# HL Paper 1

A field line is normal to an equipotential surface

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.

# Markscheme

A

# Examiners report

[N/A]

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The mass of a planet is $M$ and its radius is $R$. In order for a body of mass $m$ to escape the gravitational attraction of the planet, its kinetic energy at the surface of the planet must be at least

A. $\frac{GMm}{R}$

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

C. $\frac{GM}{R}$

D. $\frac{GM}{R^2}$

# Markscheme

A

# Examiners report

[N/A]

---

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

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

# Markscheme

A

# Examiners report

The mass of the rocket does not affect the escape speed, although it will, of course, affect the *energy* needed to escape from the Earth"s gravitational field.

---

What is the unit of $G\varepsilon_0$, where $G$ is the gravitational constant and $\varepsilon_0$ is the permittivity of free space?

A. C $kg^{-1}$

B. $C^2$ $kg^{-2}$

C. C kg

D. $C^2$ $kg^2$

# Markscheme

B

# Examiners report

[N/A]

---

In an experiment, oil droplets of mass $m$ and charge $q$ are dropped into the region between two horizontal parallel plates. The electric field $E$ between the plates can be adjusted. Air resistance is negligible. Which is correct when the droplets fall vertically at constant velocity?

A. $E$=0

B. $E < \frac{mg}{q}$

C. $E = \frac{mg}{q}$

D. $E > \frac{mg}{q}$

# Markscheme

C

# Examiners report

[N/A]

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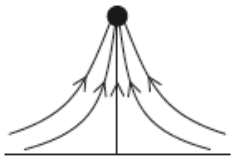
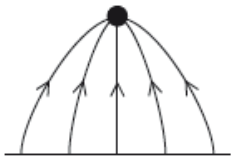
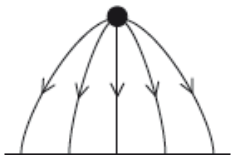
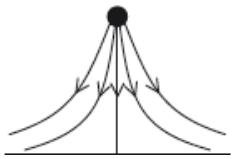
A positive point charge is placed above a metal plate at zero electric potential. Which diagram shows the pattern of electric field lines between the charge and the plate?

A.


B.


C.


D.


# Markscheme

C

# Examiners report

[N/A]

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A satellite at the surface of the Earth has a weight *W* and gravitational potential energy *E*p. The satellite is then placed in a circular orbit with a radius twice that of the Earth.

What is the weight of the satellite and the gravitational potential energy of the satellite when placed in orbit?

| | Weight | Gravitational potential energy |
|---|---|---|
| A. | $0.25\,W$ | $0.25\,E_p$ |
| B. | $0.5\,W$ | $0.25\,E_p$ |
| C. | $0.25\,W$ | $0.5\,E_p$ |
| D. | $0.5\,W$ | $0.5\,E_p$ |

# Markscheme

C

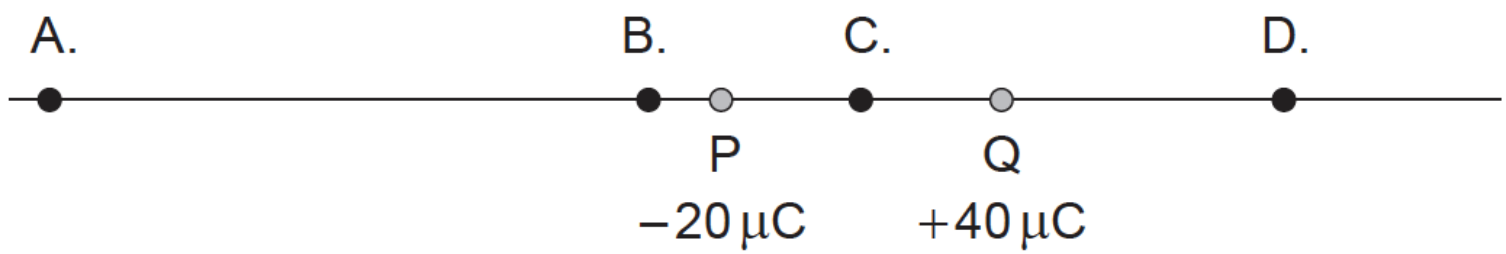
C

# Examiners report

[N/A]

---

The diagram shows two point charges P and Q. At which position is the electric field strength equal to zero?




# Markscheme

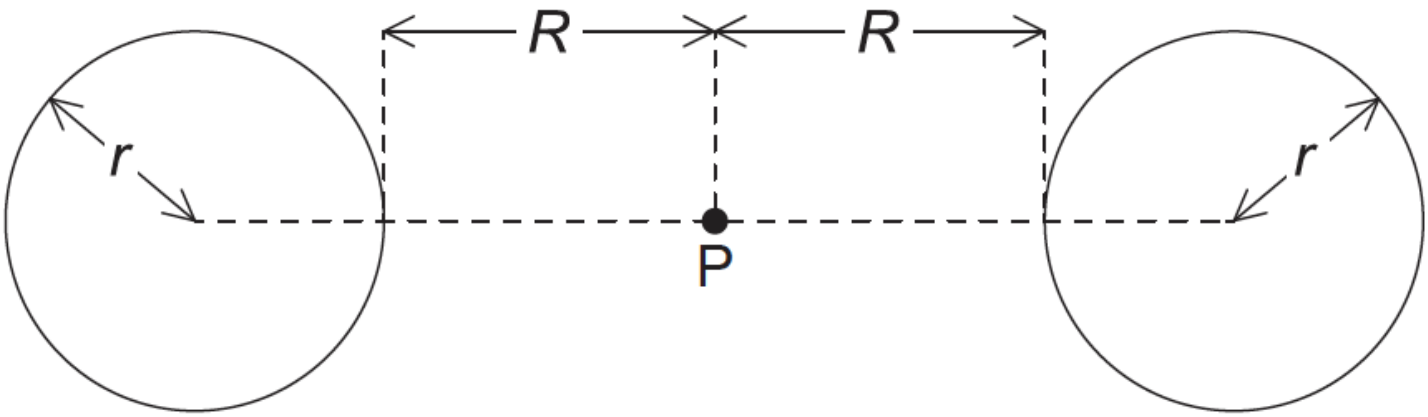
A

# Examiners report

[N/A]

---

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




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

# Markscheme

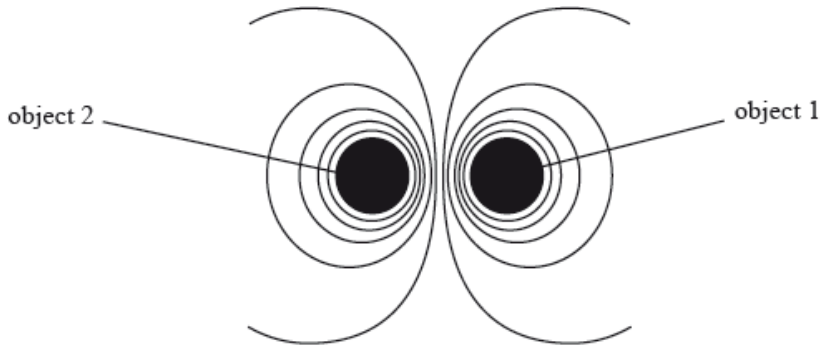
B

# Examiners report

[N/A]

---

The diagram shows equipotential lines due to two objects.




The two objects could be

A. electric charges of the same sign only.

B. masses only.

C. electric charges of opposite sign only.

D. masses or electric charges of any sign.

# Markscheme

C

# Examiners report

Candidates had presumably seen a similar diagram showing the magnetic field lines around two anti-parallel currents. We can only assume that the majority chose A, as they ‘saw’ the two objects repelling each other and assumed they must be charges of the same sign.

Teachers should emphasise the different information that equipotentials and field lines give. They are related inasmuch as the *potential gradient* is the *field strength* and so field lines are always perpendicular to the equipotentials. Any candidate sketching the field lines onto the diagram will see immediately that the only answer can be C. Alternatively they could have seen that approaching the pair of objects from below is possible without crossing any equipotentials. Hence they must be opposite charges.

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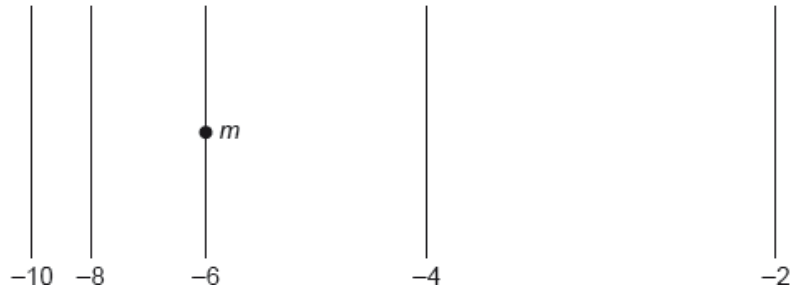
The diagram shows 5 gravitational equipotential lines. The gravitational potential on each line is indicated. A point mass *m* is placed on the middle line and is then released. Values given in MJ $kg^{-1}$.




Which is correct about the direction of motion and the acceleration of the point mass?

| | Direction | Acceleration |
|---|---|---|
| A. | to the right | decreasing |
| B. | to the right | increasing |
| C. | to the left | decreasing |
| D. | to the left | increasing |

# Markscheme

D

# Examiners report

[N/A]

---

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 3*r* above the surface?

| | 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. | $\frac{g}{9}$ | $\frac{V}{3}$ |

## Markscheme

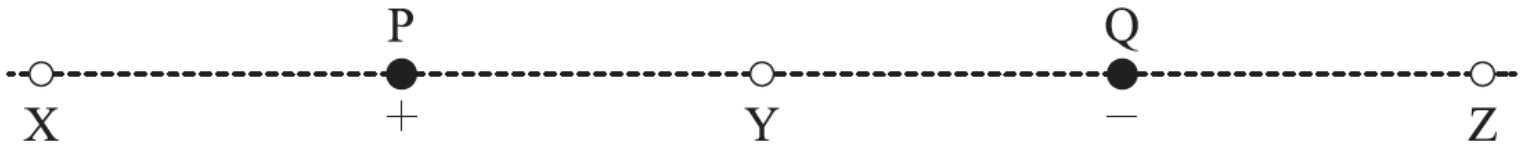
A

## Examiners report

The majority of candidates favoured D. A simple sketch will show that at a height of $3r$ above a planet, the distance to the centre of the planet is $4r$.

---

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.




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 |

## Markscheme

D

## Examiners report

[N/A]

---

A satellite is moved from a low orbit to a higher orbit. Which of the following accurately describes the energy of the satellite?

| | 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 |

## Markscheme

# Examiners report

The most popular response was B, presumably since most candidates assumed it was a closed system, despite being told that the satellite ‘is moved’. A satellite cannot obtain a higher orbit without some energy input, which leaves D as the correct response. There should be no need for recourse to formulae and calculation if the candidate has secure conceptual understanding of satellite motion.

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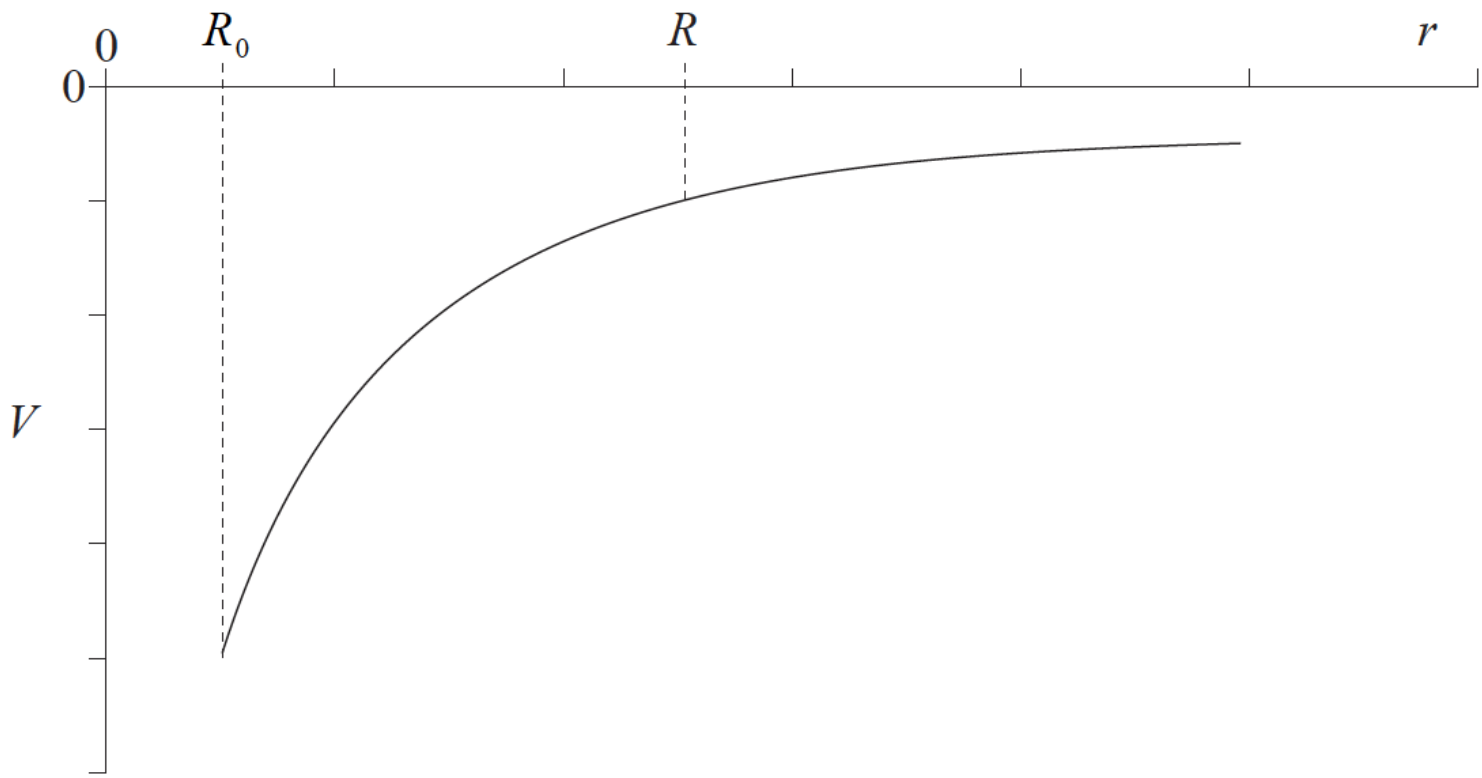
The sketch graph shows how the gravitational potential $V$ of a planet varies with distance $r$ from the centre of the planet of radius $R_0$.




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 $R^2$.

# Markscheme

B

# Examiners report

[N/A]

A spacecraft moves towards the Earth under the influence of the gravitational field of the Earth.

The three quantities that depend on the distance *r* of the spacecraft from the centre of the Earth are the

I. gravitational potential energy of the spacecraft
II gravitational field strength acting on the spacecraft
III. gravitational force acting on the spacecraft.

Which of the quantities are proportional to $\frac{1}{r^2}$?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

# Markscheme

C

# Examiners report

[N/A]

---

An electron of mass $m_e$ orbits an alpha particle of mass $m_\alpha$ in a circular orbit of radius *r*. Which expression gives the speed of the electron?

A. $\sqrt{\frac{2ke^2}{m_e r}}$

B. $\sqrt{\frac{2ke^2}{m_\alpha r}}$

C. $\sqrt{\frac{4ke^2}{m_e r}}$

D. $\sqrt{\frac{4ke^2}{m_\alpha r}}$

# Markscheme

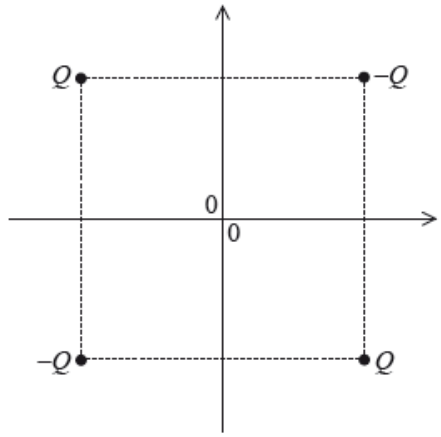
A

# Examiners report

[N/A]

---

Two positive and two negative point charges of equal magnitude are placed at the vertices of a square as shown. The origin of the axes is at the centre of the square.




The electric potential is zero

A. at the origin of the axes only.

B. along both the $x$-axis and the $y$-axis.

C. along the $y$-axis only.

D. along the $x$-axis only.

# Markscheme

B

# Examiners report

Both A and B were allowed as the wording was slightly ambiguous. The symmetry of the situation as a test charge approaches from infinity should have led the candidates to the correct response of B, though.

The poor results of candidates on questions 24 and 25 indicate that more time needs to be spent on this topic.

---

A moon of mass *M* orbits a planet of mass 100*M*. The radius of the planet is *R* and the distance between the centres of the planet and moon is 22*R*.


What is the distance from the centre of the planet at which the total gravitational potential has a maximum value?

A. 2*R*

B. 11*R*

C. 20*R*

D. 2*R* and 20*R*

# Markscheme

C

# Examiners report

[N/A]

---

The mass of the Earth is $M_E$ and the mass of the Moon is $M_M$. Their respective radii are $R_E$ and $R_M$.

Which is the ratio $\frac{\text{escape speed from the Earth}}{\text{escape speed from the Moon}}$?

A. $\sqrt{\frac{M_M R_M}{M_E R_E}}$

B. $\sqrt{\frac{M_E R_E}{M_M R_M}}$

C. $\sqrt{\frac{M_E R_M}{M_M R_E}}$

D. $\sqrt{\frac{M_M R_E}{M_E R_M}}$

# Markscheme

C

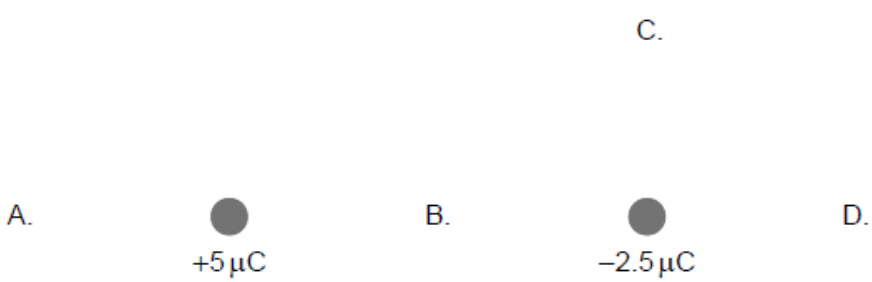
# Examiners report

[N/A]

---

Two point charges are at rest as shown.

At which position is the electric field strength greatest?




# Markscheme

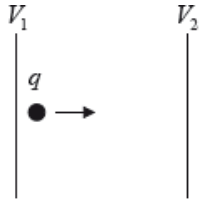
B

# Examiners report

[N/A]

---

The diagram below shows a particle with positive charge *q* accelerating between two conducting plates at potentials $V_1$ and $V_2$.




Which of the following is the kinetic energy gained by the charge in moving between the plates?

A. $V_2 q$

B. $V_1 q$

C. $(V_1 - V_2)q$

D. $(V_2 - V_1)q$

# Markscheme

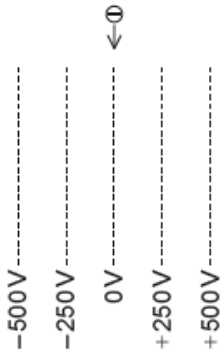
C

# Examiners report

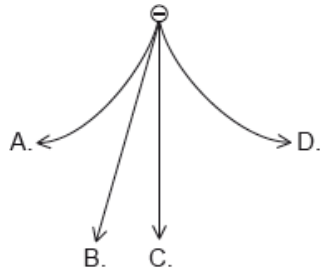
The vast majority of students incorrectly chose D as their answer. Kinetic energy gained is equal to potential energy lost. Furthermore, kinetic energy can only be positive, so, whether $q$ is negative or positive, the only correct response can be C.

---

A negatively charged particle falls vertically into a region where there is an electric field. The equipotentials of this field are shown.




What is the path followed by the particle?




# Markscheme

D

# Examiners report

[N/A]

---

Which of the following experiments provides evidence for the existence of matter waves?

A. Scattering of alpha particles

B. Electron diffraction

C. Gamma decay

D. Photoelectric effect

# Markscheme

B

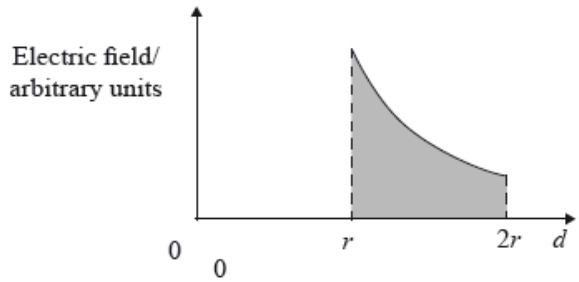
# Examiners report

[N/A]

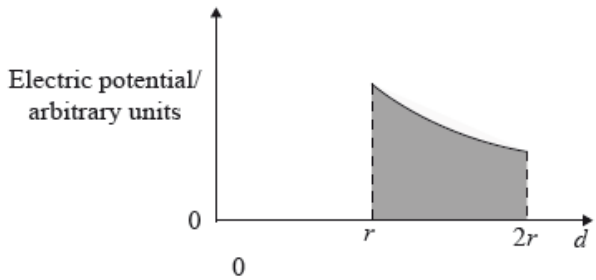
---

The two graphs below represent the variation with distance, $d$, for $d = r$ to $d = 2r$ of the electric field and the electric potential around an isolated point charge.

Graph 1:




Graph 2:




The work done by an external force in moving a test charge $+q$ from $d = 2r$ to $d = r$ is equal to $q$ multiplied by the

A. shaded area under graph 1.

B. shaded area under graph 2.

C. average value of the electric field.

D. average value of the electric potential.

# Markscheme

A

# Examiners report

[N/A]

---

A charge of –3 C is moved from A to B and then back to A. The electric potential at A is +10 V and the electric potential at B is –20 V. What is the work done in moving the charge from A to B and the total work done?

| | Work done in moving from A to B / J | Total work done / J |
|---|---|---|
| A. | 30 | 0 |
| B. | 30 | 60 |
| C. | 90 | 0 |
| D. | 90 | 180 |

# Markscheme

C

# Examiners report

[N/A]

---

Which of the following represents a scalar and a vector quantity?

| | Scalar | Vector |
|---|---|---|
| A. | electric potential | electric potential gradient |
| B. | electric potential gradient | electric potential |
| C. | electric potential | electric potential difference |
| D. | electric potential gradient | electric field |

# Markscheme

A

# Examiners report

Most students incorrectly chose D. If ‘potential gradient’ had been automatically equated with ‘field strength’ in students’ minds, then its vector nature may have been more transparent.

---

Gravitational potential at a point is defined as the work done

A. per unit mass in moving a small mass from infinity to the point.

B. in moving a unit mass from infinity to the point.

C. in moving a small mass from infinity to the point.

D. per unit mass in moving a unit mass from infinity to the point.

# Markscheme

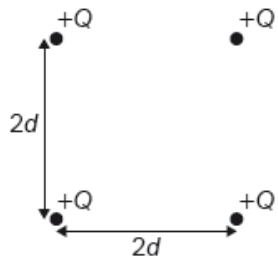
A

# Examiners report

Gravitational potential is defined in terms of moving a *small* mass. This is, yet again, a matter of candidates learning their definitions.

---

Four identical, positive, point charges of magnitude *Q* are placed at the vertices of a square of side 2*d*. What is the electric potential produced at the centre of the square by the four charges?




A. 0

B. $\frac{4kQ}{d}$

C. $\frac{\sqrt{2}kQ}{d}$

D. $\frac{2\sqrt{2}kQ}{d}$

# Markscheme

D

# Examiners report

[N/A]

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The diagram shows two parallel metal plates X and Y.

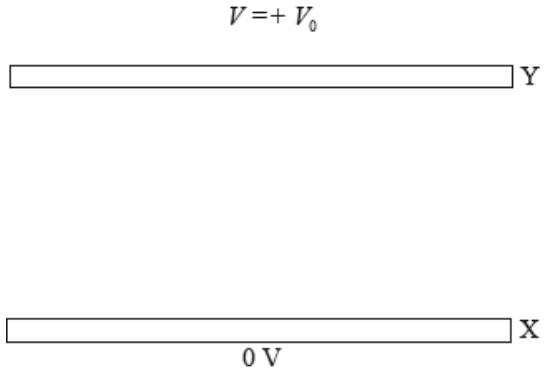



Plate X is at Earth potential (0 V) and the potential of plate Y is $V_0$.

Which of the following is correct in respect of the magnitude and the direction of the electric field between the plates?

| | Magnitude | Direction |
|---|---|---|
| A. | constant | X → Y |
| B. | increasing | Y → X |
| C. | constant | Y → X |
| D. | increasing | X → Y |

# Markscheme

C

# Examiners report

[N/A]

---

The escape speed from the surface of a planet depends on

A. both the radius and the mass of the planet.

B. only the radius of the planet.

C. only the mass of the planet.

D. only the gravitational field strength at the surface of the planet.

# Markscheme

A

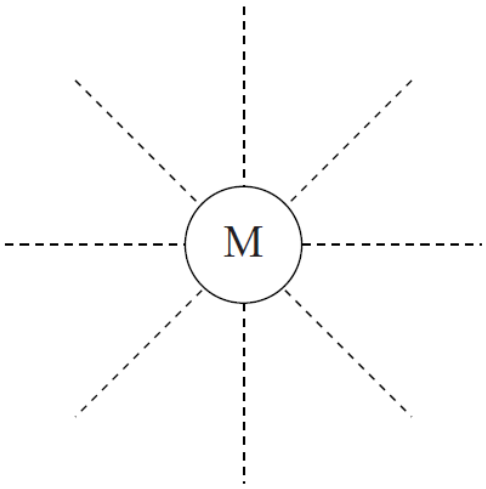
# Examiners report

[N/A]

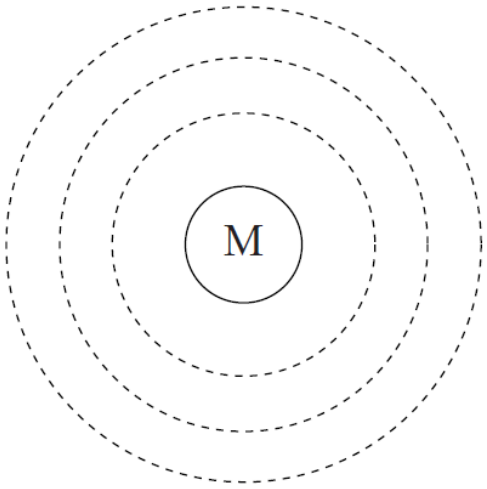
---

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?

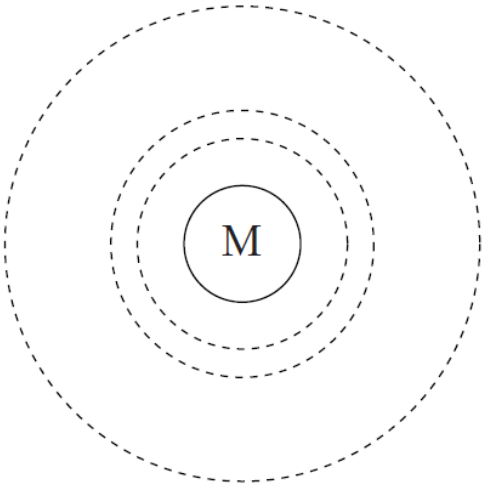
A.



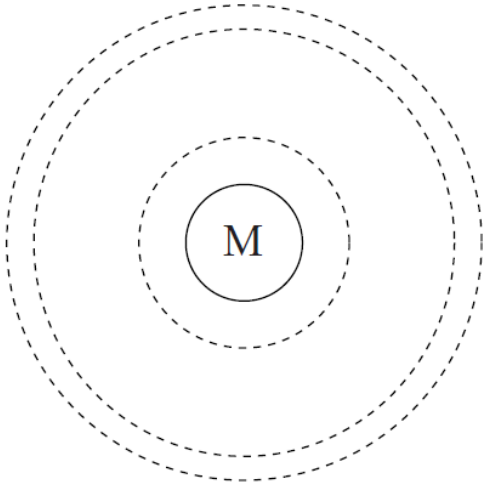

B.




C.




D.




# Markscheme

C

# Examiners report

Each diagram gives just three adjacent equipotentials. There is therefore no attempt made at completeness as may be found in a text book. Candidates should know that the two equipotentials further from the mass should have a greater distance between them than the pair closer to the mass. Hence only C can be correct.

---

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?

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

# Markscheme

D

# Examiners report

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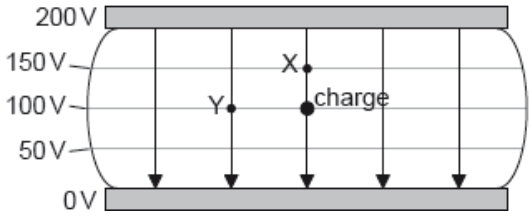
The diagram shows the electric field and the electric equipotential surfaces between two charged parallel plates. The potential difference between the plates is 200 V.




What is the work done, in nJ, by the electric field in moving a negative charge of magnitude 1 nC from the position shown to X and to Y?

| | To X | To Y |
|---|---|---|
| A. | 50 | 0 |
| B. | –50 | 0 |
| C. | 50 | 100 |
| D. | –50 | –100 |

# Markscheme

A

# Examiners report

[N/A]

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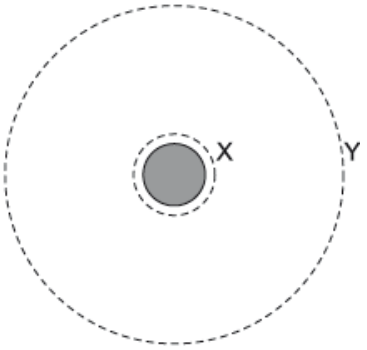
A satellite orbiting a planet moves from orbit X to orbit Y.




What is the change in the kinetic energy and the change in the gravitational potential energy as a result?

| | Kinetic energy | Gravitational potential energy |
|---|---|---|
| A. | increases | increases |
| B. | increases | decreases |
| C. | decreases | increases |
| D. | decreases | decreases |

# Markscheme

C

# Examiners report

[N/A]

---

At the surface of a planet of radius *r*, the gravitational potential is $-6.4\times10^{7}$ J kg$^{-1}$. The gravitational potential at a height of *r* above the surface is

A. $-12.8\times10^{7}$ J kg$^{-1}$.

B. $-6.4\times10^{7}$ J kg$^{-1}$.

C. $-3.2\times10^{7}$ J kg$^{-1}$.

D. $-1.6\times10^{7}$ J kg$^{-1}$.

# Markscheme

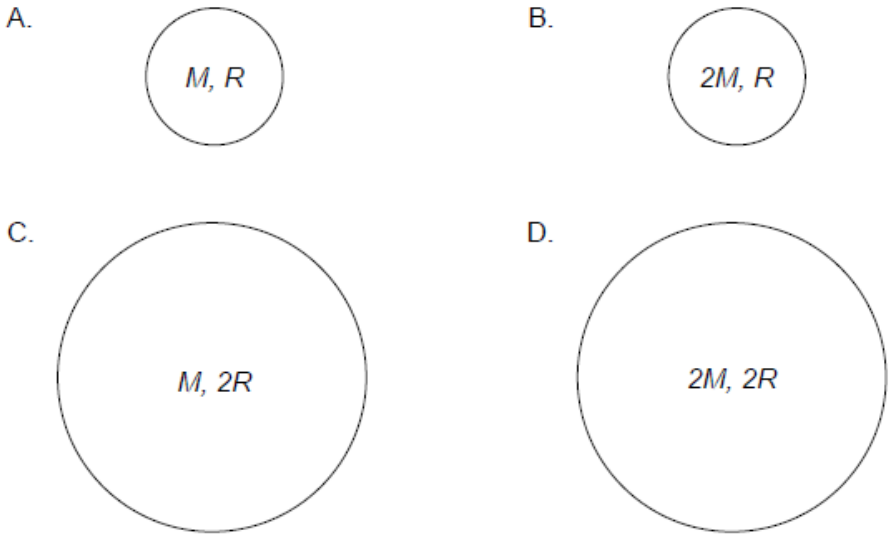
C

# Examiners report

[N/A]

---

Four uniform planets have masses and radii as shown. Which planet has the smallest escape speed?




# Markscheme

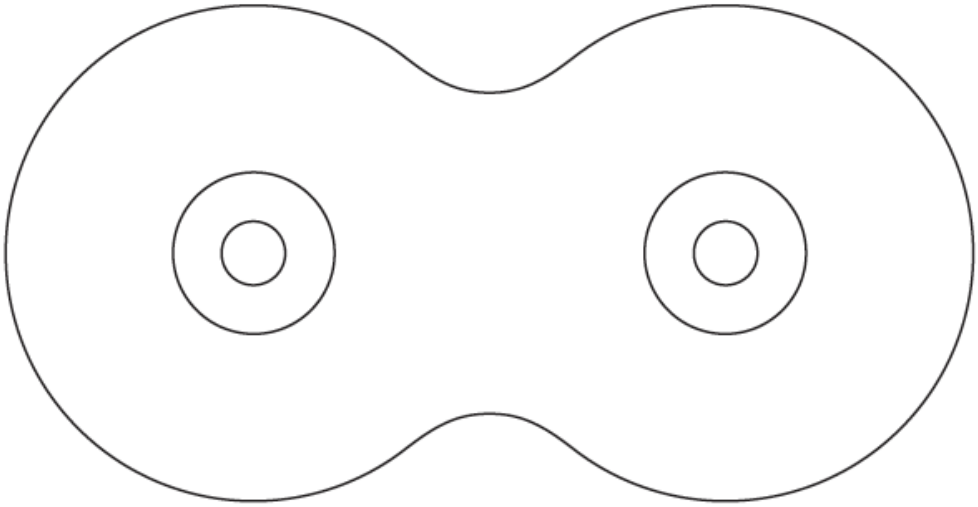
C

# Examiners report

[N/A]

---

The diagram shows equipotential lines around two sources.



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

# Markscheme

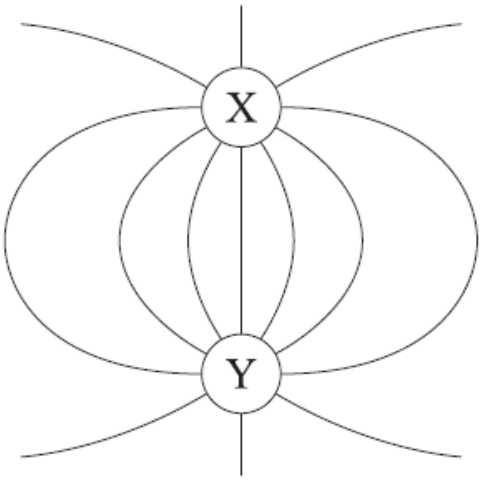
A

# Examiners report

[N/A]

---

The diagram shows the electric field pattern due to two point charges X and Y. Y is a negative charge.




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 |

# Markscheme

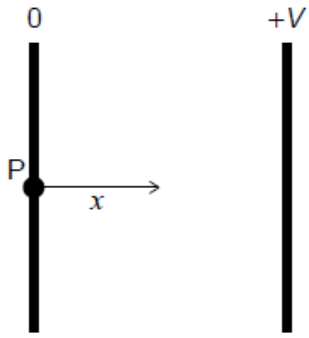
B

# Examiners report

[N/A]

---

An electric field acts in the space between two charged parallel plates. One plate is at zero potential and the other is at potential $+V$.



The distance $x$ is measured from point P in the direction perpendicular to the plate.

What is the dependence of the electric field strength $E$ on $x$ and what is the dependence of the electric potential $V$ on $x$?

| | $E$ | $V$ |
|---|---|---|
| A. | proportional to $\frac{1}{x^2}$ | constant |
| B. | constant | proportional to $x$ |
| C. | proportional to $x$ | proportional to $x$ |
| D. | proportional to $x^2$ | constant |

# Markscheme

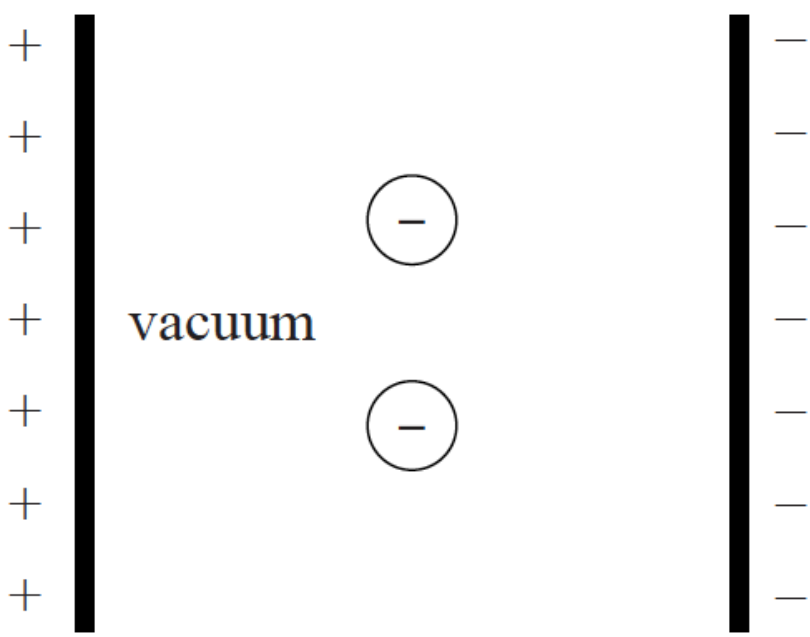
B

# Examiners report

[N/A]

---

Two negatively charged particles are released from rest half-way between two oppositely charged parallel plates in vacuum.




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.

# Markscheme

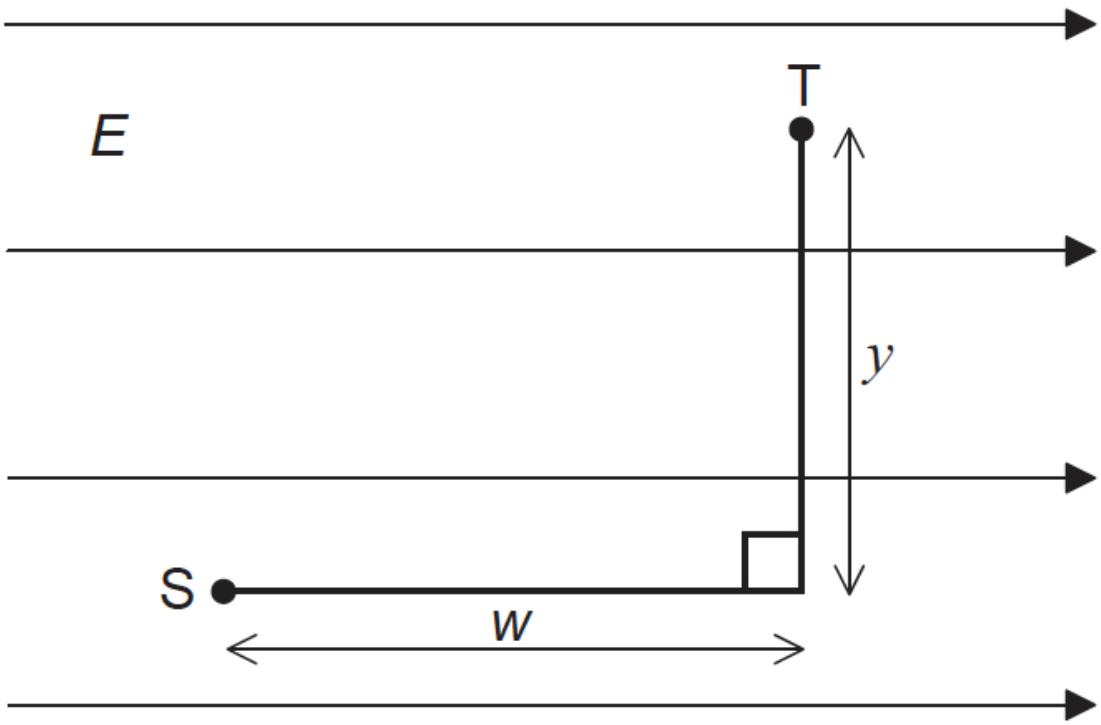
D

# Examiners report

Same time....same acceleration.....same (F/m). Hence it can only be D. Many candidates directly identified force with acceleration and chose A.

---

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.




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* $\sqrt{y^2 + w^2}$

# Markscheme

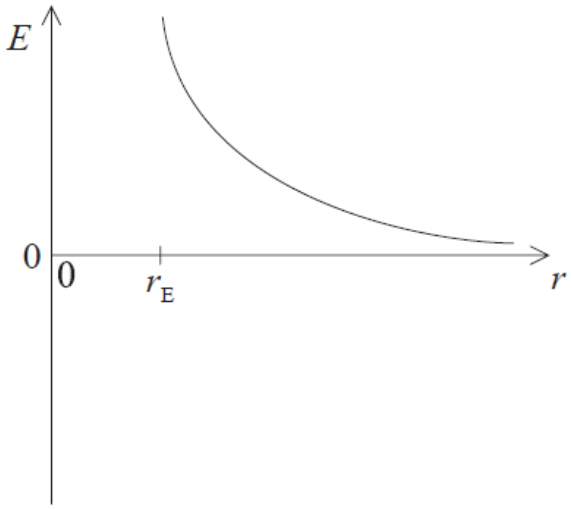
A

# Examiners report

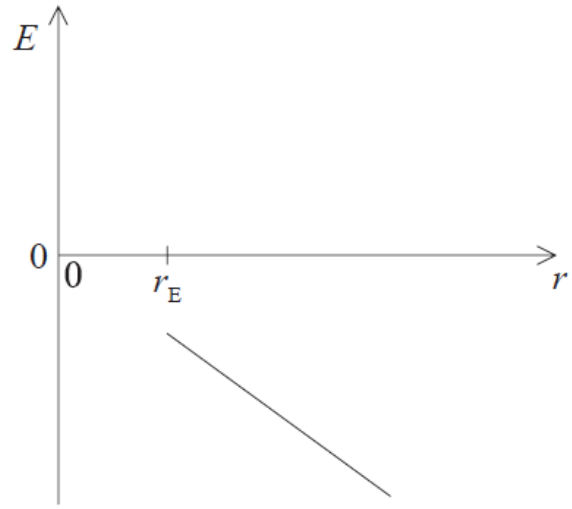
[N/A]

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?

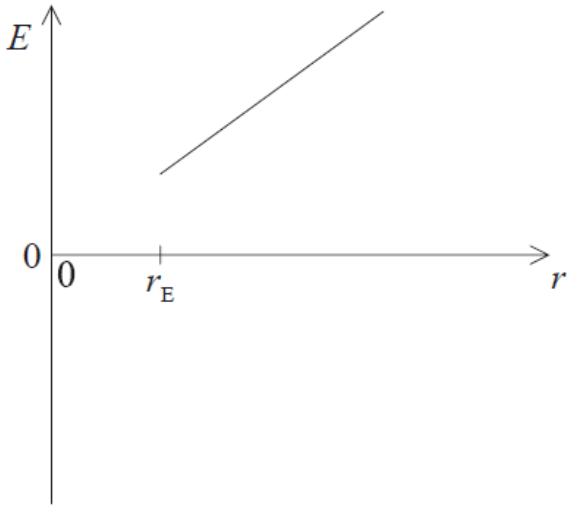
A.



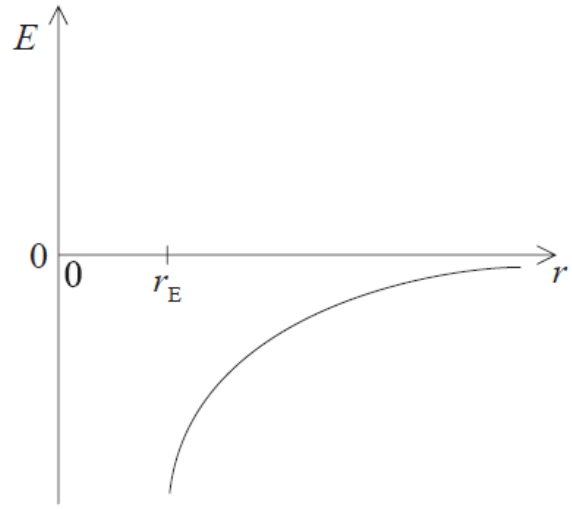

B.




C.




D.




# Markscheme

D

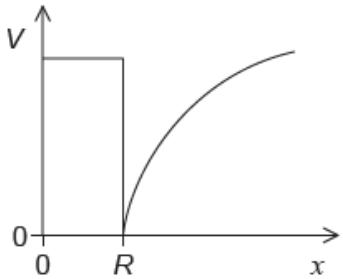
# Examiners report

[N/A]

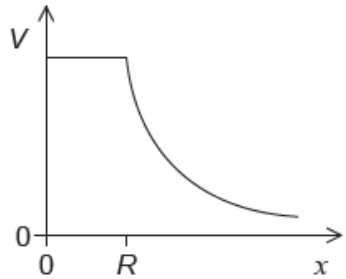
---

An isolated hollow metal sphere of radius $R$ carries a positive charge. Which graph shows the variation of potential $V$ with distance $x$ from the centre of the sphere?

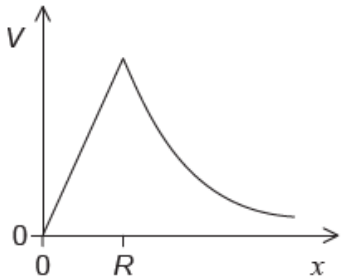
A.



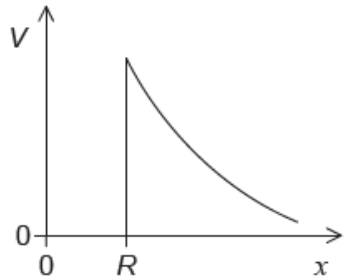

B.




C.




D.




# Markscheme

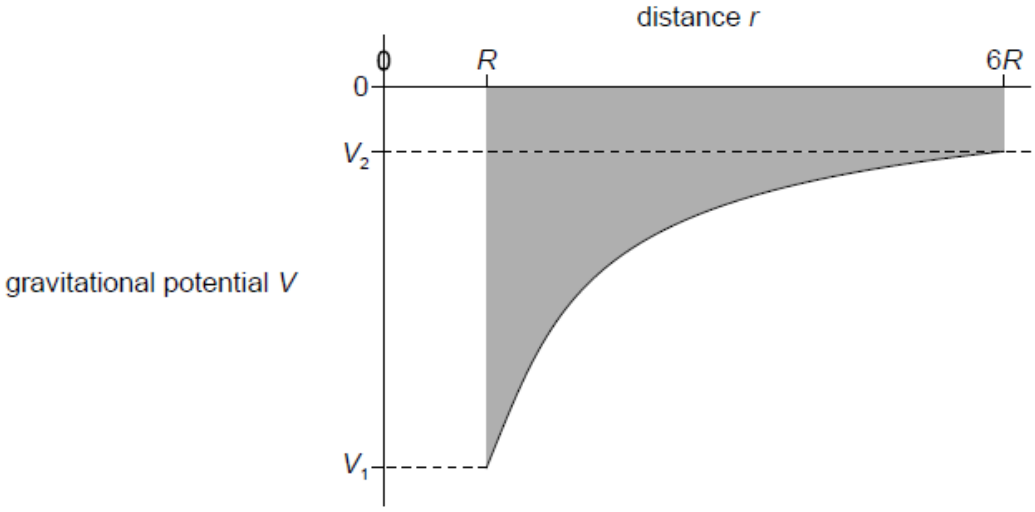
B

# Examiners report

[N/A]

---

The graph shows the variation of the gravitational potential *V* with distance *r* from the centre of a uniform spherical planet. The radius of the planet is *R*. The shaded area is *S*.




What is the work done by the gravitational force as a point mass *m* is moved from the surface of the planet to a distance 6*R* from the centre?

A. $m\,(V2 - V1)$

B. $m\,(V1 - V2)$

C. $mS$

D. $S$

# Markscheme

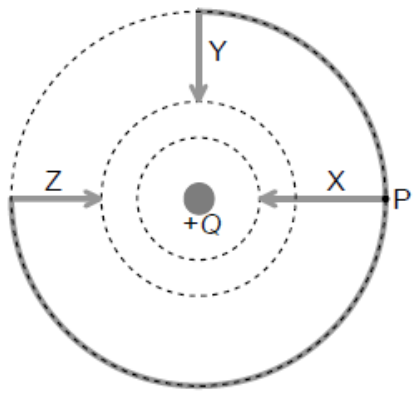
B

# Examiners report

[N/A]

---

A positive charge *Q* is deposited on the surface of a small sphere. The dotted lines represent equipotentials.




A small positive point charge is moved from point P closer to the sphere along three different paths X, Y and Z. The work done along each path is $W_X$, $W_Y$ and $W_Z$. What is a correct comparison of $W_X$, $W_Y$ and $W_Z$?

A. $W_Z > W_Y > W_X$

B. $W_X > W_Y = W_Z$

C. $W_X = W_Y = W_Z$

D. $W_Z = W_Y > W_X$

# Markscheme

B

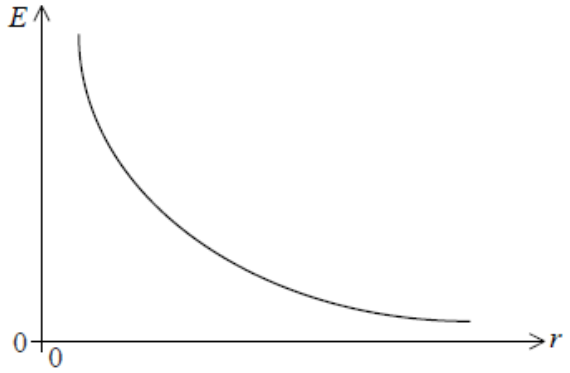
# Examiners report

[N/A]

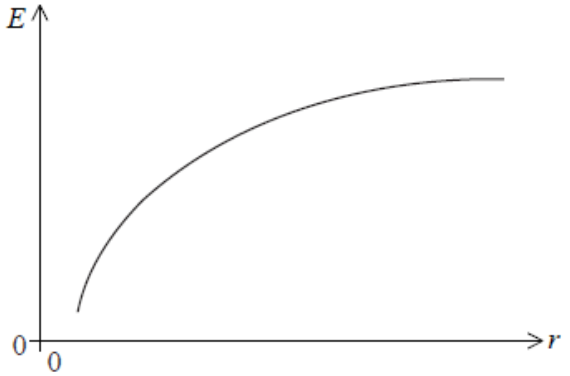
---

Which of the following graphs represents how the total energy *E* of an orbiting satellite varies with orbital radius *r*?

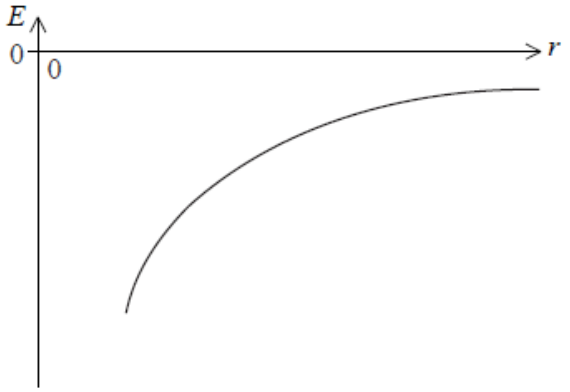
A.



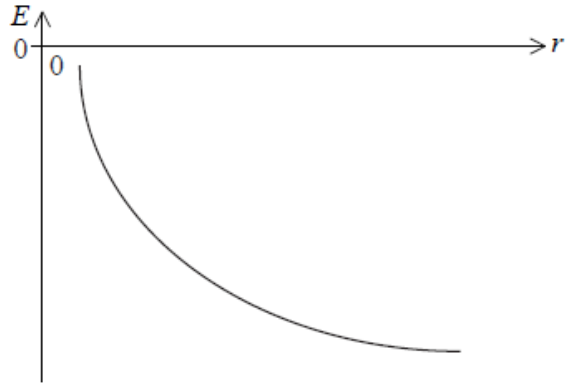

B.




C.




D.




# Markscheme

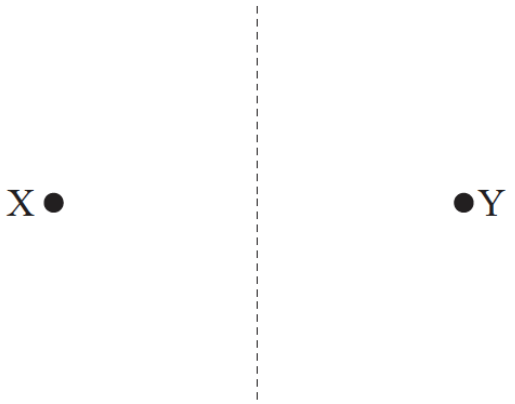
C

# Examiners report

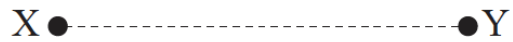
[N/A]

Which diagram shows a correct equipotential line due to two point charges X and Y of opposite sign?

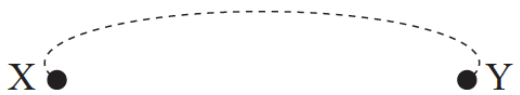
A.




B.




C.




D.


# Markscheme

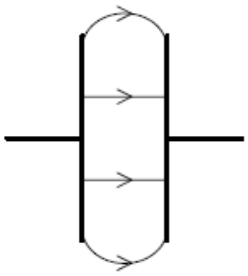
A

# Examiners report

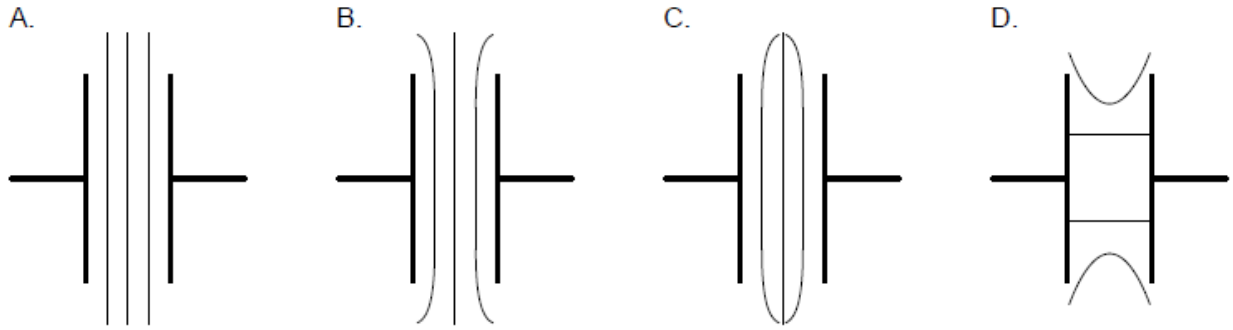
Candidates are required to give the best answer. A is possible, but more importantly, B, C and D are patently incorrect to anyone who knows what an equipotential is. Hence A must be selected.

---

Two parallel metal plates are connected to a dc power supply. An electric field forms in the space between the plates as shown.



What is the shape of the equipotentials surfaces that result from this arrangement?




## Markscheme

B

## Examiners report

[N/A]

---

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 2*r*. Which of the following describes the variations in kinetic energy and total energy of the spacecraft?

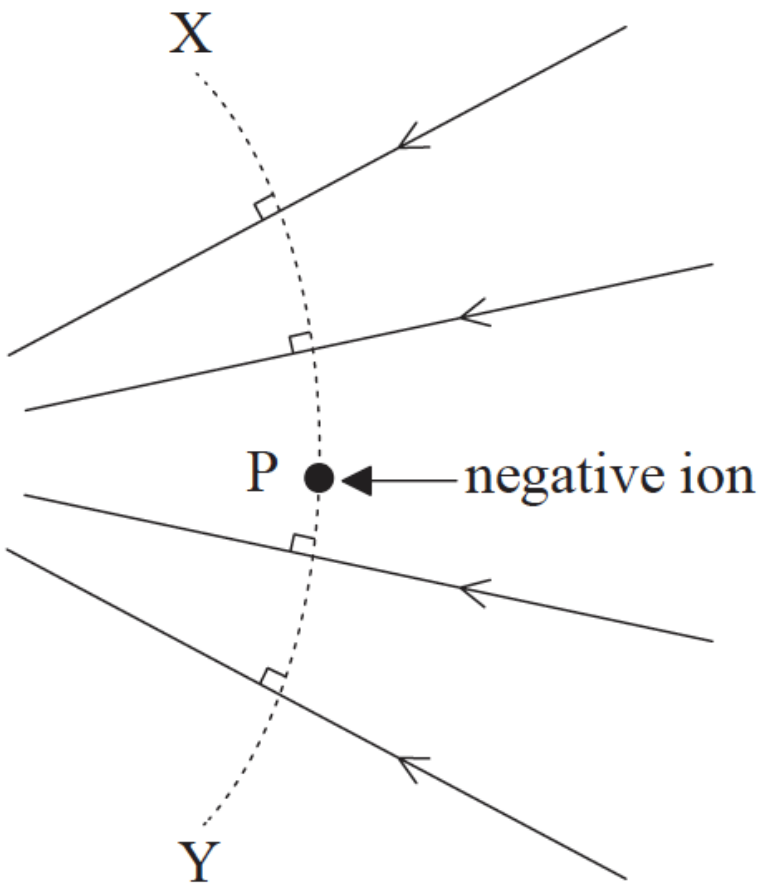
| | Kinetic energy | Total energy |
|---|---|---|
| A. | decrease | increase |
| B. | decrease | decrease |
| C. | increase | increase |
| D. | increase | decrease |

## Markscheme

A

# Examiners report

A negative ion is held at point P in an electric field as represented by the arrowed field lines.




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 |

# Markscheme

D

## Examiners report

The only reasonable distractor was B, with some candidates clearly not taking into account that it was a *negative* ion.

---

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?

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

## Markscheme

D

## Examiners report

[N/A]

---

A satellite of mass 1500 kg is in the Earth's gravitational field. It moves from a point where the gravitational potential is –30 MJ $kg^{-1}$ to a point where the gravitational potential is –20 MJ $kg^{-1}$. What is the direction of movement of the satellite and the change in its gravitational potential energy?

| | Direction of movement of satellite | Change in gravitational potential energy / GJ |
|---|---|---|
| A. | away from Earth | 15 |
| B. | away from Earth | 75 |
| C. | towards Earth | 15 |
| D. | towards Earth | 75 |

# Markscheme

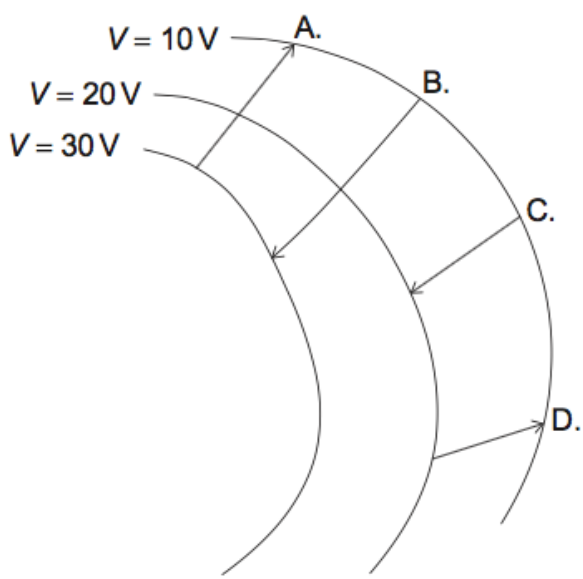
A

# Examiners report

[N/A]

---

A negative charge moves in an electric field. Equipotential lines for the field and four possible paths of the charge are shown. Which path corresponds to the largest work done on the charge by the field?



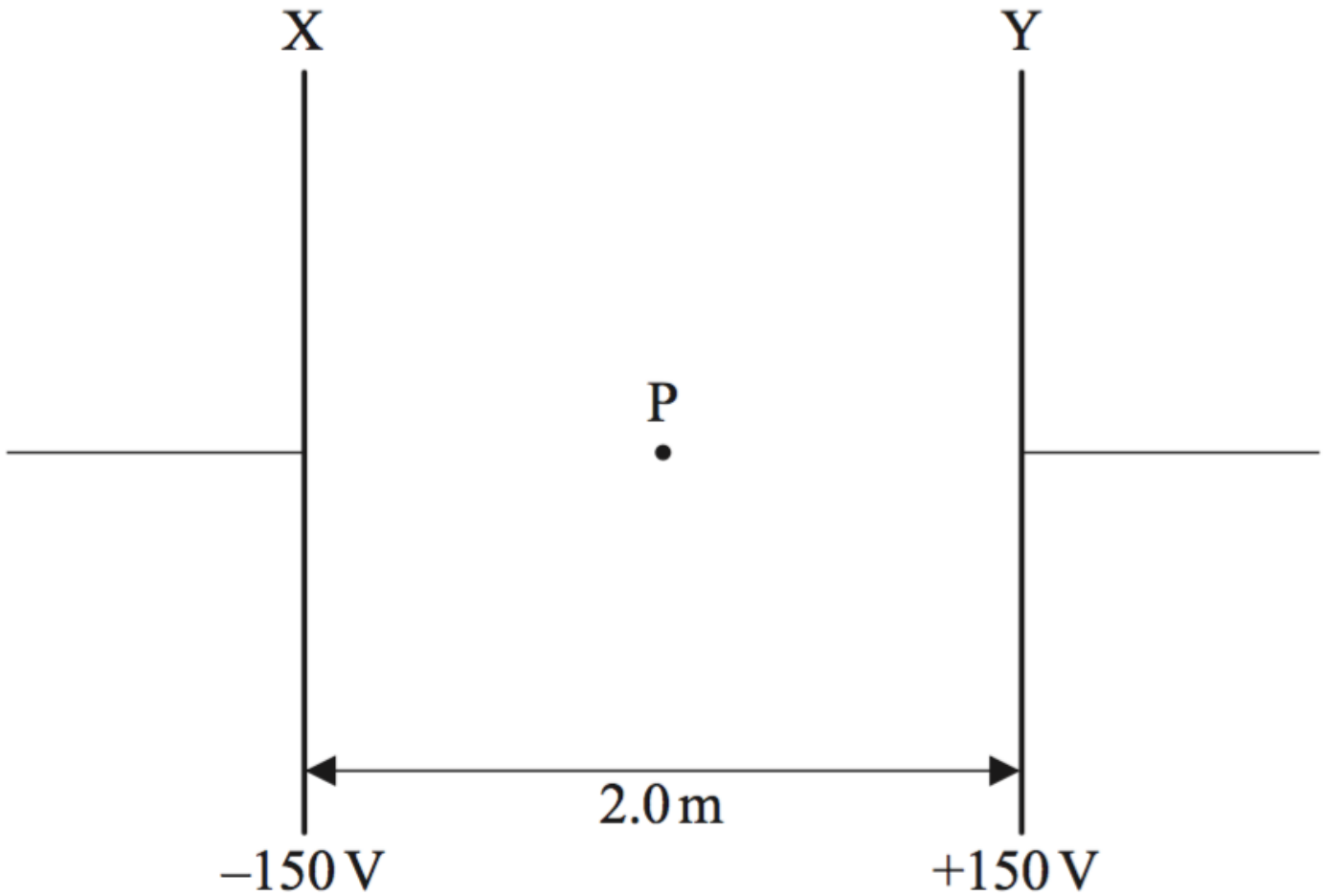

# Markscheme

B

# Examiners report

[N/A]

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.




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

# Markscheme

B

# Examiners report

Many candidates chose D, despite the use of $Vm^{-1}$ as the units of electric field strength.

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?

| | Speed | Gravitational potential energy |
|---|---|---|
| A. | decreases | decreases |
| B. | decreases | increases |
| C. | increases | increases |
| D. | increases | decreases |

## Markscheme

D

## Examiners report

[N/A]

---

A satellite orbits a planet. Which graph shows how the kinetic energy $E_K$, the potential energy $E_P$ and the total energy $E$ of the satellite vary with distance $x$ from the centre of the planet?

## Markscheme

B

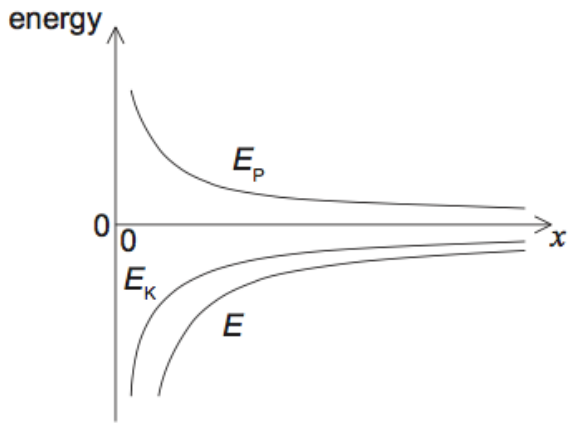
## Examiners report

[N/A]

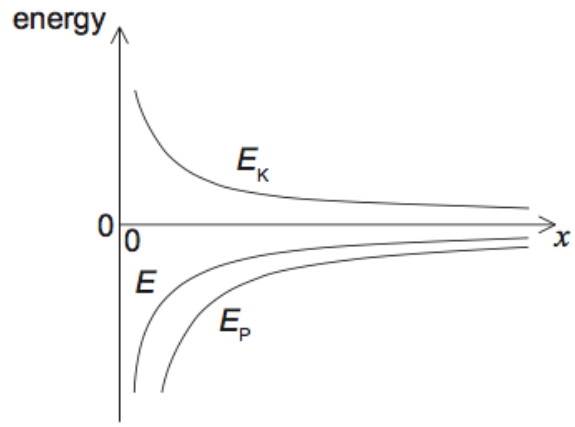
---

The graph shows the variation with distance $r$ of the electric potential $V$ for a positively charged hollow sphere of radius $R$.

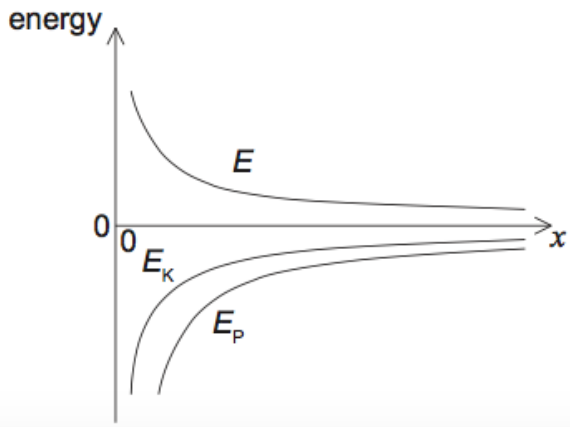
A.



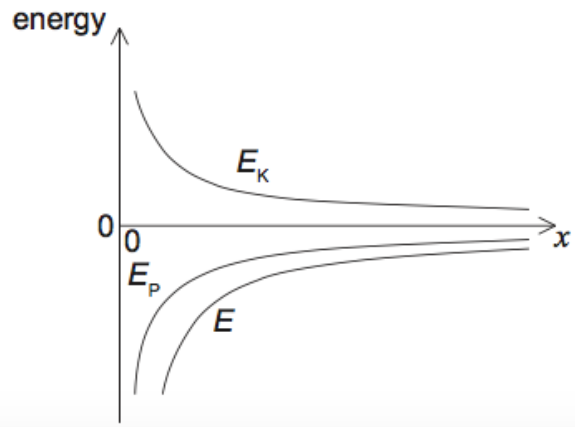

B.

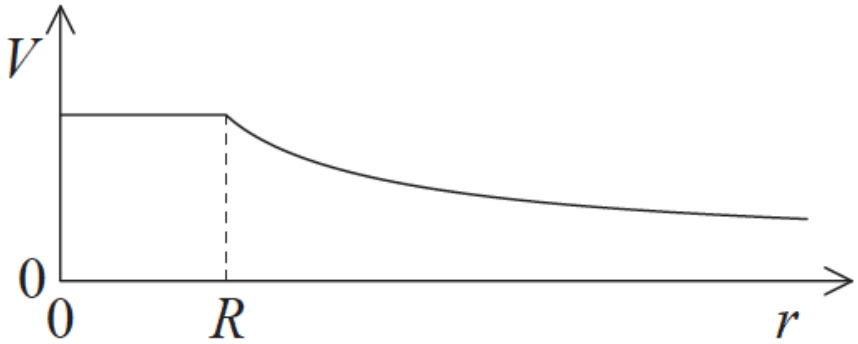



C.



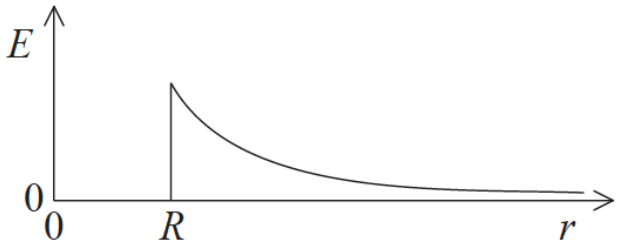

D.



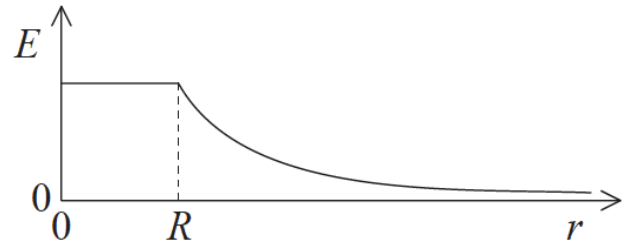




Which graph shows how the magnitude of the electric field $E$ varies with $r$?

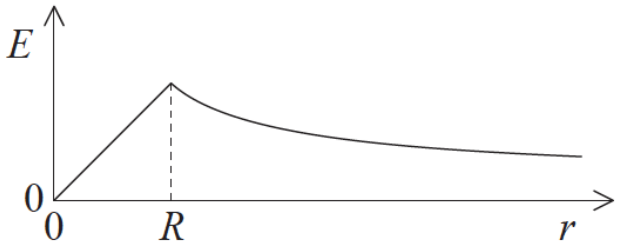
A.



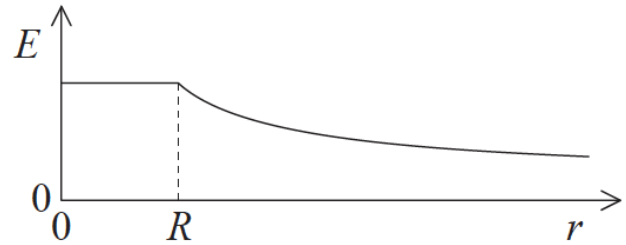

B.




C.




D.



# Markscheme

A

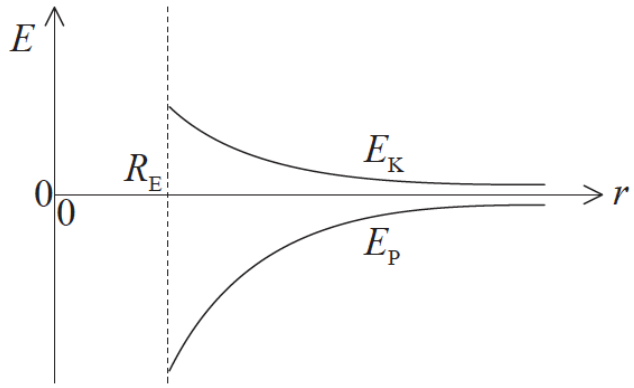
# Examiners report

The question can either by approached from taking the gradient of the electric potential graph to provide the electric field strength, or by knowing that the electric field inside a charged sphere is equal to zero, they would be able to opt for the correct response.

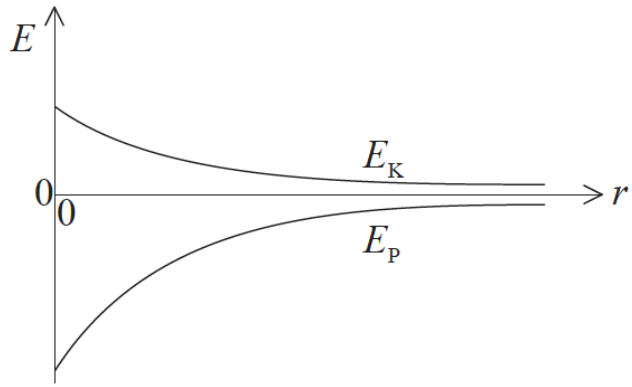
---

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 $r$?

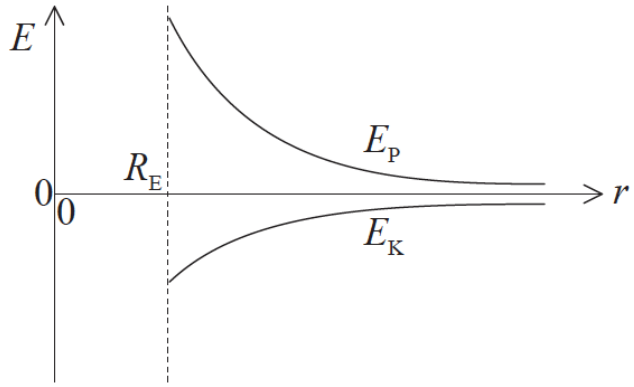
A.



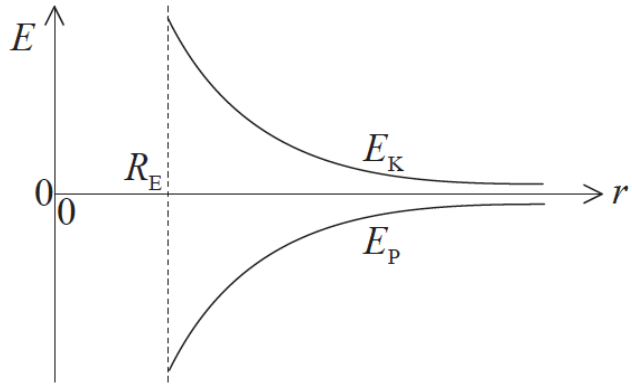

B.




C.




D.




# Markscheme

A

# Examiners report

[N/A]

---

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?

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

## Markscheme

C

## Examiners report

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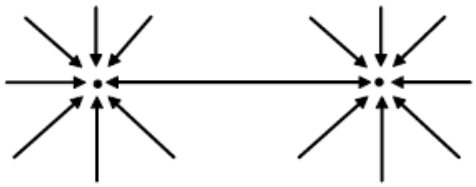
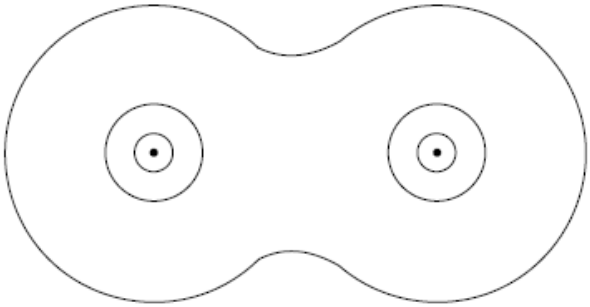
Which of the diagrams below best represents the equipotential surfaces around two identical point masses?

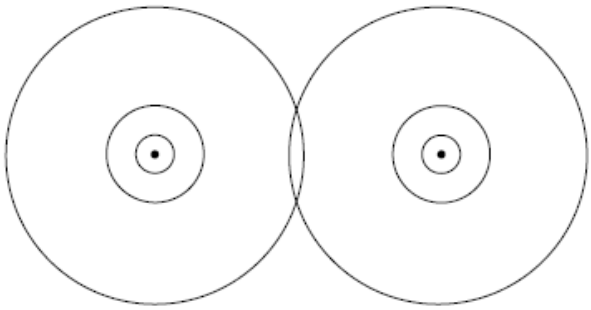
A.



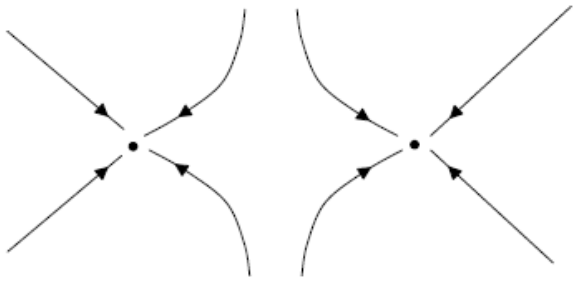
B.



C.



D.



# Markscheme

B

# Examiners report

[N/A]