AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.7.2 GRAVITATIONAL FIELDS AND 3.7.3 ELECTRIC FIELDS

SCORE	PERCENTAGE
/176	%

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Q1.

(a) Define the electric field strength at a point in an electric field.

_____

_____

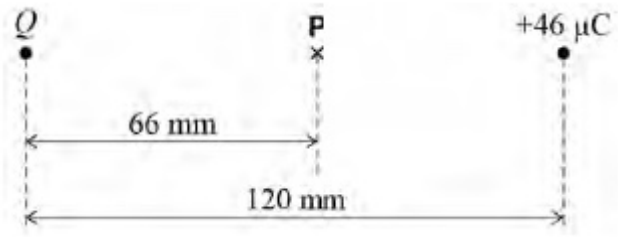
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(2)

(b) **Figure 1** shows a point charge of +46 μC placed 120 mm from a point charge Q.

Figure 1



Position **P** is on the line joining the charges at a distance 66 mm from charge Q. The resultant electric field strength at position **P** is zero.

Calculate the charge Q.

Q = _____ C

(3)

(c) Explain, without calculation, whether net work must be done in moving a proton from infinity to position **P** in **Figure 1**.

_____

_____

_____

_____

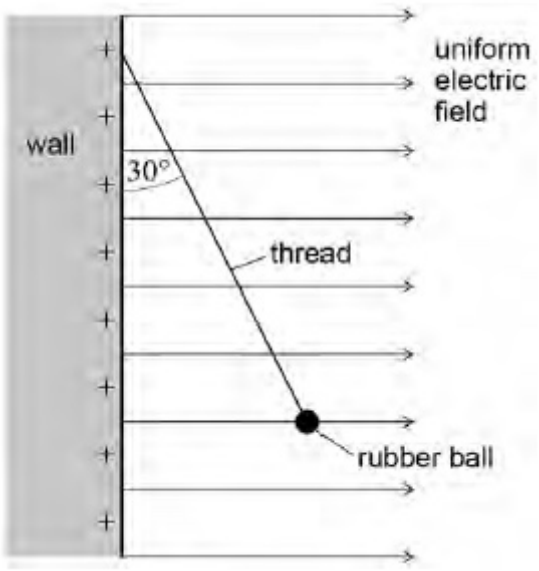
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(2)

(d) A small rubber ball coated with a conducting paint carries a positive charge. The ball is suspended in equilibrium from a vertical wall by an uncharged non-conducting thread of negligible mass. The wall is positively charged and produces a horizontal uniform electric field perpendicular to the wall along the whole of its length.
Figure 2 shows that the thread makes an angle of 30° to the wall.

Figure 2



The thread breaks.

Explain the motion of the ball.

(2)
(Total 9 marks)

Q2.

The distance between the Sun and the Earth is 1.5×10^{11} m

What is the gravitational force exerted on the Sun by the Earth?

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A 3.5×10^{22} N ⬭

B 1.7×10^{26} N ⬭

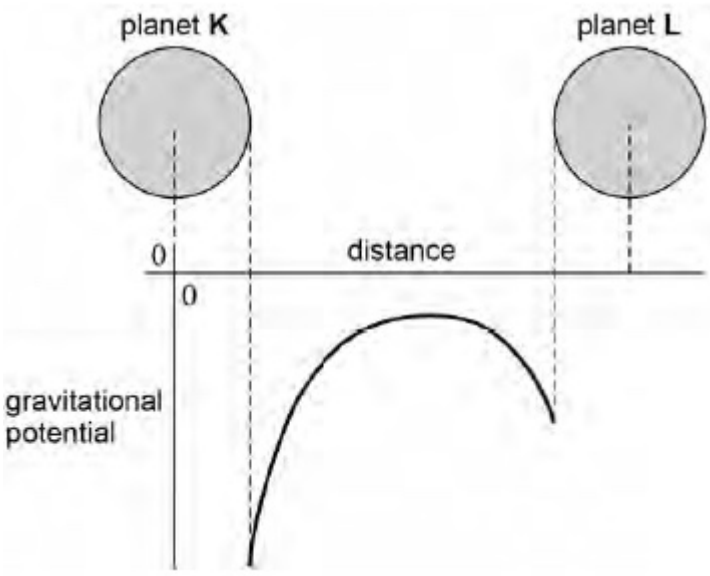
C 5.3×10^{33} N ⬭

D 8.9×10^{50} N ⬭

(Total 1 mark)

Q3.

The graph shows how the gravitational potential varies with distance between two planets, **K** and **L**, that have the same radius.



Which statement is correct?

A The mass of **L** is greater than the mass of **K**. ⬭

B The gravitational field strength at the surface of **L** is greater than that at the surface of **K**. ⬭

C The escape velocity from planet **L** is greater than that from planet **K**. ⬭

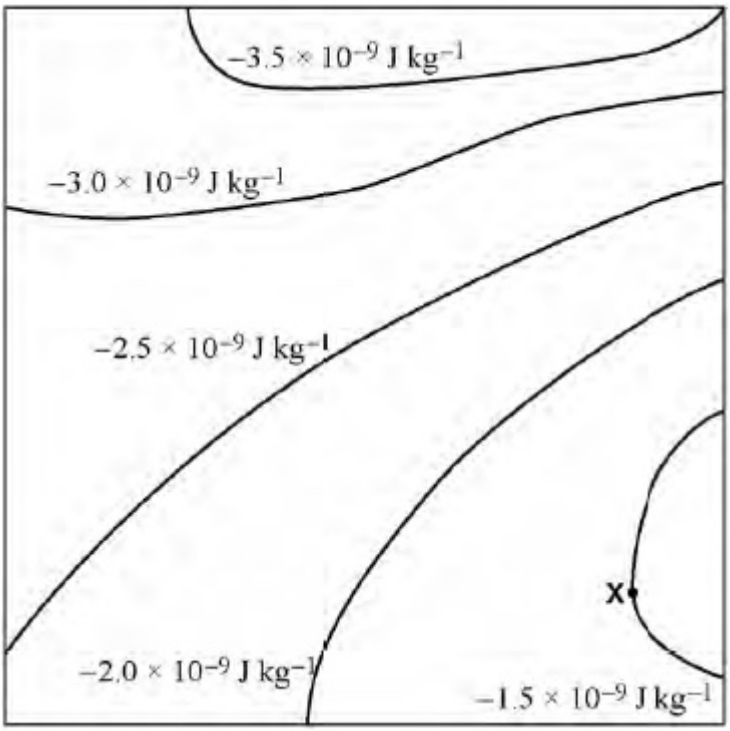
D More work must be done to move a mass of 1 kg from the surface of **K** to a distant point, than 1 kg from the surface of **L**. ⬭

(Total 1 mark)

Q4.

The diagram shows equipotential lines near a group of asteroids.

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Which arrow shows the direction of the gravitational field at **X**?

A ↑ ⬭

B ↓ ⬭

C ← ⬭

D → ⬭

(Total 1 mark)

Q5.

Planet **N** has a gravitational potential $-V$ at its surface. Planet **M** has double the density and double the radius of planet **N**. Both planets are spherical and have uniform density.

What is the gravitational potential at the surface of planet **M**?

A $-16V$ ⬭

B $-8V$ ⬭

C $-4V$ ⬭

D $-0.2V$ ⬭

(Total 1 mark)

Q6.

A spacecraft of mass 1.0×10^6 kg is in orbit around the Sun at a radius of 1.1×10^{11} m

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The spacecraft moves into a new orbit of radius 2.5×10^{11} m around the Sun.

What is the total change in gravitational potential energy of the spacecraft?

A -6.76×10^{14} J ⬭

B -3.38×10^{14} J ⬭

C 3.38×10^{14} J ⬭

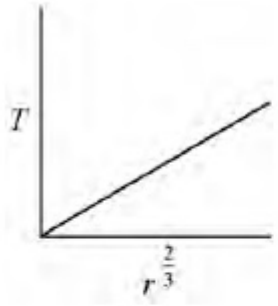
D 6.76×10^{14} J ⬭

(Total 1 mark)

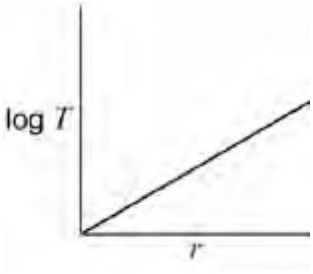
Q7.

Which graph shows the relationship between the time period T and the orbital radius r of a planet in orbit around the Sun?

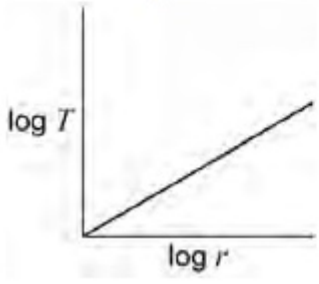
A



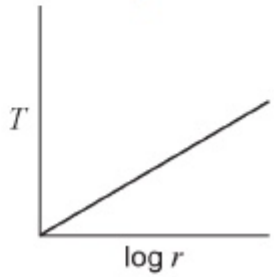
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q8.

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The Earth can be assumed to be a uniform sphere of radius R.

What is the mean density of the Earth?

A $\frac{3g}{4\pi RG}$ ⬭

B $\frac{3RG}{4\pi g}$ ⬭

C $\frac{3G}{4\pi Rg}$ ⬭

D $\frac{3Rg}{4\pi G}$ ⬭

(Total 1 mark)

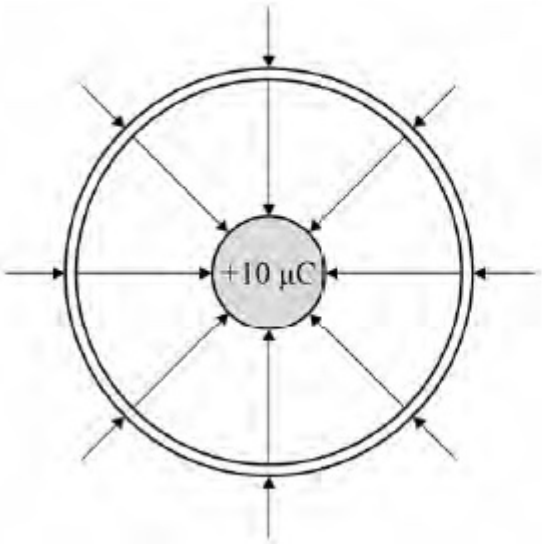
Q9.

A conducting sphere holding a charge of +10 μC is placed centrally inside a second uncharged conducting sphere.

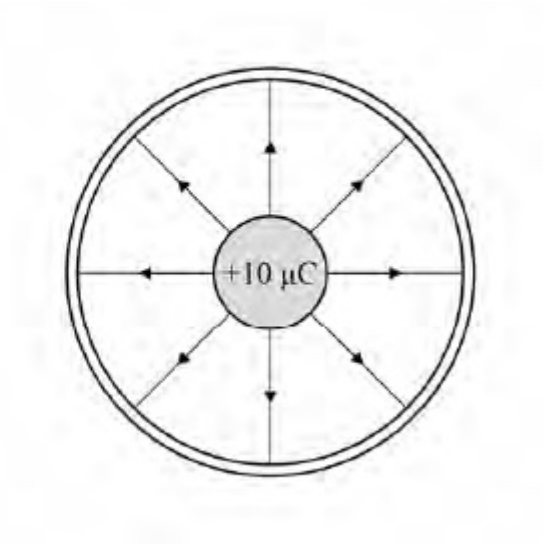
Which diagram shows the electric field lines for the system?

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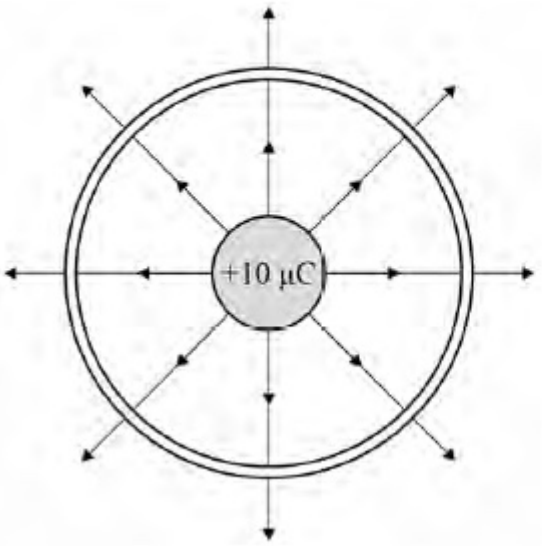
A



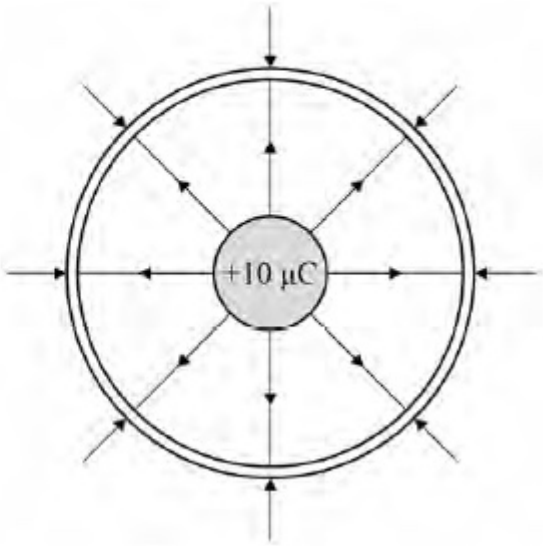
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q10.

A charged spherical conductor has a radius r. An electric field of strength E exists at the surface due to the charge.

What is the potential of the spherical conductor?

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A $r^2 E$ ⬭

B $r E^2$ ⬭

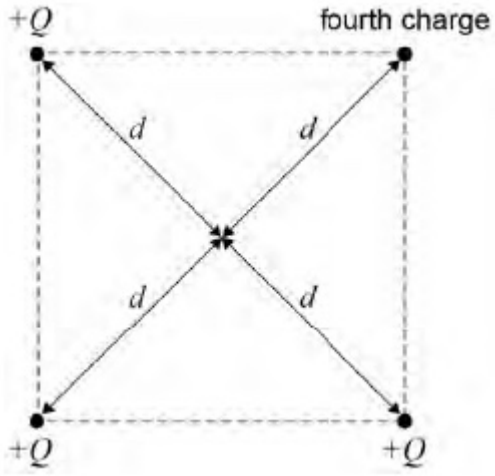
C $\frac{E}{r}$ ⬭

D $r E$ ⬭

(Total 1 mark)

Q11.

Four positive charges are fixed at the corners of a square as shown.



The total potential at the centre of the square, a distance d from each charge, is $\frac{5Q}{4\pi\varepsilon_o d}$

Three of the charges have a charge of +Q

What is the magnitude of the fourth charge?

A $-\frac{7Q}{4}$ ⬭

B Q ⬭

C $\sqrt{2}Q$ ⬭

D $2Q$ ⬭

(Total 1 mark)

Q12.

A gravimeter is an instrument used to measure the acceleration due to gravity. The gravimeter measures the distance fallen by a free-falling mirror in a known time.

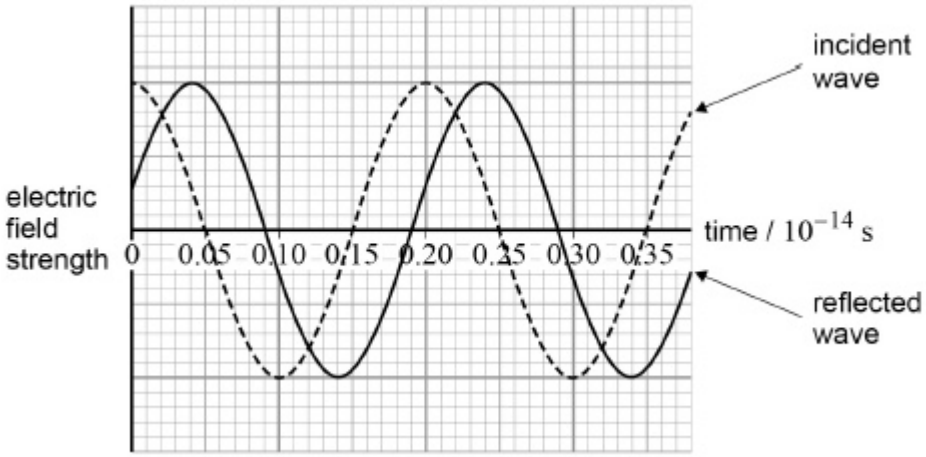
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To do this, monochromatic light is reflected normally off the mirror, creating interference between the incident and reflected waves. The mirror is released from rest and falls, causing a change in the phase difference between the incident and reflected waves at a detector.

At the point of release of the mirror, the waves are in phase, resulting in a maximum intensity at the detector. The next maximum is produced at the detector when the mirror has fallen through a distance equal to half a wavelength of the light. The gravimeter records the number of maxima detected in a known time as the mirror falls. These data are used by the gravimeter to compute the acceleration of the free-falling mirror.

Figure 1 illustrates the phase relationship between the incident and reflected waves at the detector for one position of the mirror.

Figure 1



(a) Show that the wavelength of the light is 600 nm.

(3)

(b) Determine the phase difference, in rad, between the incident and reflected waves shown in **Figure 1**.

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phase difference = _____ rad

(2)

(c) A maximum is detected each time the mirror travels a distance equal to half a wavelength of the light.

In one measurement 2.37×10^5 maxima are recorded as the mirror is released from rest and falls for 0.120 s.

Using an appropriate equation of motion, calculate the acceleration due to gravity that the gravimeter computes from these data.

State your answer to 3 significant figures.

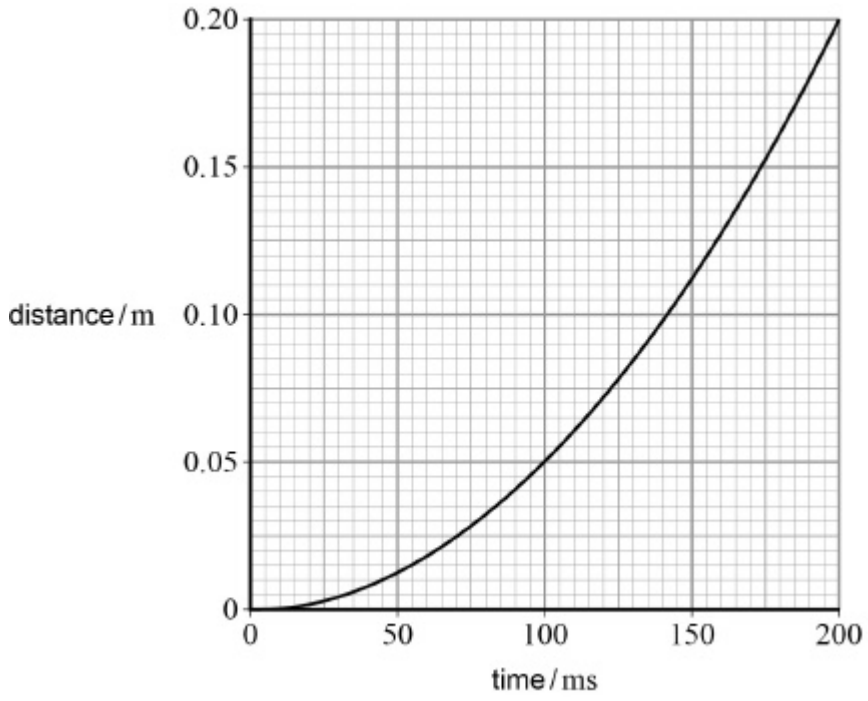
wavelength of the light = 600 nm

acceleration due to gravity = _____ m s^{-2}

(3)

(d) **Figure 2** is a graph that the gravimeter could produce to show how the distance travelled by the mirror varies with time as it falls.

Figure 2



Determine the gradient of the line when the time is 0.12 s.

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gradient = _____

(2)

(e) State what this gradient represents.

_____

(1)

(Total 11 marks)

Q13.

(a) State what is represented by gravitational field lines.

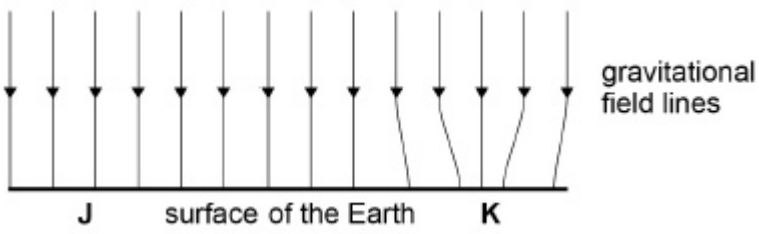
_____

_____

(1)

(b) **Figure 1** shows the gravitational field above a small horizontal region on the surface of the Earth.

Figure 1



Suggest why the field lines converge over a small area at **K**.

_____

_____

_____

_____

(2)

(c) A ball travelling at constant speed passes position **J** moving towards position **K** in **Figure 1**.

Assume friction is negligible.

Explain any change in the speed of the ball as it approaches **K**.

_____

_____

_____

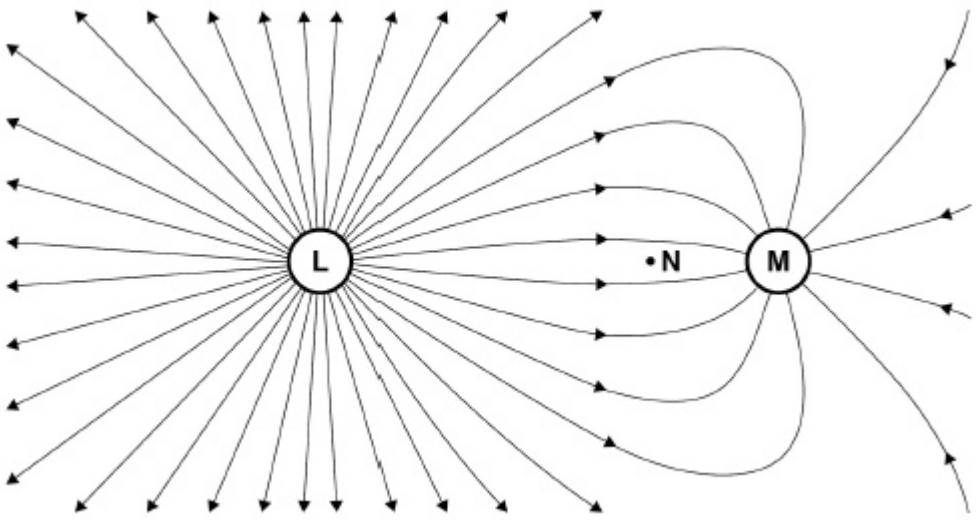
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(2)

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(d) **Figure 2** shows lines of force for the electric field surrounding two charged objects **L** and **M**.

Figure 2



Explain why the lines of force shown in **Figure 2** cannot represent a gravitational field.

_____

_____

(1)

(e) State which object **L** or **M** has a charge with the greater magnitude.

object _____

State which object **L** or **M** has a positive charge.

object _____

(1)

(f) Draw, on **Figure 2**, an equipotential line that passes through point **N**.
Do **not** extend your line beyond the given field lines.

(2)
(Total 9 marks)

Q14.

(a) Derive an expression to show that for satellites in a circular orbit

$$T^2 \propto r^3$$

where T is the period of orbit and r is the radius of the orbit.

(2)

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(b) Pluto is a dwarf planet. The mean orbital radius of Pluto around the Sun is 5.91×10^9 km compared to a mean orbital radius of 1.50×10^8 km for the Earth.

Calculate in years the orbital period of Pluto.

orbital period of Pluto = _____ yr

(2)

(c) A small mass released from rest just above the surface of Pluto has an acceleration of 0.617 m s^{-2}.

Assume Pluto has no atmosphere that could provide any resistance to motion.

Calculate the mass of Pluto.

Give your answer to an appropriate number of significant figures.

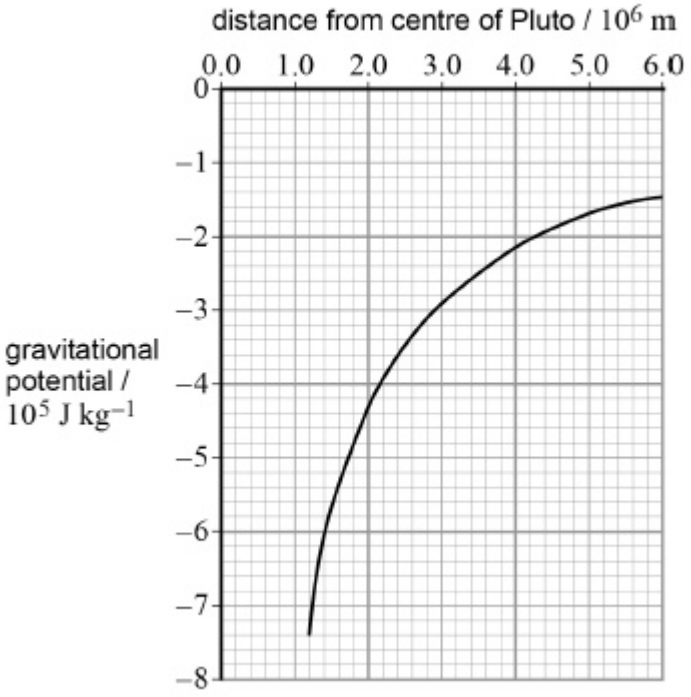
radius of Pluto = 1.19×10^6 m

mass of Pluto = _____ kg

(3)

(d) The graph shows the variation in gravitational potential with distance from the centre of Pluto for points at and above its surface.

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A meteorite hits Pluto and ejects a lump of ice from the surface that travels vertically at an initial speed of 1400 m s^{-1}.

Determine whether this lump of ice can escape from Pluto.

_____

_____

(3)

(Total 10 marks)

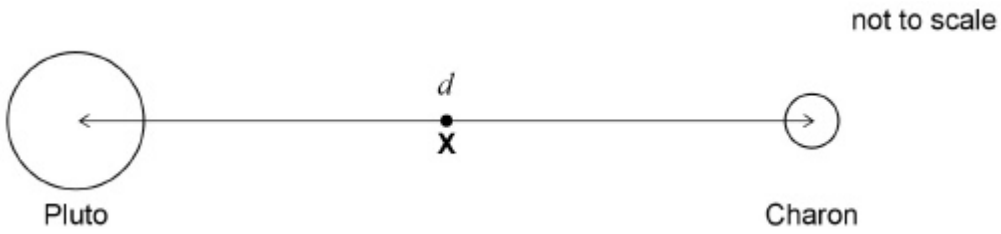
Q15.

Charon is a moon of Pluto that has a mass equal to $\frac{1}{9}$ that of Pluto.

The distance between the centre of Pluto and the centre of Charon is *d*.

X is the point at which the resultant gravitational field due to Pluto and Charon is zero.

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What is the distance of **X** from the centre of Pluto?

A $\frac{2}{9}d$ ⬭

B $\frac{2}{3}d$ ⬭

C $\frac{3}{4}d$ ⬭

D $\frac{8}{9}d$ ⬭

(Total 1 mark)

Q16.

The distance between the Sun and Mars varies from 2.1×10^{11} m to 2.5×10^{11} m.
When Mars is closest to the Sun, the force of gravitational attraction between them is F.

What is the force of gravitational attraction between them when they are furthest apart?

A $0.71F$ ⬭

B $0.84F$ ⬭

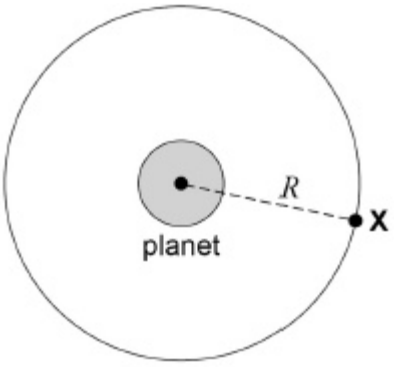
C $1.2F$ ⬭

D $1.4F$ ⬭

(Total 1 mark)

Q17.

A satellite **X** of mass m is in a concentric circular orbit of radius R about a planet of mass M.



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What is the kinetic energy of **X**?

A $\frac{GMm}{2R}$ ⬭

B $\frac{GMm}{R}$ ⬭

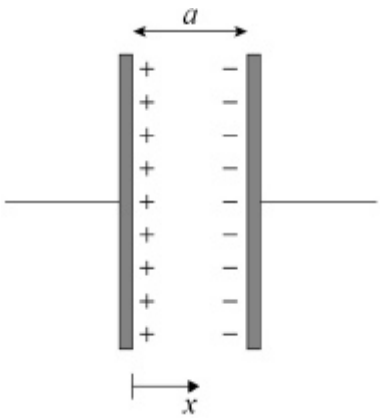
C $\frac{2GMm}{R}$ ⬭

D $\frac{4GMm}{R}$ ⬭

(Total 1 mark)

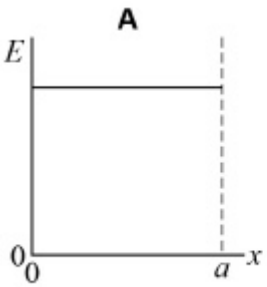
Q18.

Two parallel metal plates of separation a carry equal and opposite charges.

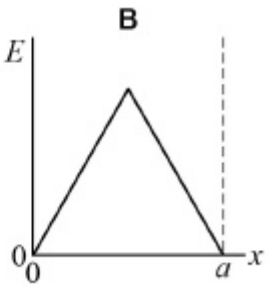


Which graph best represents how the electric field strength E varies with the distance x in the space between the two plates?

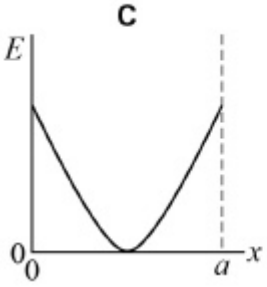
A



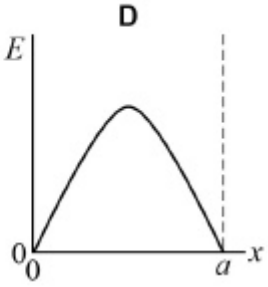
B



C



D



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A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q19.

A particle of mass m and charge q is accelerated through a potential difference V over a distance d.

What is the average acceleration of the particle?

A $\frac{qV}{md}$ ⬭

B $\frac{mV}{qd}$ ⬭

C $\frac{V}{mqd}$ ⬭

D $\frac{dV}{mq}$ ⬭

(Total 1 mark)

Q20.

An electron moves through a distance of 0.10 m parallel to the field lines of a uniform electric field of strength 2.0 kN C^{-1}.

What is the work done on the electron?

A zero ⬭

B 1.6×10^{-17} J ⬭

C 3.2×10^{-17} J ⬭

D 1.6×10^{-21} J ⬭

(Total 1 mark)

Q21.

A parallel-plate capacitor is fully charged and then disconnected from the power supply. A dielectric is then inserted between the plates.

Which row correctly identifies the charge on the plates and the electric field strength between the plates?

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	Charge	Electric field strength	
A	Stays the same	Increases	⬭
B	Increases	Decreases	⬭
C	Increases	Increases	⬭
D	Stays the same	Decreases	⬭

(Total 1 mark)

Q22.

Read the following passage and answer the questions that follow.

A mass spectrometer is an instrument for measuring the masses of isotopes. The main working parts of the instrument are shown in **Figure 1**.

Figure 1

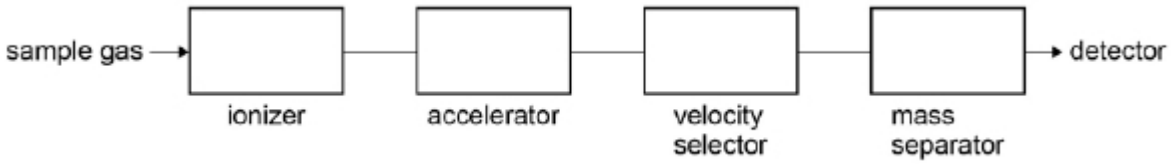
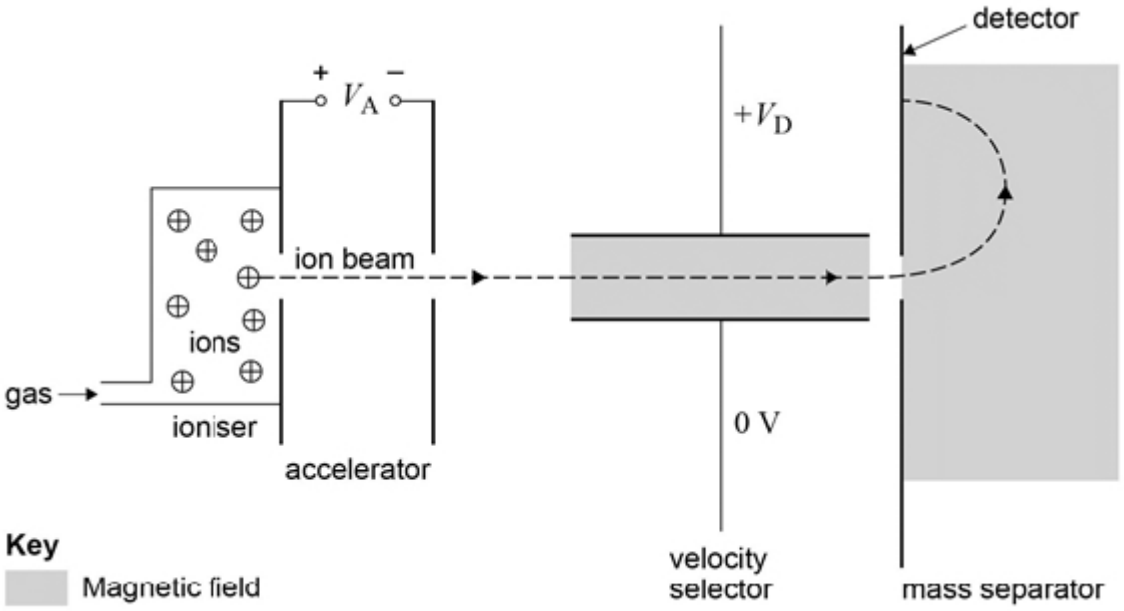


Figure 2 shows the components in more detail. Positive ions are created in the ionizer. Some of these ions enter the accelerator where they are accelerated by a potential difference V_A. The ions emerge from the accelerator with different speeds and enter the velocity selector.

The velocity selector contains a region where there is a uniform magnetic field at right angles to an electric field. This electric field is formed between two parallel plates held at a potential difference V_D. This combination of fields only allows ions of a particular velocity to enter the mass separator. Here ions of different mass are separated by a uniform magnetic field. Finally the ions are detected.

Figure 2

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(a) Explain what is meant by ionisation.

_____

_____

(1)

(b) Discuss the energy transfers that take place in the accelerator as the ion passes through it. Assume the ions are in a perfect vacuum.

_____

_____

_____

_____

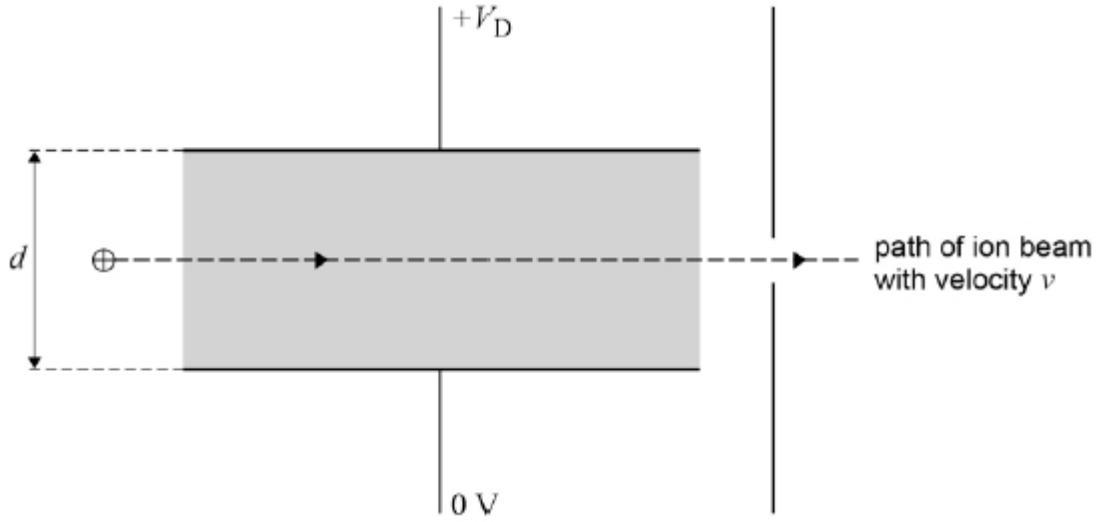
_____

(3)

(c) **Figure 3** shows the path taken by an ion that moves through the velocity selector at a velocity v.

Figure 3

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Discuss how the path changes when an ion enters the velocity selector with a velocity greater than v.

(3)

(d) Draw, on **Figure 3**, the path of the ion that is suggested by your answer to part **(c)**.

(1)

(e) Ions created in the ioniser may have the same charge but a different number of nucleons.

Discuss how the path of an ion in the mass separator is affected when it has more nucleons.

(2)

(f) Some ions are created with the same mass but a double charge. The path of the ions shown in **Figure 2** is that of a singly charged ion.

Compare, with justification, the path of a doubly charged ion through the mass spectrometer with that of a singly charged ion of the same mass.

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_____

_____

_____

_____

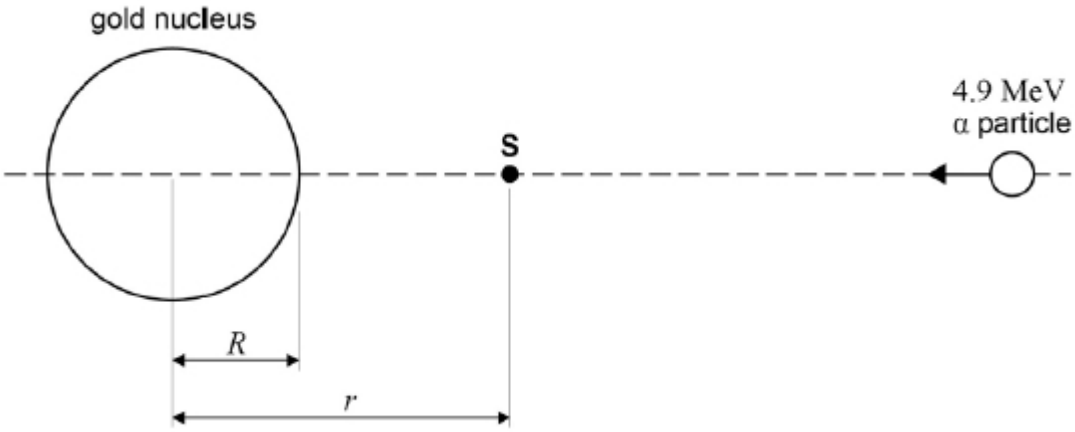
_____

(3)

(Total 13 marks)

Q23.

An α particle with an initial kinetic energy of 4.9 MeV is directed towards the centre of a gold nucleus of radius R which contains 79 protons. The α particle is brought to rest at point **S**, a distance r from the centre of the nucleus as shown in the diagram below.



(a) Calculate the electric potential energy, in J, of the α particle at point **S**.

electric potential energy = _____ J

(2)

(b) Calculate r, the distance of closest approach of the α particle to the nucleus.

r = _____ m

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(3)

(c) Determine the number of nucleons in the gold nucleus.

R, radius of the gold nucleus = 7.16×10^{-15} m
$R_0 = 1.23 \times 10^{-15}$ m

number of nucleons = _____

(3)

(d) The target nucleus is changed to one that has fewer protons. The α particle is given the same initial kinetic energy.

Explain, without further calculation, any changes that occur to the distance r. Ignore any recoil effects.

_____

_____

_____

_____

(2)

(Total 10 marks)

Q24.

(a) Define the gravitational potential at a point.

_____

_____

_____

_____

(2)

(b) Explain why gravitational potential is always negative.

_____

_____

_____

_____

(2)

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(c) Show that the magnitude of the gravitational potential at the Earth's surface due to the mass of the Earth is about 6.3×10^7 J kg^{-1}.

(2)

(d) A satellite is launched into a geostationary orbit.

Describe and explain **two** features of a geostationary orbit.

1. _____

_____

_____

2. _____

_____

_____

(2)

(e) The satellite has a mass of 1200 kg and the radius of its orbit is 4.23×10^7 m.

Calculate the gain in gravitational potential energy of the satellite when it is placed into orbit from the Earth's surface.

gain in potential energy = _____J

(3)

(f) Impulse engines are used to place the satellite into an orbit with a longer period.

Discuss any changes this makes to the orbital motion of the satellite.

_____

_____

_____

_____

_____

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_____

(4)

(Total 15 marks)

Q25.

The distance between the centres of the Earth and the Moon is 3.8×10^8 m. The mass of the Earth is 6.0×10^{24} kg and the mass of the Moon is 7.4×10^{22} kg.

A spacecraft of mass 10×10^3 kg is moving along a line joining their centres.

At what distance from the centre of the Earth would the spacecraft experience no resultant force due to the Earth and the Moon?

A 3.8×10^7 m ⬭

B 4.8×10^7 m ⬭

C 3.4×10^8 m ⬭

D 3.8×10^8 m ⬭

(Total 1 mark)

Q26.

An electron on the surface of the Earth is placed in an electric field of strength 5000 N C^{-1}.

What is $\left(\frac{electric\ force}{gravitational\ force}\right)$ for the electron?

A 1.1×10^{-14} ⬭

B 2.9×10^{-10} ⬭

C 3.4×10^9 ⬭

D 9.0×10^{13} ⬭

(Total 1 mark)

Q27.

The radius of a planet is R. The gravitational potential at the surface of the planet due to its mass is −4000 J kg^{-1}.

What is the gravitational potential at a distance $2R$ from the centre of the planet?

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A −1000 J kg^{-1} ⬭

B −2000 J kg^{-1} ⬭

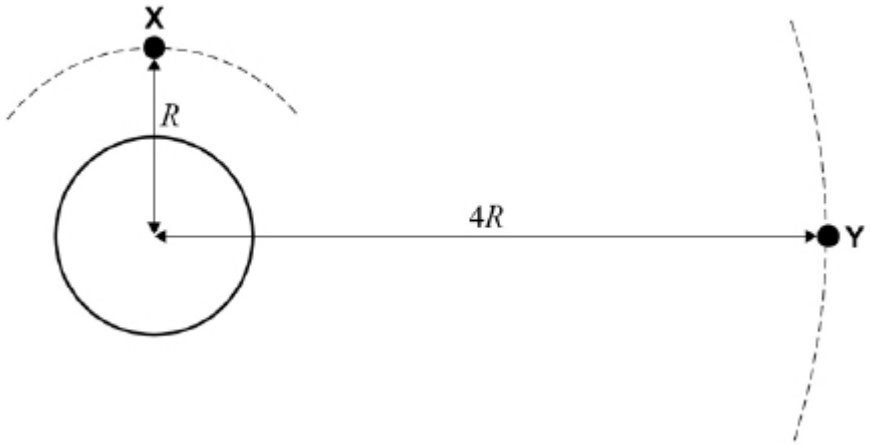
C −4000 J kg^{-1} ⬭

D −8000 J kg^{-1} ⬭

(Total 1 mark)

Q28.

Satellites **X** and **Y** orbit the Earth at distances R and $4R$ respectively, as shown in the diagram.



Which statement is **incorrect**?

A The speed of **Y** is greater than the speed of **X** ⬭

B The time period of **Y** is greater than the time period of **X**. ⬭

C The potential energy of **Y** is greater than the potential energy of **X**. ⬭

D The gravitational force acting on **Y** is less than the gravitational force acting on **X**. ⬭

(Total 1 mark)

Q29.

An α particle makes a head−on collision with a gold nucleus containing 79 protons. The distance of closest approach of the α particle to the nucleus is 4.0 × 10^{-14} m.

What electrostatic force acts on the gold nucleus when at this separation?

A 9.1 × 10^{-11} N ⬭

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B 23 N ⬭

C 290 N ⬭

D 1.4×10^{20} N ⬭

(Total 1 mark)

Q30.

An electron moving with constant speed enters a uniform electric field at right angles to the direction of the field.

What is true about the force acting on the electron?

A It is at right angles to the direction of the field. ⬭

B It is in the opposite direction to the direction of the field. ⬭

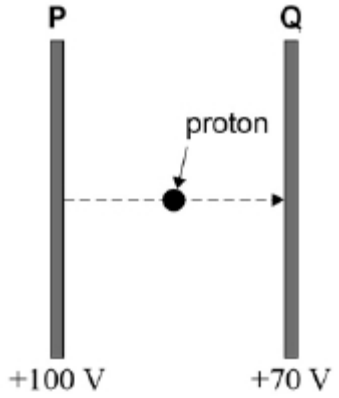
C It causes the electron to continue in the same direction with its speed increasing steadily. ⬭

D It causes the electron to continue in the same direction with its speed decreasing steadily. ⬭

(Total 1 mark)

Q31.

Two fixed parallel metal plates **P** and **Q** are at constant electrical potentials of +100 V and +70 V respectively. A proton travelling from **P** to **Q** experiences a force F due to the electric field between **P** and **Q**, and a change of potential energy of ΔE_p.



Which line, **A** to **B**, in the table gives the direction of F and the value of ΔE_p?

	Direction of F	ΔE_p	
A	towards **P**	+30 eV	⬭
B	towards **Q**	+30 eV	⬭

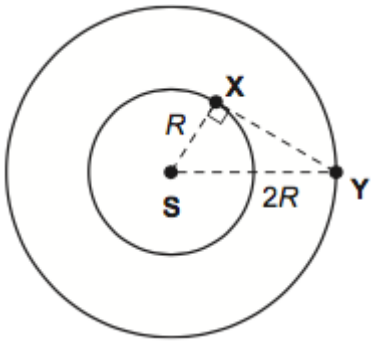
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C	towards **Q**	−30 eV	⬭
D	towards **P**	−30 eV	⬭

(Total 1 mark)

Q41.

Two planets **X** and **Y** are in concentric circular orbits about a star **S**. The radius of the orbit of **X** is *R* and the radius of orbit of **Y** is 2*R* .



The gravitational force between **X** and **Y** is F when angle **SXY** is 90°, as shown in the diagram.

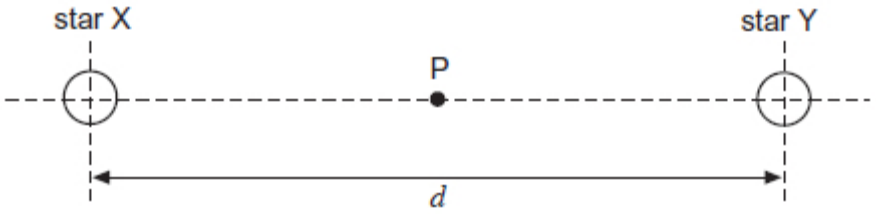
What is the gravitational force between **X** and **Y** when they are nearest to each other?

A $2\,F$
B $3\,F$
C $4\,F$
D $5\,F$

(Total 1 mark)

Q42.

X and Y are two stars of equal mass M. The distance between their centres is d.



What is the gravitational potential at the mid-point P between them?

A $\frac{GM}{2d}$

B $-\frac{GM}{d}$

C $-\frac{4GM}{d}$

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D $-\frac{8GM}{d}$

(Total 1 mark)

Q43.

A geosynchronous satellite is in a constant radius orbit around the Earth. The Earth has a mass of 6.0×10^{24} kg and a radius of 6.4×10^{6} m.

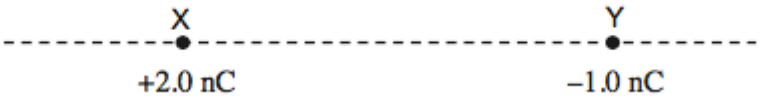
What is the height of the satellite above the Earth's surface?

A 1.3×10^{7} m
B 3.6×10^{7} m
C 4.2×10^{7} m
D 4.8×10^{7} m

(Total 1 mark)

Q44.

A +2.0 nC point charge X is at a fixed distance from a –1.0 nC point charge Y. The force between the two charges is F.



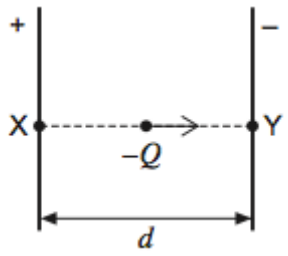
If an **additional** charge of +2.0 nC is supplied to both X and Y, which line, **A** to **D**, in the table gives the magnitude and direction of the force on X?

	Magnitude	**Direction**
A	$2F$	from X to Y
B	$4F$	from X to Y
C	$2F$	from Y to X
D	$4F$	from Y to X

(Total 1 mark)

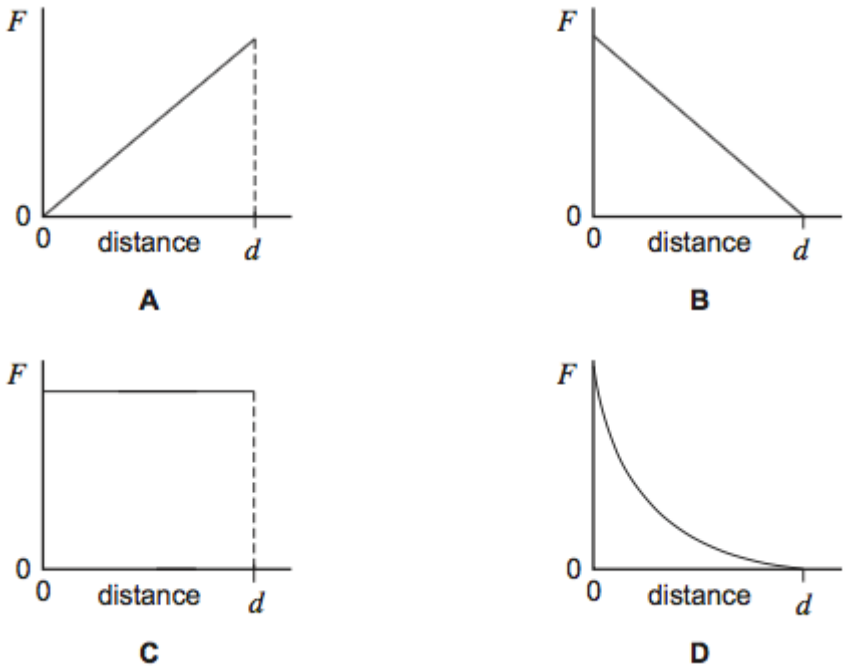
Q45.

The diagram shows a charge $-Q$ being moved from point X to point Y between two charged parallel plates separated by a distance d.



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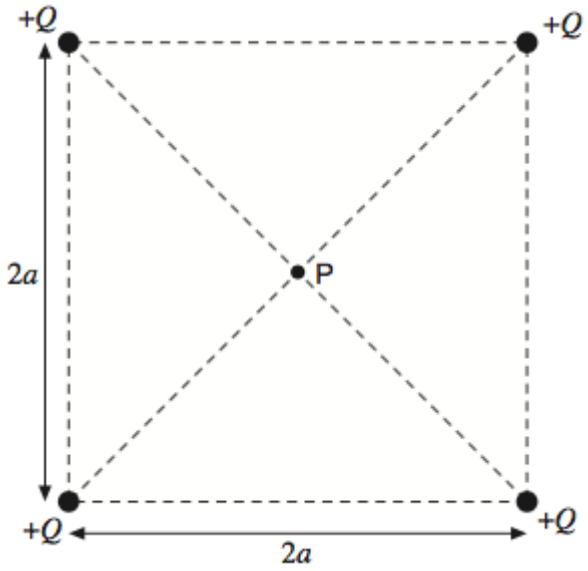
Which one of the following graphs best illustrates how the magnitude of force F on the charge varies with distance as it moves towards Y?



(Total 1 mark)

Q46.

The diagram shows four point charges, each $+Q$, at the corners of a square of side $2a$.



What is the electric field strength at P, the centre of the square?

A zero

B $\frac{Q}{4\pi\varepsilon_0 a^2}$

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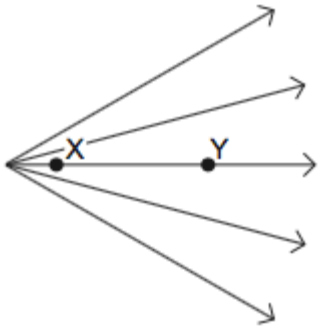
C $\frac{Q}{2\pi\varepsilon_0 a^2}$

D $\frac{Q}{\pi\varepsilon_0 a^2}$

(Total 1 mark)

Q47.

The diagram shows the field lines in a region of an electric field created by a positive charge.



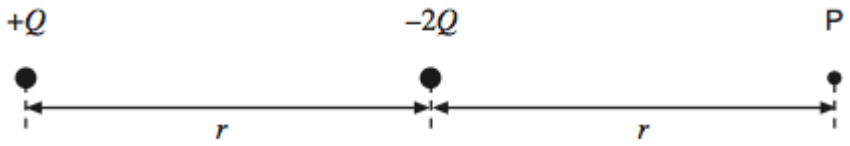
Which one of the following statements is correct?
When moving from X to Y

A the electric potential is constant.
B the electric potential increases.
C the electric potential decreases.
D the electric potential changes from positive to negative.

(Total 1 mark)

Q48.

The diagram shows two point charges of magnitude $+Q$ and $-2Q$ placed a distance r apart.



What is the electric potential at point P, a distance r to the right of the $-2Q$ charge?

A $-\frac{3Q}{8\pi\varepsilon_0 r}$

B $-\frac{Q}{2\pi\varepsilon_0 r}$

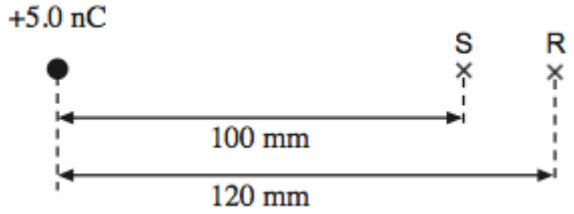
C $+\frac{Q}{8\pi\varepsilon_0 r}$

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D $+\frac{5Q}{8\pi\varepsilon_0 r}$

(Total 1 mark)

Q49.



The potentials at points R and S due to the +5.0 nC charge are 375 V and 450 V respectively.

How much work is done when a +2.0 nC charge is moved from R to S?

A 0.12 μJ
B 0.15 μJ
C 0.19 μJ
D 0.38 μJ

(Total 1 mark)

Q50.

The gravitational constant, G, is a constant of proportionality in Newton's law of gravitation. The permittivity of free space, ε_0, is a constant of proportionality in Coulomb's law.

When comparing the electrostatic force acting on a pair of charged particles to the gravitational force between them, the product $\varepsilon_0 G$ can appear in the calculation.

Which is a unit for $\varepsilon_0 G$?

A $C^2\ kg^{-2}$
B $C^2\ m^{-2}$
C $F\ kg^2\ N^{-1}\ m^{-2}$
D it has no unit

(Total 1 mark)

Q51.

The planet Venus may be considered to be a sphere of uniform density 5.24×10^3 kg m^{-3}. The gravitational field strength at the surface of Venus is 8.87 N kg^{-1}.

(a) (i) Show that the gravitational field strength g_s at the surface of a planet is related to the the density ρ and the radius R of the planet by the expression

$$g_s = \frac{4}{3}\pi G R \rho$$

where G is the gravitational constant.

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(2)

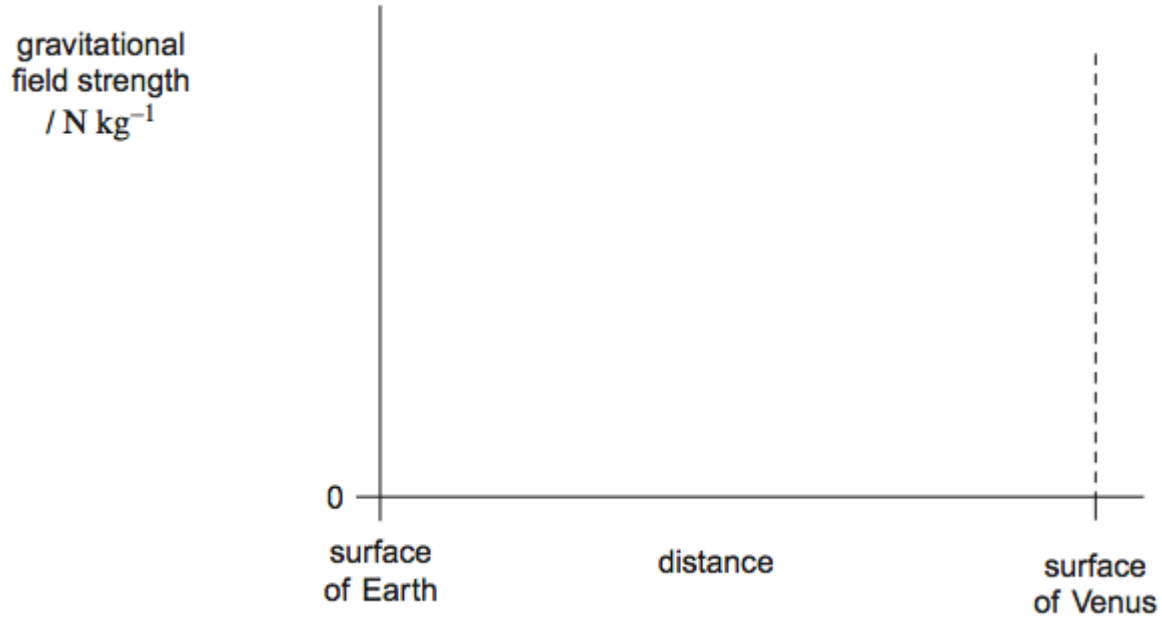
(ii) Calculate the radius of Venus.

Give your answer to an appropriate number of significant figures.

radius = _____ m

(3)

(b) At a certain time, the positions of Earth and Venus are aligned so that the distance between them is a minimum.
Sketch a graph on the axes below to show how the magnitude of the gravitational field strength g varies with distance along the shortest straight line between their surfaces.
Consider only the contributions to the field produced by Earth and Venus.
Mark values on the vertical axis of your graph.



(3)

(Total 8 marks)

Q52.

The Rosetta space mission placed a robotic probe on Comet 67P in 2014.

(a) The total mass of the Rosetta spacecraft was 3050 kg. This included the robotic probe of mass 108 kg and 1720 kg of propellant. The propellant was used for

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changing velocity while travelling in deep space where the gravitational field strength is negligible.

Calculate the change in gravitational potential energy of the Rosetta spacecraft from launch until it was in deep space.
Give your answer to an appropriate number of significant figures.

Mass of the Earth = 6.0×10^{24} kg
Radius of the Earth = 6400 km

change in gravitational potential energy _____ J

(4)

(b) As it approached the comet, the speed of the Rosetta spacecraft was reduced to match that of the comet. This was done in stages using four 'thrusters'. These were fired simultaneously in the same direction.

Explain how the propellant produces the thrust.

_____

_____

_____

_____

_____

_____

_____

(3)

(c) Each thruster provided a constant thrust of 11 N.

Calculate the deceleration of the Rosetta spacecraft produced by the four thrusters when its mass was 1400 kg.

decleration _____ m s^{-2}

(1)

(d) Calculate the maximum change in speed that could be produced using the 1720 kg of propellants.

Assume that the speed of the exhaust gases produced by the propellant was 1200 m s^{-1}

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maximum change in speed _____ m s^{-1}

(3)

(e) When the robotic probe landed, it had to be anchored to the comet due to the low gravitational force. Comet 67P has a mass of about 1.1×10^{13} kg. A possible landing site was about 2.0 km from the centre of mass.

(i) Calculate the gravitational force acting on the robotic probe when at a distance of 2.0 km from the centre of mass of the comet.

gravitational force _____ N

(3)

(ii) Calculate the escape velocity for an object 2.0 km from the centre of mass of the comet.

escape velocity _____ m s^{-1}

(3)

(iii) A scientist suggests using a drill to make a vertical hole in a rock on the surface of the comet. The anchoring would be removed from the robotic probe before the drill was used. The drill would exert a force of 25 N for 4.8 s.

Explain, with the aid of a calculation, whether this process would cause the robotic probe to escape from the comet.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 20 marks)

Q53.

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Two identical uniform spheres each of radius R are placed in contact. The gravitational force between them is F.

The spheres are now separated until the force of attraction is $\frac{F}{9}$.

What is the distance between the **surfaces** of the spheres after they have been separated?

A $2R$

B $4R$

C $8R$

D $12R$

(Total 1 mark)

Q54.

A satellite of mass m is in a circular orbit at height R above the surface of a uniform spherical planet of radius R and density ρ.

What is the force of gravitational attraction between the satellite and the planet?

A $\frac{\pi\rho GmR}{3}$

B $\frac{2\pi\rho GmR}{3}$

C $\frac{\pi\rho GmR^2}{3}$

D $\frac{2\pi\rho GmR^2}{3}$

(Total 1 mark)

Q55.

The following data refers to two planets, P and Q.

	Radius / km	**Density / kg m^{-3}**
planet P	8000	6000
planet Q	16 000	3000

The gravitational field strength at the surface of P is 13.4 N kg^{-1}.
What is the gravitational field strength at the surface of Q?

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A 3.4 N kg^{-1}

B 13.4 N kg^{-1}

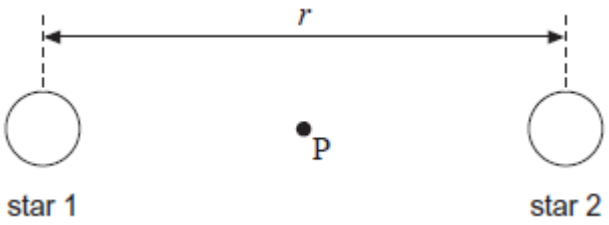
C 53.6 N kg^{-1}

D 80.4 N kg^{-1}

(Total 1 mark)

Q56.

The diagram shows an isolated binary star system. The two stars have equal masses, M, and the distance between their centres is r.



The point P is half-way between the two stars.
What is the gravitational field strength at P?

A zero

B $-\frac{GM}{r^2}$

C $-\frac{2GM}{r^2}$

D $-\frac{4GM}{r^2}$

(Total 1 mark)

Q57.

Which one of the following statements about gravitational potential is **incorrect**?

A It is analogous to the electric potential at a point in an electric field.

B It is equal to the gravitational potential energy of a mass of 1 kg.

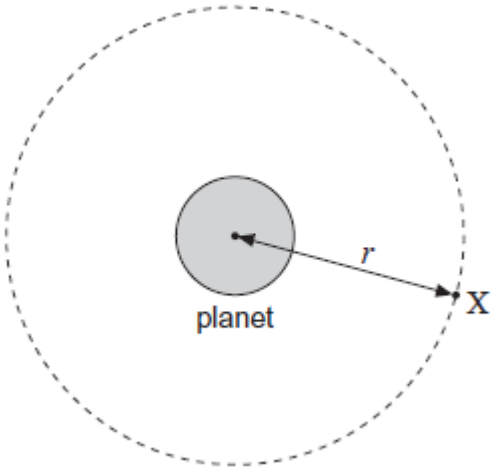
C It is a vector quantity.

D The difference in gravitational potential between two points at different heights above the Earth depends on the position of the points.

Q58.

A satellite X is in a circular orbit of radius r about the centre of a spherical planet of mass M.

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Which line, **A** to **D**, in the table gives correct expressions for the centripetal acceleration a and the speed v of the satellite?

	Centripetal acceleration a	Speed v
A	$\frac{GM}{2r}$	$\sqrt{\frac{GM}{2r}}$
B	$\frac{GM}{2r}$	$\sqrt{\frac{GM}{r}}$
C	$\frac{GM}{r^2}$	$\sqrt{\frac{GM}{2r}}$
D	$\frac{GM}{r^2}$	$\sqrt{\frac{GM}{r}}$

(Total 1 mark)

Q59.

A satellite orbiting the Earth moves to an orbit which is closer to the Earth.

Which line, **A** to **D**, in the table shows correctly what happens to the speed of the satellite and to the time it takes for one orbit of the Earth?

	Speed of satellite	Time For One Orbit Of Earth
A	decreases	decreases
B	decreases	increases
C	increases	decreases

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D	increases	increases

(Total 1 mark)

Q60.

A positive ion has a charge−to−mass ratio of 2.40×10^7 C kg^{-1}. It is held stationary in a vertical electric field.
Which line, **A** to **D**, in the table shows correctly both the strength and the direction of the electric field?

	Electric field strength / V m^{-1}	**Direction**
A	4.09×10^{-7}	upwards
B	4.09×10^{-7}	downwards
C	2.45×10^{6}	upwards
D	2.45×10^{6}	downwards

(Total 1 mark)

Q61.

In the equation $X = \frac{ab}{r^n}$, X represents a physical variable in an electric or a gravitational field, a is a constant, b is either mass or charge and n is a number.

Which line, **A** to **D**, in the table provides a consistent representation of X, a and b according to the value of n?

The symbols E, g, V and r have their usual meanings.

	n	***X***	***a***	***b***
A	1	E	$\frac{1}{4\pi\varepsilon_0}$	charge
B	1	V	$\frac{1}{4\pi\varepsilon_0}$	mass
C	2	g	G	mass
D	2	V	G	charge

(Total 1 mark)

Q62.

Which one of the following statements is correct?

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An electron follows a circular path when it is moving at right angles to

A a uniform magnetic field.

B a uniform electric field.

C uniform electric and magnetic fields which are perpendicular.

D uniform electric and magnetic fields which are in opposite directions.

(Total 1 mark)

Q63.

(a) State, in words, Coulomb's law.

_____

_____

_____

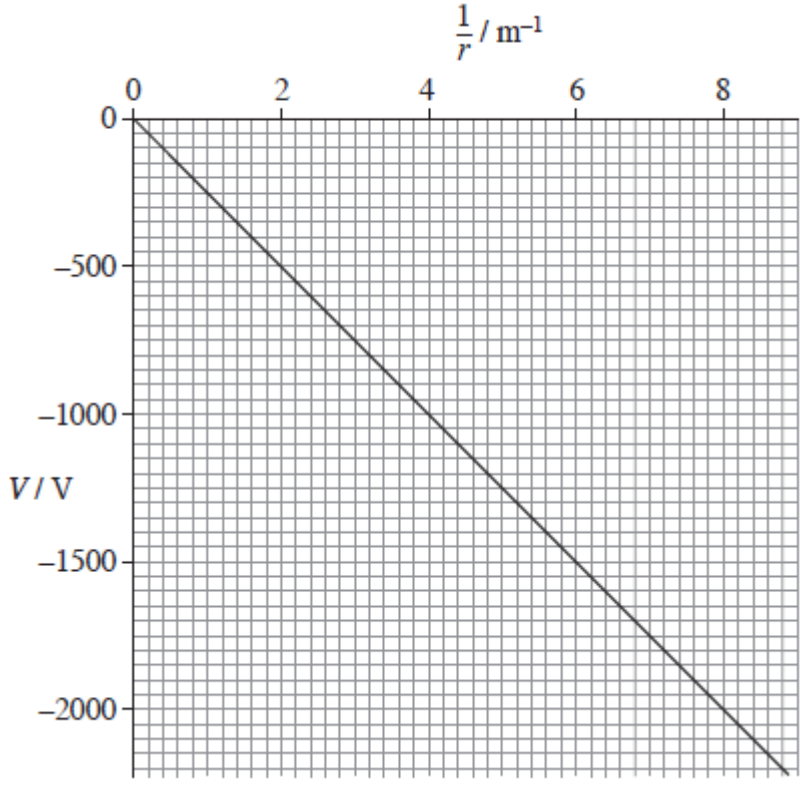
_____

_____

_____

(2)

(b) The graph shows how the electric potential, V, varies with $\frac{1}{r}$, where r is the distance from a point charge Q.



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State what can be deduced from the graph about how V depends on r and explain why all the values of V on the graph are negative.

_____

_____

_____

_____

(2)

(c) (i) Use data from the graph to show that the magnitude of Q is about 30 nC.

(2)

(ii) A +60 nC charge is moved from a point where r = 0.20 m to a point where r = 0.50 m. Calculate the work done.

(2)

work done _____ J

(iii) Calculate the electric field strength at the point where r = 0.40 m.

electric field strength _____ V m^{-1}

(2)

(Total 10 marks)

Q64.

(a) (i) State what is meant by the term **escape velocity**.

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_____

_____

(1)

(ii) Show that the escape velocity, v, at the Earth's surface is given by $v = \sqrt{\frac{2GM}{R}}$

where M is the mass of the Earth
and R is the radius of the Earth.

(2)

(iii) The escape velocity at the Moon's surface is 2.37×10^3 m s^{-1} and the radius of the Moon is 1.74×10^6 m.

Determine the mean density of the Moon.

mean density _____ kg m^{-3}

(2)

(b) State **two** reasons why rockets launched from the Earth's surface do **not** need to achieve escape velocity to reach their orbit.

_____

_____

_____

_____

(2)

(Total 7 marks)

Q65.

(a) Explain why astronauts in an orbiting space vehicle experience the sensation of weightlessness.

_____

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(2)

(b) A space vehicle has a mass of 16 800 kg and is in orbit 900 km above the surface of the Earth.

mass of the Earth = 5.97×10^{24} kg
radius of the Earth = 6.38×10^{6} m

(i) Show that the orbital speed of the vehicle is approximately 7400 m s^{-1}.

(4)

(ii) The space vehicle moves from the orbit 900 km above the Earth's surface to an orbit 400 km above the Earth's surface where the orbital speed is 7700 m s^{-1}.

Calculate the total change that occurs in the energy of the space vehicle.
Assume that the vehicle remains outside the atmosphere after the change of orbit.
Use the value of 7400 m s^{-1} for the speed in the initial orbit.

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change in energy _____ J

(4)

(Total 10 marks)

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