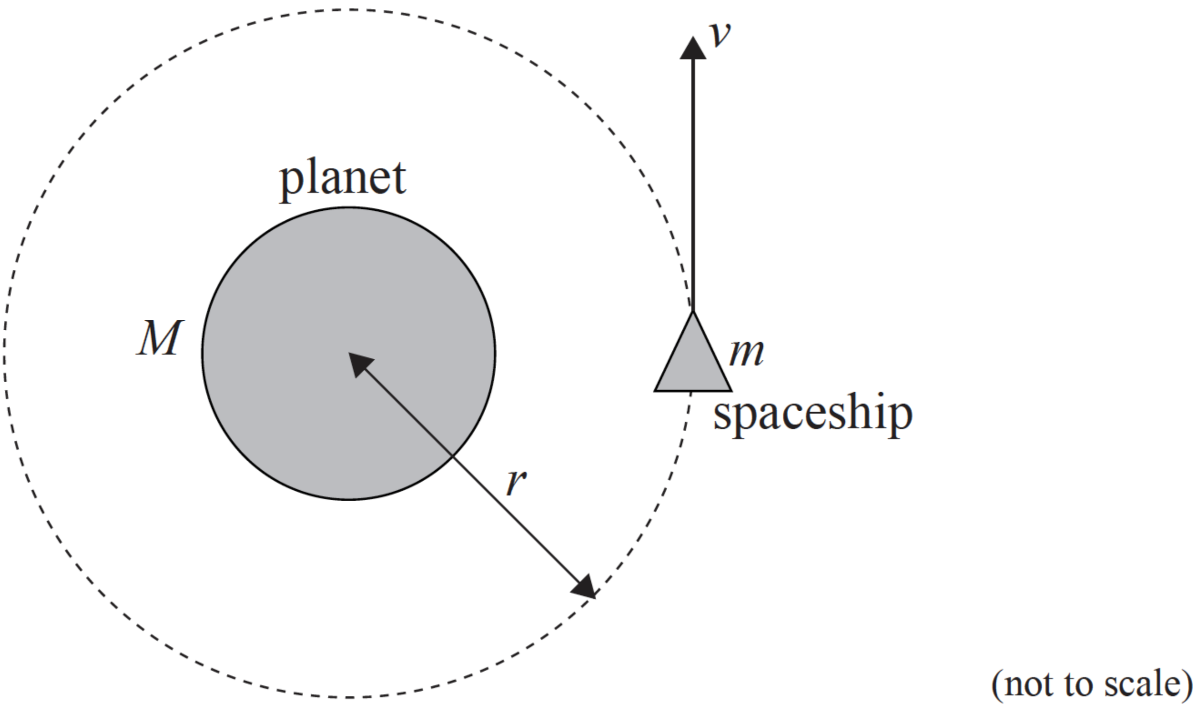
Part 2 Orbital motion

A spaceship of mass *m* is moving at speed *v* in a circular orbit of radius *r* around a planet of mass *M*.



16g. (i) Identify the force that causes the centripetal acceleration of the spaceship. *[4 marks]*

(ii) Explain why astronauts inside the spaceship would feel “weightless”, even though there is a force acting on them.

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16h. Deduce that the speed of the spaceship is $v = \sqrt{\frac{GM}{r}}$. *[2 marks]*

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16i. The table gives equations for the forms of energy of the orbiting spaceship. *[4 marks]*

Form of Energy	**Equation**
Kinetic	$E_K = \frac{GMm}{2r}$
Gravitational potential	$E_P = -\frac{GMm}{r}$
Total (kinetic + potential)	$E = -\frac{GMm}{2r}$

The spaceship passes through a cloud of gas, so that a small frictional force acts on the spaceship.

(i) State and explain the effect that this force has on the total energy of the spaceship.

(ii) Outline the effect that this force has on the speed of the spaceship.

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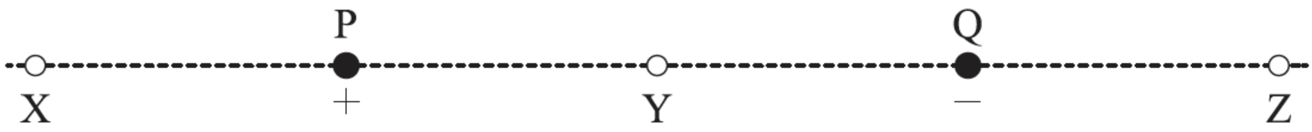
17. A positive point charge P and a negative point charge Q of equal magnitude are held at fixed positions. Y is midway between P and Q. *[1 mark]*

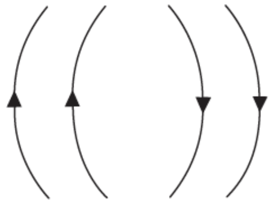


Which of the following gives the direction of the electric field due to the charges at X, Y and Z?

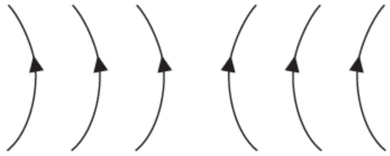
	X	Y	Z
A.	to right	to left	to right
B.	to right	to right	to left
C.	to left	to right	to right
D.	to left	to right	to left

18. What field pattern can be produced by two point charges? *[1 mark]*

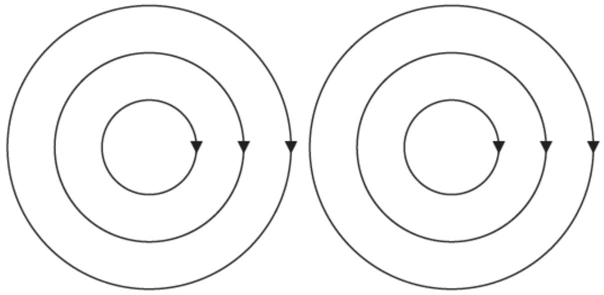
A.



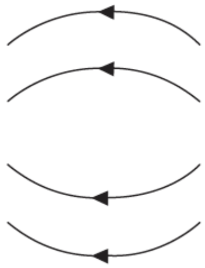
B.



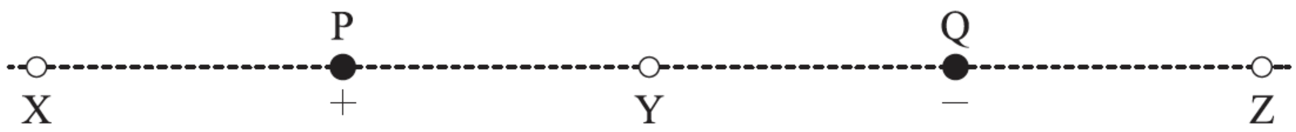
C.



D.



19. A positive point charge P and a negative point charge Q of equal magnitude are held at fixed positions. Y is a point midway between P and Q. *[1 mark]*



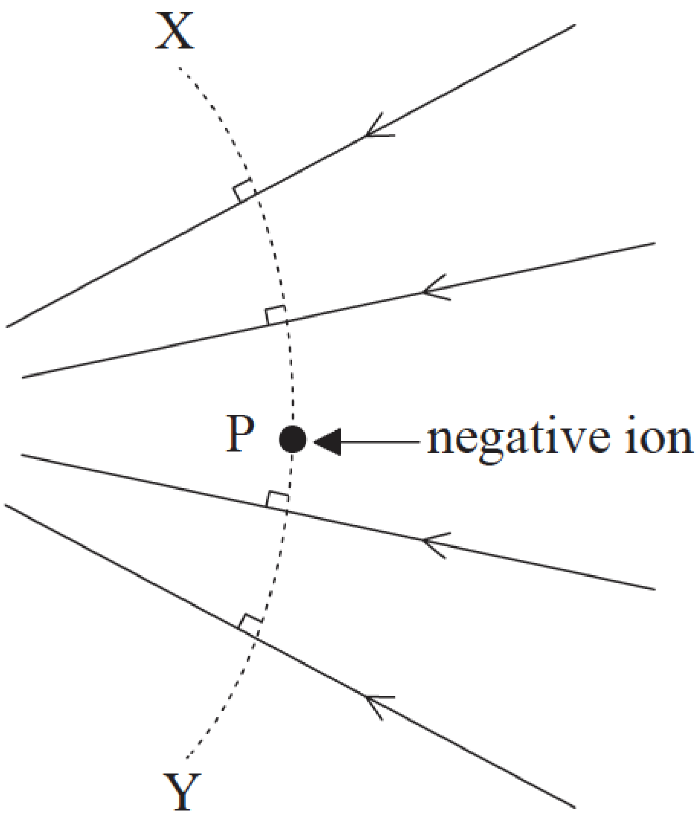
Which of the following gives the direction of the electric field due to the charges at X, Y and Z?

	X	Y	Z
A.	to right	to left	to right
B.	to right	to right	to left
C.	to left	to right	to right
D.	to left	to right	to left

20. At the surface of a planet of radius r, the gravitational field strength is g and the gravitational potential is V. Which gives the gravitational field strength and gravitational potential at a height $3r$ above the surface? *[1 mark]*

	Gravitational field strength	**Gravitational potential**
A.	$\frac{g}{16}$	$\frac{V}{4}$
B.	$\frac{g}{3}$	$\frac{V}{3}$
C.	$\frac{g}{4}$	$\frac{V}{4}$
D.	$\frac{g}{9}$	$\frac{V}{3}$

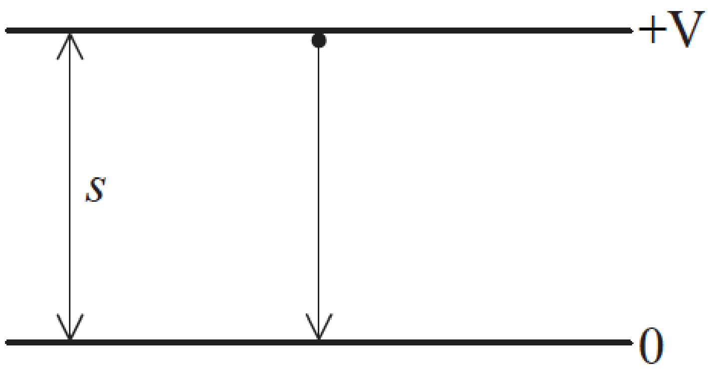
21. A negative ion is held at point P in an electric field as represented by the arrowed field lines. *[1 mark]*



Which of the following describes the effect on the negative ion when it is displaced in a particular direction?

	Direction of displacement	Effect on the negative ion
A.	to the left	magnitude of electric force on the ion is unchanged
B.	to the right	potential energy of ion increases
C.	along XY towards X	potential energy of ion increases
D.	along XY towards Y	magnitude of electric force on the ion is unchanged

22. An electron of mass m_e and charge e accelerates between two plates separated by a distance s in a vacuum. The potential difference between the plates is V. *[1 mark]*



What is the acceleration of the electron?

A. $\frac{m_e ev}{s}$

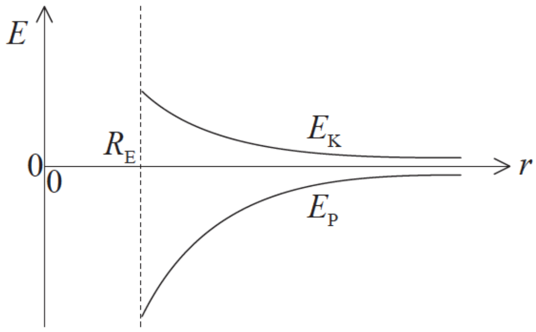
B. $\frac{m_e v}{es}$

C. $\frac{eV}{m_e s}$

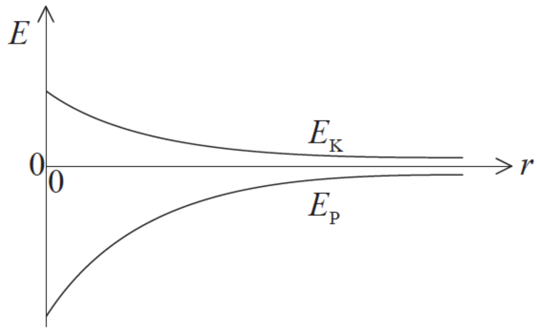
D. $\frac{V}{m_e es}$

23. A satellite is in orbit about Earth at a distance r from the centre of Earth. The gravitational potential energy of the satellite is E_P and its kinetic energy is E_K. The radius of Earth is R_E. Which graph shows how both E_P and E_K vary with r? *[1 mark]*

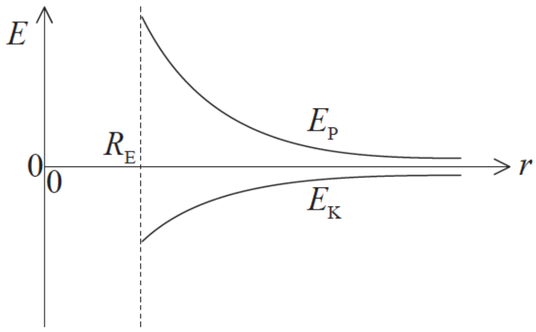
A.



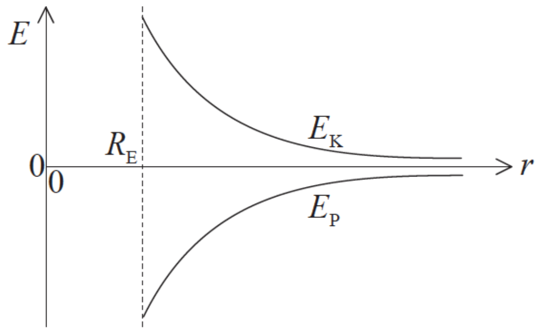
B.



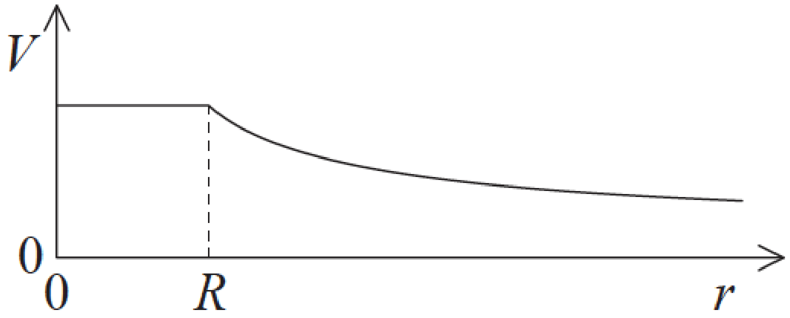
C.



D.

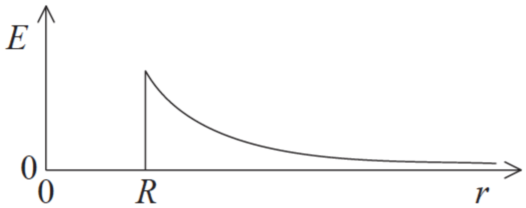


24. The graph shows the variation with distance *r* of the electric potential *V* for a positively charged hollow sphere of radius *R*. *[1 mark]*

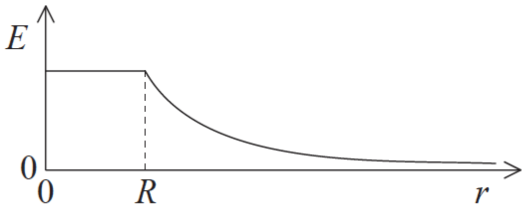


Which graph shows how the magnitude of the electric field *E* varies with *r*?

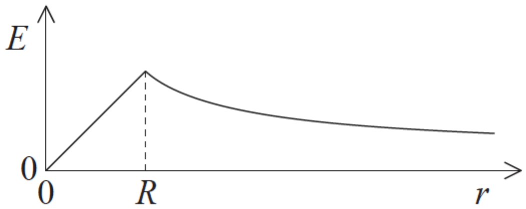
A.



B.



C.



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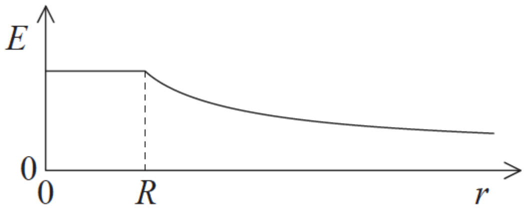
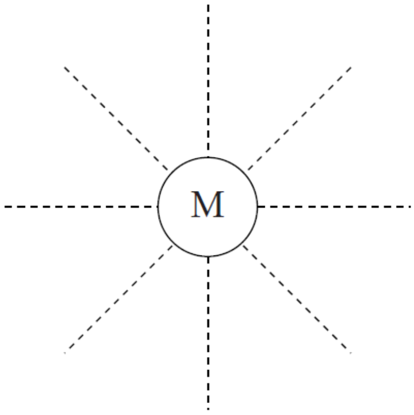
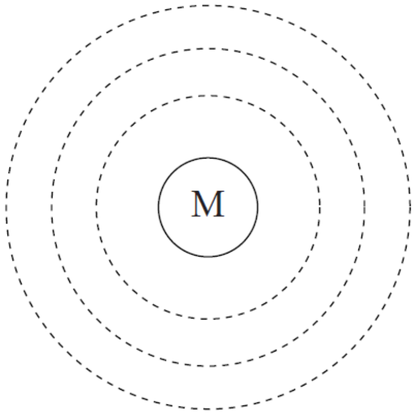


25. M is a spherical mass situated far away from any other masses. Which of the following represents gravitational equipotential surfaces having constant potential difference between them? *[1 mark]*

A.



B.



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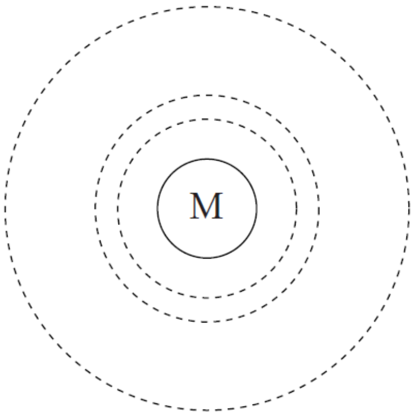
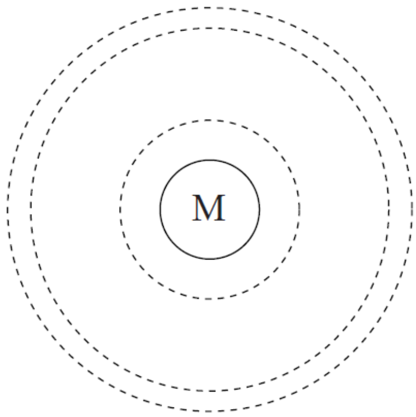
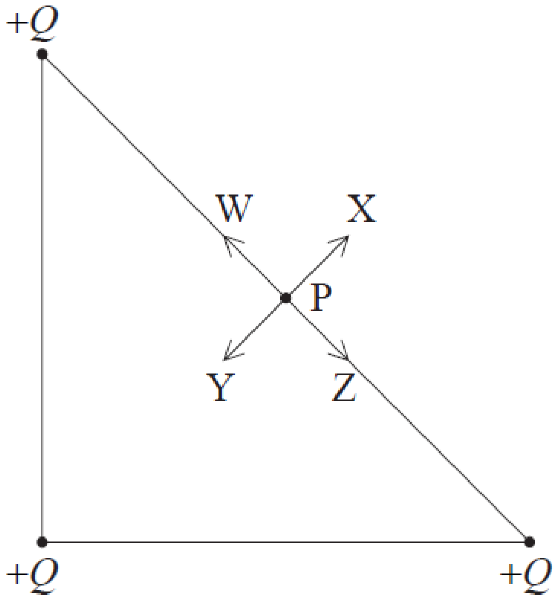


D.



26. Three positive point charges +*Q* are fixed in position at the vertices of an isosceles triangle. P is the mid point between two of the charges. *[1 mark]*



Which arrow correctly identifies the direction of the electric field at point P?

A. W
B. X
C. Y
D. Z

Part 2 Gravitational potential

27a. Define *gravitational potential* at a point in a gravitational field. *[3 marks]*

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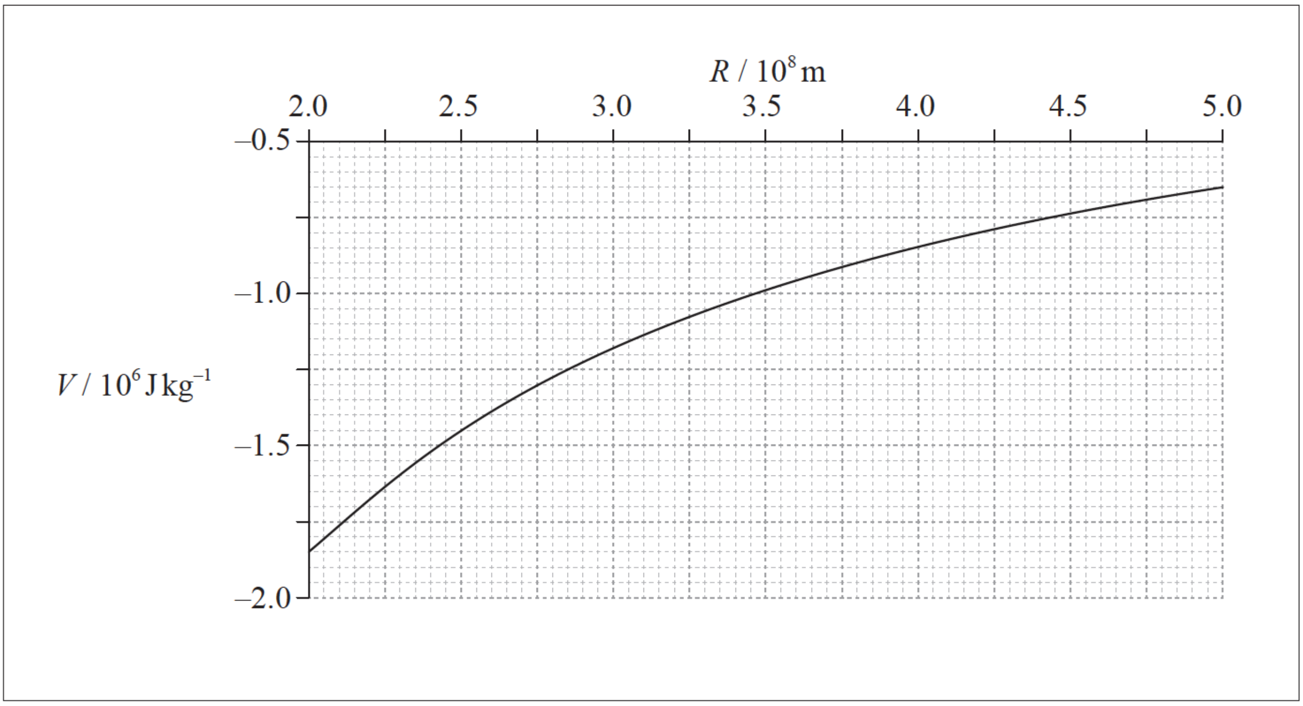
27b. The graph shows how the gravitational potential V of Earth varies with distance R from the centre of Earth in the range $R=2.0\times10^{8}$ m to $R=5.0\times10^{8}$ m. *[6 marks]*



The Moon is at a distance of 4.0×10^{8} m from the centre of Earth. At some time in the past it was at a distance of 2.7×10^{8} m from the centre of Earth.

Use the graph opposite to determine

(i) the present day magnitude of the acceleration of the Moon.

(ii) by how much the potential energy of the Moon has changed as a result of moving from $R=2.7\times10^{8}$ m to $R=4.0\times10^{8}$ m. The mass of the Moon is 7.4×10^{22} kg.

27c. State why the change of potential energy in (f)(ii) is an increase. *[1 mark]*

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28. The escape speed of a rocket from the surface of Earth depends on the universal gravitational constant *G*. Other factors that may affect the escape speed are the *[1 mark]*

I. mass of Earth
II. radius of Earth
III. mass of the rocket.

Which of the above factors is/are correct?

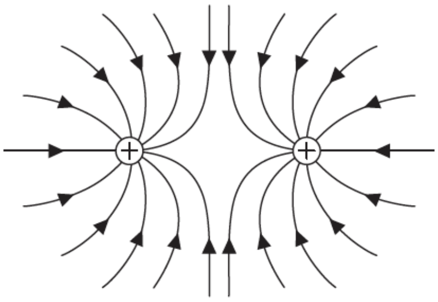
A. I and II only
B. I and III only
C. II only
D. III only

29. A satellite in orbit about Earth moves to another orbit that is closer to the surface of Earth. When the satellite moves into the orbit closer to Earth, which of the following correctly describes the change in speed of the satellite and the change in its gravitational potential energy? *[1 mark]*

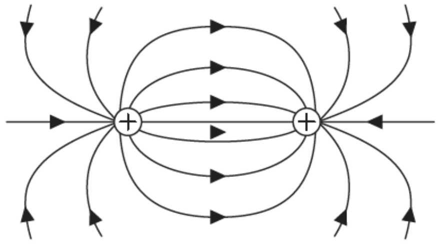
	Speed	**Gravitational potential energy**
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

30. Which diagram shows the electric field pattern surrounding two equal positive point charges? *[1 mark]*

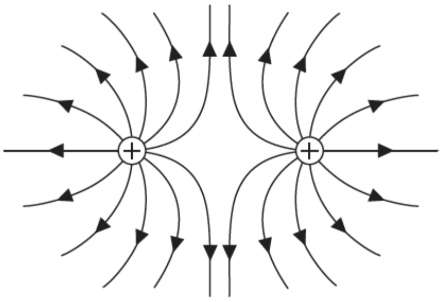
A.



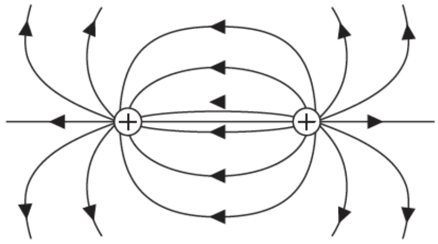
B.



C.



D.



31. A satellite is moved from a low orbit to a higher orbit. Which of the following accurately describes the energy of the satellite? *[1 mark]*

	Total energy	**Gravitational potential energy**	**Kinetic energy**
A.	stays the same	decreases	increases
B.	stays the same	increases	decreases
C.	increases	decreases	increases
D.	increases	increases	decreases

32a. Define *electric field strength*. *[2 marks]*

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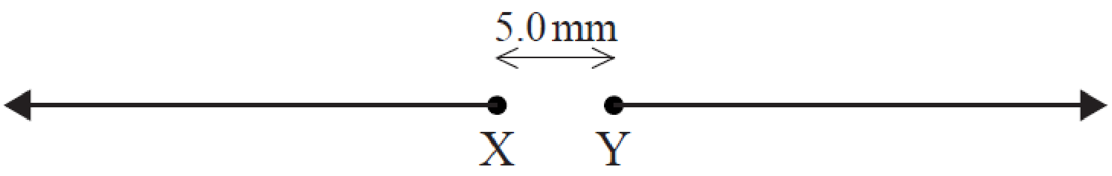
32c. The diagram shows two isolated electrons, X and Y, initially at rest in a vacuum. The initial separation of the electrons is 5.0 mm. The electrons subsequently move apart in the directions shown. *[8 marks]*

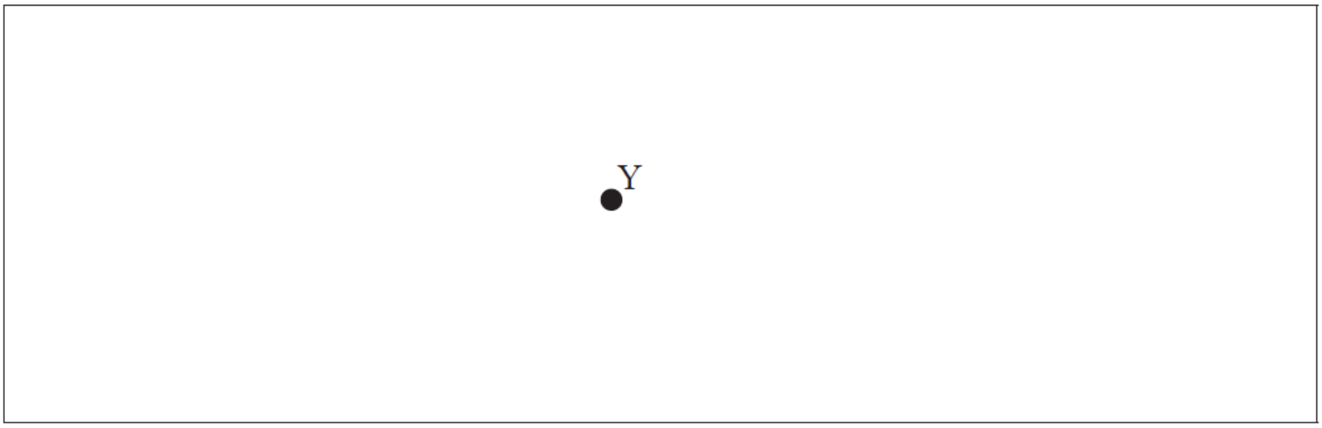


(i) Show that the initial electric force acting on each electron due to the other electron is approximately 9×10^{-24}N.

(ii) Calculate the initial acceleration of one electron due to the force in (c)(i).

(iii) Discuss the motion of one electron after it begins to move.

(iv) The diagram shows Y as seen from X, at one instant. Y is moving into the plane of the paper. For this instant, draw on the diagram the shape and direction of the magnetic field produced by Y.



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33. A particle of mass *m* is a distance *R* from the surface of Earth of mass *M*. The force acting on the particle is *F*. Which of the following is the gravitational field strength at *R*? *[1 mark]*

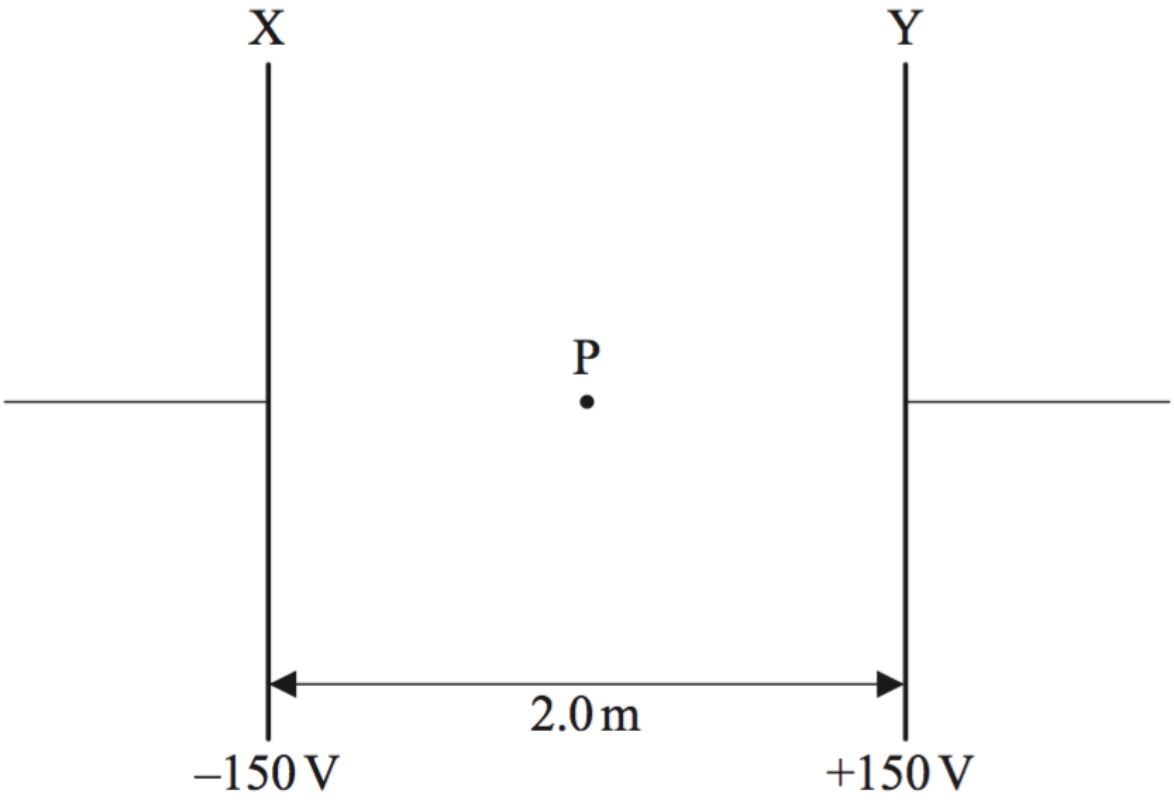
A. $\frac{Gm}{R^2}$

B. $\frac{GmM}{R^2}$

C. $\frac{F}{m}$

D. $\frac{F}{M}$

34. Two charged parallel metal plates, X and Y, are separated by a distance of 2.0 m. X is at a potential of -150 V and Y is at a potential of +150 V. *[1 mark]*



Point P is midway between X and Y. Which of the following gives the electric field strength at point P?

A. 150 Vm^{-1} to the right
B. 150 Vm^{-1} to the left
C. 300 Vm^{-1} to the right
D. 300 Vm^{-1} to the left

35. A satellite in close-Earth orbit moves to an orbit further from the Earth's surface. Which of the following concerning the speed of the satellite and its gravitational potential energy in the new orbit is correct? *[1 mark]*

	Speed of the satellite	Gravitational potential energy
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

36. The electric field strength between two oppositely charged parallel plates *[1 mark]*

A. has the same value everywhere between the two plates.

B. decreases from the positive plate to the negative plate.

C. is larger at the edges than in the center.

D. is smaller at the edges than in the center.

37. At the surface of a planet of radius *r*, the gravitational potential is -6.4×10^{7} J kg^{-1}. The gravitational potential at a height of *r* above the surface is *[1 mark]*

A. -12.8×10^{7} J kg^{-1}.

B. -6.4×10^{7} J kg^{-1}.

C. -3.2×10^{7} J kg^{-1}.

D. -1.6×10^{7} J kg^{-1}.

This question is in **two** parts. **Part 1** is about gravitational force fields. **Part 2** is about properties of a gas.

Part 1 Gravitational force fields

38a. State Newton’s universal law of gravitation. *[2 marks]*

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38b. A satellite of mass *m* orbits a planet of mass *M*. Derive the following relationship between the period of the satellite *T* and the radius of its orbit *R* (Kepler’s third law). *[3 marks]*

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

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38c. A polar orbiting satellite has an orbit which passes above both of the Earth's poles. One polar orbiting satellite used for Earth observation has an orbital period of 6.00×10^3 s. *[8 marks]*

Mass of Earth $= 5.97 \times 10^{24}$ kg
Average radius of Earth $= 6.37 \times 10^6$ m

(i) Using the relationship in (b), show that the average height above the surface of the Earth for this satellite is about 800 km.

(ii) The satellite moves from an orbit of radius 1200 km above the Earth to one of radius 2500 km. The mass of the satellite is 45 kg.

Calculate the change in the gravitational potential energy of the satellite.

(iii) Explain whether the gravitational potential energy has increased, decreased or stayed the same when the orbit changes, as in (c)(ii).

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This question is in two parts. **Part 1** is about electric charge and electric circuits. **Part 2** is about momentum.

Part 1 Electric charge and electric circuits

39a. State Coulomb's law. *[2 marks]*

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39b. In a simple model of the hydrogen atom, the electron can be regarded as being in a circular orbit about the proton. The radius of the orbit is 2.0×10^{-10} m. *[7 marks]*

(i) Determine the magnitude of the electric force between the proton and the electron.

(ii) Calculate the magnitude of the electric field strength *E* and state the direction of the electric field due to the proton at a distance of 2.0×10^{-10} m from the proton.

(iii) The magnitude of the gravitational field due to the proton at a distance of 2.0×10^{-10} m from the proton is *H*. Show that the ratio $\frac{H}{E}$ is of the order 10^{-28}C kg^{-1}.

(iv) The orbital electron is transferred from its orbit to a point where the potential is zero. The gain in potential energy of the electron is 5.4×10^{-19}J. Calculate the value of the potential difference through which the electron is moved.

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39c. An electric cell is a device that is used to transfer energy to electrons in a circuit. A particular circuit consists of a cell of emf ε and internal resistance r connected in series with a resistor of resistance 5.0 Ω. *[6 marks]*

(i) Define *emf of a cell.*

(ii) The energy supplied by the cell to one electron in transferring it around the circuit is 5.1×10^{-19}J. Show that the emf of the cell is 3.2V.

(iii) Each electron in the circuit transfers an energy of 4.0×10^{-19} J to the 5.0 Ω resistor. Determine the value of the internal resistance *r.*

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40. A spacecraft moves from point X to point Y in the gravitational field of Earth. At point X, the gravitational potential is -14MJkg^{-1}. At point Y, the gravitational potential is -2MJkg^{-1}. Which of the following describes the direction of the motion of the spacecraft relative to Earth and the change in gravitational potential? *[1 mark]*

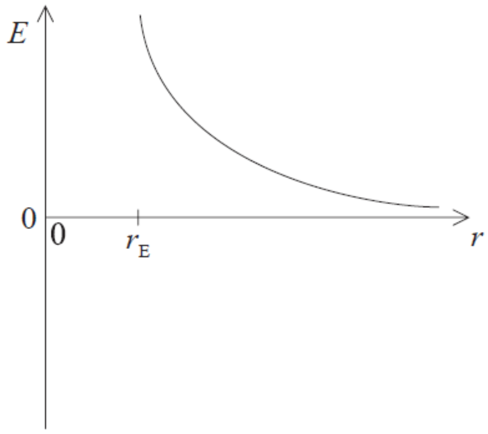
	Direction of Motion	Change in gravitational potential
A.	towards Earth	$+12\,\text{MJ kg}^{-1}$
B.	towards Earth	$-12\,\text{MJ kg}^{-1}$
C.	away from Earth	$+12\,\text{MJ kg}^{-1}$
D.	away from Earth	$-12\,\text{MJ kg}^{-1}$

41. A spacecraft is in orbit at a distance r from the centre of the Earth. The engine of the spacecraft is fired and it moves to a new orbit of radius $2r$. Which of the following describes the variations in kinetic energy and total energy of the spacecraft? *[1 mark]*

	Kinetic energy	Total energy
A.	decrease	increase
B.	decrease	decrease
C.	increase	increase
D.	increase	decrease

42. Which graph shows how the total energy E of an orbiting satellite varies with distance r from the centre of the Earth, where r_E is the radius of the Earth? *[1 mark]*

A.



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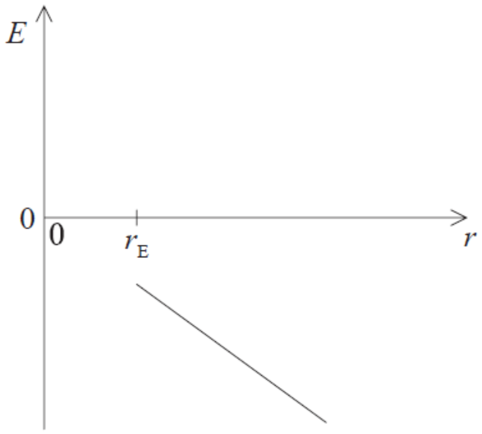

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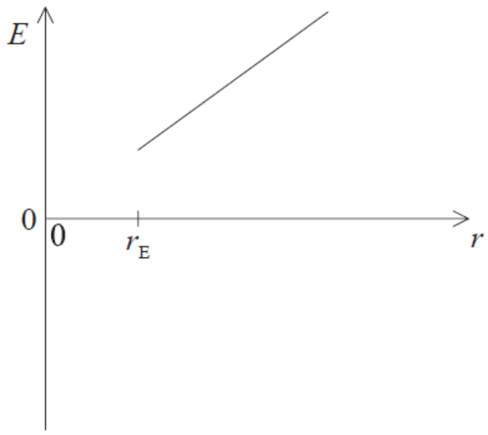

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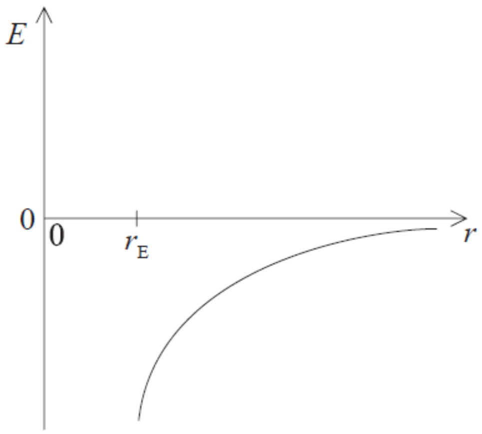
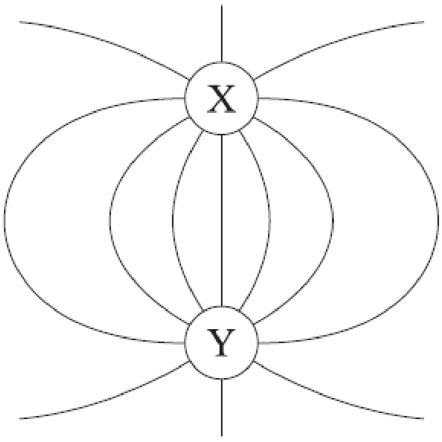


43. The diagram shows the electric field pattern due to two point charges X and Y. Y is a negative charge. *[1 mark]*



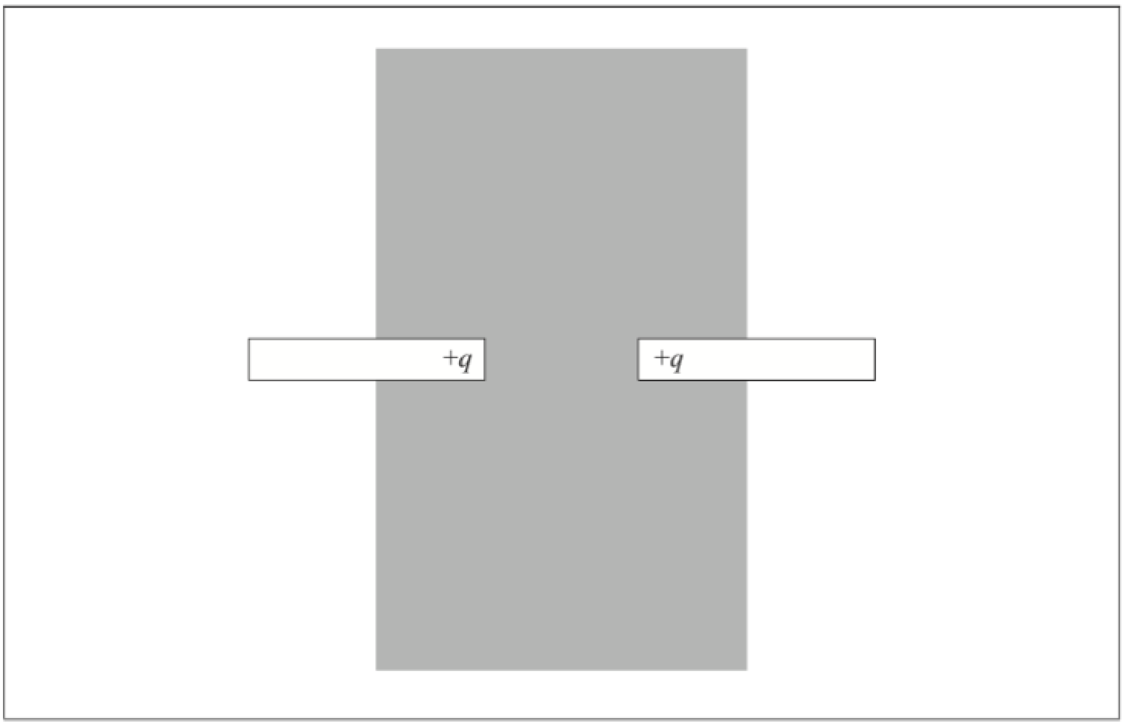
Which of the following correctly identifies the charge X and the direction of the electric field?

	Sign of charge X	Direction of electric field
A.	positive	Y to X
B.	positive	X to Y
C.	negative	X to Y
D.	negative	Y to X

This question is in **two** parts. **Part 1** is about electric charge and resistance. **Part 2** is about orbital motion.

Part 1 Electric charge and resistance

44. Two plastic rods each have a positive charge $+q$ situated at one end. The rods are arranged as shown. *[3 marks]*



Assume that the charge at the end of each rod behaves as a point charge. Draw, in the shaded area on the diagram

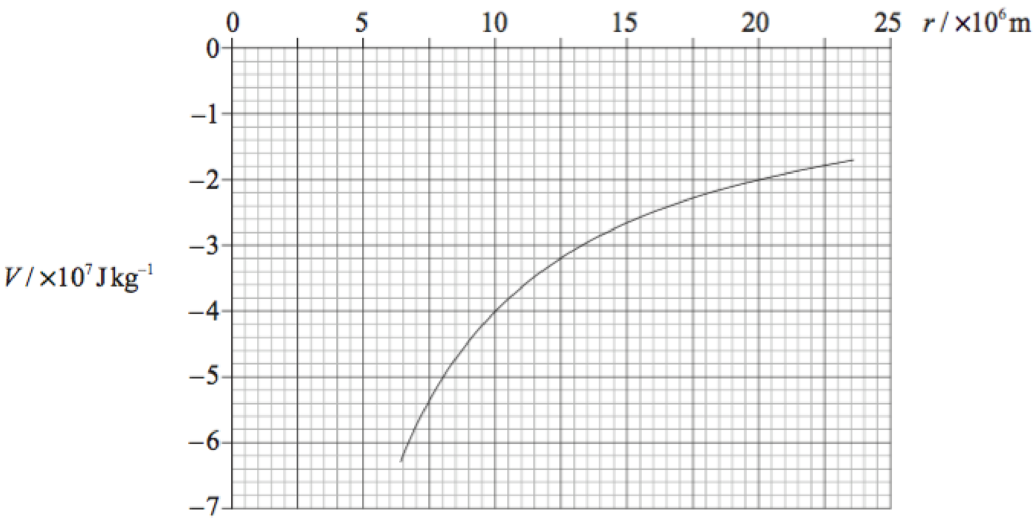
(i) the electric field pattern due to the two charges.

(ii) a line to represent an equipotential surface. Label the line with the letter V.

Part 2 Orbital motion

45a. A satellite, of mass m, is in orbit about Earth at a distance r from the centre of Earth. Deduce that the kinetic energy E_K of the satellite is equal to half the magnitude of the potential energy E_P of the satellite. *[3 marks]*

45b. The graph shows the variation with distance *r* of the Earth's gravitational potential *V*. Values of *V* for $r<R$, where *R* is the radius of Earth, are not shown. *[6 marks]*



The satellite in (a) has a mass of 8.2×10^{2}kg and it is in orbit at a distance of 1.0×10^{7}m from the centre of Earth. Using data from the graph and your answer to (a), calculate for the satellite

(i) its total energy.

(ii) its orbital speed.

(iii) the energy it must gain to move to an orbit a distance 2.0×10^{7} m from the centre of the Earth.

This question is about electric potential.

46a. Define *electric potential* at a point in an electric field. *[3 marks]*

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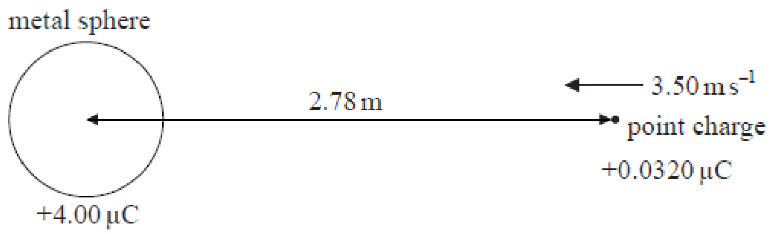
46b. A positive point charge is moving towards a small, charged metal sphere along a radial path. *[6 marks]*



At the position shown in the diagram, the point charge has a speed of 3.50 m s^{-1} and is at a distance of 2.78 m from the centre of the metal sphere. The charge on the sphere is +4.00 μC.

(i) State the direction of the velocity of the point charge with respect to an equipotential surface due to the metal sphere.

(ii) Show that the electric potential *V* due to the charged sphere at a distance of 2.78 m from its centre is 1.29×10^4 V.

(iii) The electric potential at the surface of the sphere is 7.20×10^4 V. The point charge has a charge of +0.0320 μC and its mass is 1.20×10^{-4} kg. Determine if the point charge will collide with the metal sphere.

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This question is about escape speed and gravitational effects.

47a. Explain what is meant by escape speed. *[2 marks]*

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47b. Titania is a moon that orbits the planet Uranus. The mass of Titania is 3.5×10^{21} kg. The radius of Titania is 800 km. *[5 marks]*

(i) Use the data to calculate the gravitational potential at the surface of Titania.

(ii) Use your answer to (b)(i) to determine the escape speed for Titania.

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47c. An astronaut visiting Titania throws an object away from him with an initial horizontal velocity of 1.8 m s^{-1}. The object is 1.5 m above the moon's surface when it is thrown. The gravitational field strength at the surface of Titania is 0.37 N kg^{-1}. *[3 marks]*

Calculate the distance from the astronaut at which the object first strikes the surface.

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Part 2 Satellite

48a. State, in words, Newton's universal law of gravitation. *[2 marks]*

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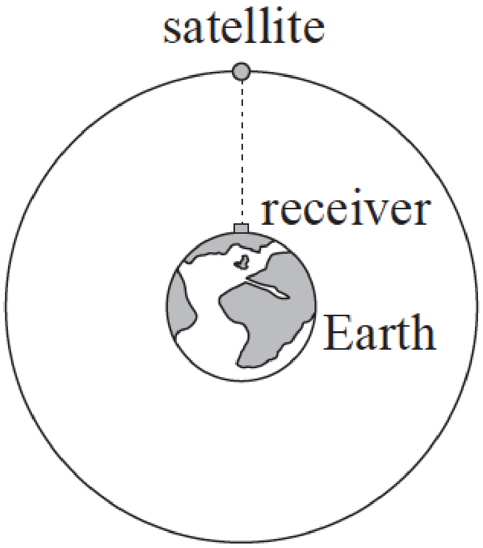
48b. The diagram shows a satellite orbiting the Earth. The satellite is part of the network of global-positioning satellites (GPS) that transmit radio signals used to locate the position of receivers that are located on the Earth. *[3 marks]*



(not to scale)

When the satellite is directly overhead, the microwave signal reaches the receiver 67ms after it leaves the satellite.

(i) State the order of magnitude of the wavelength of microwaves.

(ii) Calculate the height of the satellite above the surface of the Earth

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48c. (i) Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant. *[8 marks]*

(ii) Calculate the gravitational field strength due to the Earth at the position of the satellite.

Mass of Earth = 6.0×10^{24}kg
Radius of Earth = 6.4×10^{6}m

(iii) Determine the orbital speed of the satellite.

(iv) Determine, in hours, the orbital period of the satellite.

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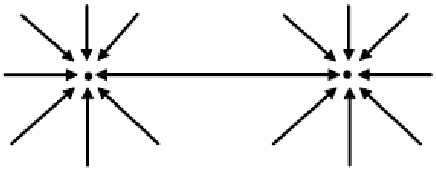
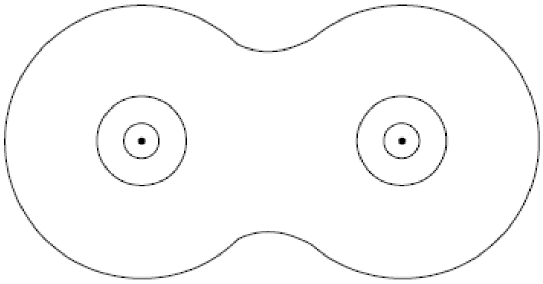
49. Which of the diagrams below best represents the equipotential surfaces around two identical point masses? *[1 mark]*

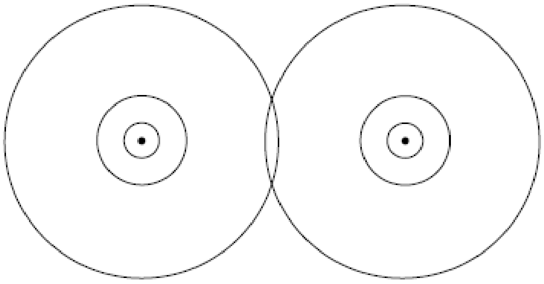
A.



B.



C.



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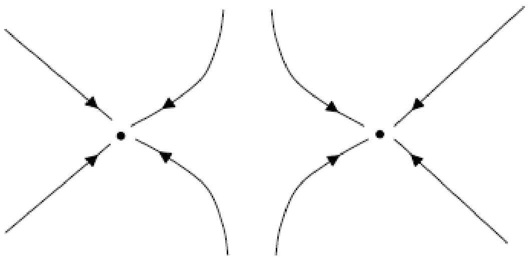
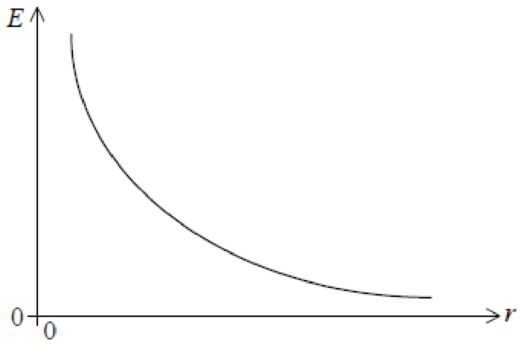
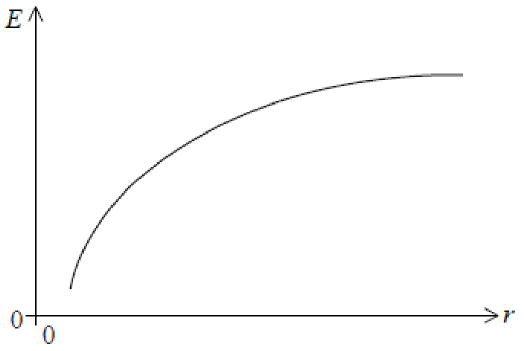


50. Which of the following graphs represents how the total energy E of an orbiting satellite varies with orbital radius r? *[1 mark]*

A.



B.



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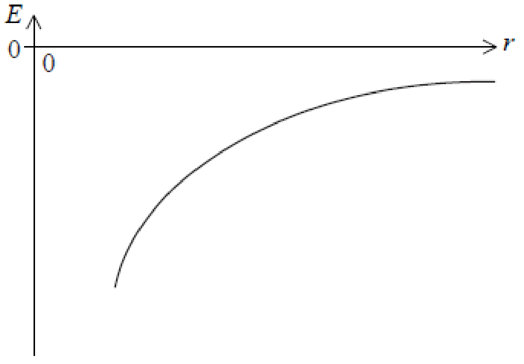

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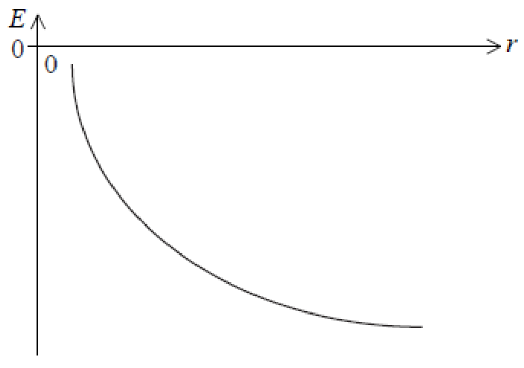
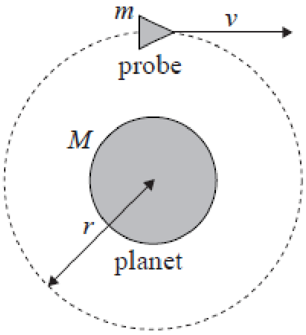


This question is about a probe in orbit.

A probe of mass *m* is in a circular orbit of radius *r* around a spherical planet of mass *M*.



(diagram not to scale)

51a. State why the work done by the gravitational force during one full revolution of the probe is zero. *[1 mark]*

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51b. Deduce for the probe in orbit that its *[4 marks]*

(i) speed is $v = \sqrt{\frac{GM}{r}}$.

(ii) total energy is $E = -\frac{GMm}{2r}$.

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51c. It is now required to place the probe in another circular orbit further away from the planet. To do this, the probe's engines will be fired for a very short time. *[2 marks]*

State and explain whether the work done on the probe by the engines is positive, negative **or** zero.

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