

**Q1.** A small mass is situated at a point on a line joining two large masses  $m_1$  and  $m_2$  such that it experiences no resultant gravitational force. If its distance from the mass  $m_1$  is  $r_1$  and its distance from the mass  $m_2$  is  $r_2$ , what is the value of the ratio  $\frac{r_1}{r_2}$ ?

**A**  $\frac{m_1^2}{m_2^2}$

**B**  $\frac{m_2^2}{m_1^2}$

**C**  $\sqrt{\frac{m_1}{m_2}}$

**D**  $\sqrt{\frac{m_2}{m_1}}$

(Total 1 mark)

**Q2.** The force between two point charges is  $F$  when they are separated by a distance  $r$ . If the separation is increased to  $3r$  what is the force between the charges?

**A**  $\frac{F}{3r}$

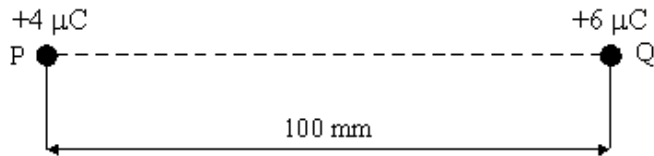
**B**  $\frac{F}{9r}$

**C**  $\frac{F}{3}$

**D**  $\frac{F}{9}$

(Total 1 mark)

**Q3.** Two charges, P and Q, are 100 mm apart.



X is a point on the line between P and Q. If the potential at X is 0 V, what is the distance from P to X?

- A 40 mm
- B 45 mm
- C 50 mm
- D 60 mm

(Total 1 mark)

**Q4.** Two protons, each of mass  $m$  and charge  $e$ , are a distance  $d$  apart. Which one of the following expressions correctly gives the ratio  $\left(\frac{\text{electrostatic force}}{\text{gravitational force}}\right)$  for the forces acting between them?

- A  $\frac{4\pi\epsilon_0 e^2}{Gm^2}$
- B  $\frac{Ge^2}{4\pi\epsilon_0 m^2}$
- C  $\frac{e^2 m^2}{4\pi\epsilon_0 G}$
- D  $\frac{e^2}{4\pi\epsilon_0 Gm^2}$

(Total 1 mark)

- Q5.** At a distance  $R$  from a fixed charge, the electric field strength is  $E$  and the electric potential is  $V$ . Which line, **A** to **D**, gives the electric field strength and electric potential at a distance  $2R$  from the charge?

	electric field strength	electric potential
<b>A</b>	$\frac{E}{2}$	$\frac{V}{4}$
<b>B</b>	$\frac{E}{2}$	$\frac{V}{2}$
<b>C</b>	$\frac{E}{4}$	$\frac{V}{2}$
<b>D</b>	$\frac{E}{4}$	$\frac{V}{4}$

(Total 1 mark)

- Q6.** At the surface of the Earth the gravitational field strength is  $g$ , and the gravitational potential is  $V$ . The radius of the Earth is  $R$ . An object, whose weight on the surface of the Earth is  $W$ , is moved to a height  $3R$  above the surface. Which line, **A** to **D**, in the table gives the weight of the object and the gravitational potential at this height?

	weight	gravitational potential
<b>A</b>	$\frac{W}{16}$	$\frac{V}{4}$
<b>B</b>	$\frac{W}{4}$	$\frac{V}{3}$
<b>C</b>	$\frac{W}{4}$	$\frac{V}{4}$
<b>D</b>	$\frac{W}{16}$	$\frac{V}{3}$

(Total 1 mark)

**Q7.** An electron and a proton are  $1.0 \times 10^{-10}$  m apart. In the absence of any other charges, what is the electric potential energy of the electron?

- A  $+2.3 \times 10^{-18}$  J
- B  $-2.3 \times 10^{-18}$  J
- C  $+2.3 \times 10^{-8}$  J
- D  $-2.3 \times 10^{-8}$  J

(Total 1 mark)

**Q8.** A planet has a radius half of the Earth's radius and a mass a quarter of the Earth's mass. What is the approximate gravitational field strength on the surface of the planet?

- A  $1.6 \text{ N kg}^{-1}$
- B  $5.0 \text{ N kg}^{-1}$
- C  $10 \text{ N kg}^{-1}$
- D  $20 \text{ N kg}^{-1}$

(Total 1 mark)

**Q9.** A satellite of mass  $m$  travels in a circular orbit of radius  $r$  around a planet of mass  $M$ . Which one of the following expressions gives the angular speed of the satellite?

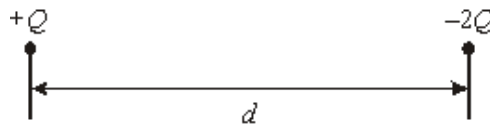
- A  $\sqrt{GMr}$
- B  $\sqrt{Gmr}$
- C  $\sqrt{\frac{Gm}{r^3}}$
- D  $\sqrt{\frac{GM}{r^3}}$

(Total 1 mark)

- Q10.** Two isolated point charges are separated by 0.04 m and attract each other with a force of  $20 \mu\text{N}$ . If the distance between them is increased by 0.04 m, what is the new force of attraction?
- A  $5 \mu\text{N}$
  - B  $10 \mu\text{N}$
  - C  $20 \mu\text{N}$
  - D  $40 \mu\text{N}$

(Total 1 mark)

**Q11.**



The diagram shows two particles at a distance  $d$  apart. One particle has charge  $+Q$  and the other  $-2Q$ . The two particles exert an electrostatic force of attraction,  $F$ , on each other. Each particle is then given an additional charge  $+Q$  and their separation is increased to a distance of  $2d$ . Which one of the following gives the force that now acts between the two particles?

- A an attractive force of  $\frac{F}{4}$
- B a repulsive force of  $\frac{F}{4}$
- C an attractive force of  $\frac{F}{2}$
- D a repulsive force of  $\frac{F}{2}$

(Total 1 mark)

- Q12.** Masses of  $M$  and  $2M$  exert a gravitational force  $F$  on each other when the distance between their centres is  $r$ . What is the gravitational force between masses of  $2M$  and  $4M$  when the distance between their centres is  $4r$ ?

- A  $0.25 F$
- B  $0.50 F$
- C  $0.75 F$
- D  $1.00 F$

(Total 1 mark)

**Q13.** The Earth has density  $\rho$  and radius  $R$ . The gravitational field strength at the surface is  $g$ . What is the gravitational field strength at the surface of a planet of density  $2\rho$  and radius  $2R$ ?

- A  $g$
- B  $2g$
- C  $4g$
- D  $16g$

(Total 1 mark)

**Q14.** A planet has a radius half the Earth's radius and a mass a quarter of the Earth's mass. What is the approximate gravitational field strength on the surface of the planet?

- A  $1.6 \text{ N kg}^{-1}$
- B  $5.0 \text{ N kg}^{-1}$
- C  $10 \text{ N kg}^{-1}$
- D  $20 \text{ N kg}^{-1}$

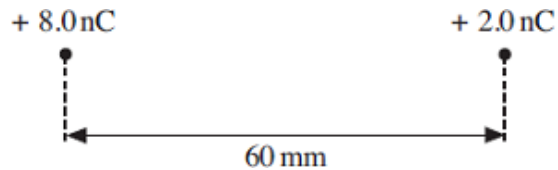
(Total 1 mark)

**Q15.** Two protons, each of mass  $m$  and charge  $e$ , are a distance  $d$  apart. Which one of the following expressions correctly gives the ratio  $\left(\frac{\text{electrostatic force}}{\text{gravitational force}}\right)$  for the forces acting between them?

- A  $\frac{4\pi\epsilon_0 e^2}{Gm^2}$
- B  $\frac{Ge^2}{4\pi\epsilon_0 m^2}$
- C  $\frac{e^2 m^2}{4\pi\epsilon_0 G}$
- D  $\frac{e^2}{4\pi\epsilon_0 Gm^2}$

(Total 1 mark)

**Q16.** The distance between two point charges of + 8.0 nC and + 2.0 nC is 60 mm.



At a point between the charges, on the line joining them, the resultant electric field strength is zero. How far is this point from the + 8.0 nC charge?

- A 20 mm
- B 25 mm
- C 40 mm
- D 45 mm

(Total 1 mark)

**Q17.** A repulsive force  $F$  acts between two positive point charges separated by a distance  $r$ . What will be the force between them if each charge is doubled and the distance between them is halved?

- A  $F$
- B  $2F$
- C  $4F$
- D  $16F$

(Total 1 mark)

**Q18.** Which one of the following statements about *electric field strength* and *electric potential* is **incorrect**?

- A Electric potential is a scalar quantity.
- B Electric field strength is a vector quantity.
- C Electric potential is zero whenever the electric field strength is zero.
- D The potential gradient is proportional to the electric field strength.

(Total 1 mark)

**Q19.** A satellite is in orbit at a height  $h$  above the surface of a planet of mass  $M$  and radius  $R$ . What is the velocity of the satellite?

A  $\sqrt{\frac{GM}{(R+h)}}$

B  $\sqrt{\frac{GM(R+h)}{R}}$

C  $\frac{\sqrt{GM(\sqrt{R+h})}}{R}$

D  $\frac{\sqrt{GM}}{(R+h)}$

(Total 1 mark)

**Q20.** The Earth has density  $\rho$  and radius  $R$ . The gravitational field strength at the surface is  $g$ . What is the gravitational field strength at the surface of a planet of density  $2\rho$  and radius  $2R$ ?

A  $g$

B  $2g$

C  $4g$

D  $16g$

(Total 1 mark)

**Q21.** The gravitational field strength on the surface of a planet orbiting a star is  $8.0 \text{ N kg}^{-1}$ . If the planet and star have a similar density but the diameter of the star is 100 times greater than the planet, what would be the gravitational field strength at the surface of the star?

A  $0.0008 \text{ N kg}^{-1}$

B  $0.08 \text{ N kg}^{-1}$

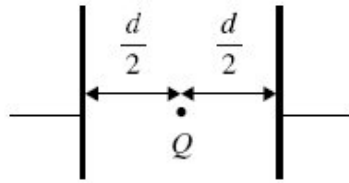
C  $800 \text{ N kg}^{-1}$

D  $8000 \text{ N kg}^{-1}$

(Total 1 mark)



- Q22.** Two parallel metal plates separated by a distance  $d$  have a potential difference  $V$  across them.  
What is the magnitude of the electrostatic force acting on a charge  $Q$  placed midway between the plates?



- A  $\frac{2VQ}{d}$
- B  $\frac{VQ}{d}$
- C  $\frac{VQ}{2d}$
- D  $\frac{Qd}{V}$

(Total 1 mark)

- Q23.** The gravitational potential at the surface of the Earth, of radius  $R$ , is  $V$ . What is the gravitational potential at a point at a height  $R$  above the Earth's surface?

- A  $\frac{V}{4}$
- B  $\frac{V}{2}$
- C  $V$
- D  $2V$

(Total 1 mark)

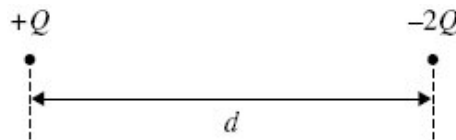
**Q24.** A spherical planet of uniform density  $\rho$  has radius  $R$ .

Which line, **A** to **D**, in the table gives correct expressions for the mass of the planet and the gravitational field strength at its surface?

	mass of planet	gravitational field strength at surface
<b>A</b>	$\frac{4\pi R^2 \rho}{3}$	$\frac{4\pi GR\rho}{3}$
<b>B</b>	$\frac{4\pi R^3 \rho}{3}$	$\frac{4\pi GR\rho}{3}$
<b>C</b>	$\frac{4\pi R^2 \rho}{3}$	$\frac{4\pi G\rho}{3}$
<b>D</b>	$\frac{4\pi R^3 \rho}{3}$	$\frac{4\pi G\rho}{3}$

(Total 1 mark)

**Q25.**

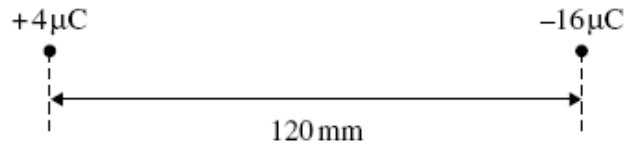


The diagram shows two particles at a distance  $d$  apart. One particle has charge  $+Q$  and the other  $-2Q$ . The two particles exert an electrostatic force of attraction,  $F$ , on each other. Each particle is then given an additional charge  $+Q$  and their separation is increased to a distance  $2d$ . Which one of the following gives the force that now acts between the two particles?

- A** an attractive force of  $\frac{F}{4}$
- B** a repulsive force of  $\frac{F}{4}$
- C** an attractive force of  $\frac{F}{2}$
- D** a repulsive force of  $\frac{F}{2}$

(Total 1 mark)

Q26.



The diagram shows two charges,  $+4\ \mu\text{C}$  and  $-16\ \mu\text{C}$ ,  $120\ \text{mm}$  apart. What is the distance from the  $+4\ \mu\text{C}$  charge to the point between the two charges where the resultant electric potential is zero?

- A  $24\ \text{mm}$
- B  $40\ \text{mm}$
- C  $80\ \text{mm}$
- D  $96\ \text{mm}$

(Total 1 mark)

Q27. The force between two point charges is  $F$  when they are separated by a distance  $r$ . If the separation is increased to  $3r$ , what is the force between the charges?

- A  $\frac{F}{3r}$
- B  $\frac{F}{9r}$
- C  $\frac{F}{3}$
- D  $\frac{F}{9}$

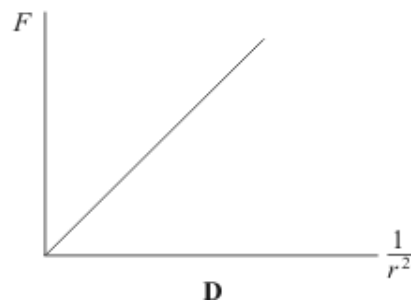
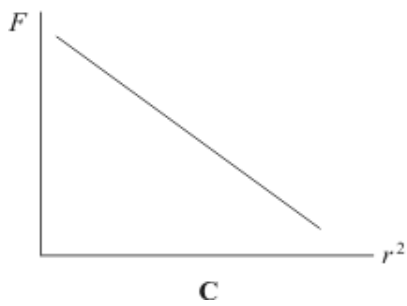
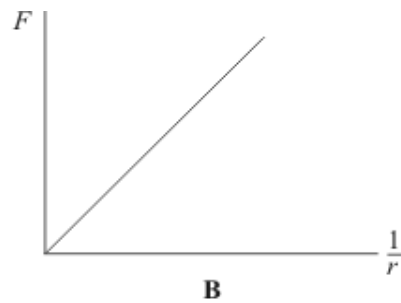
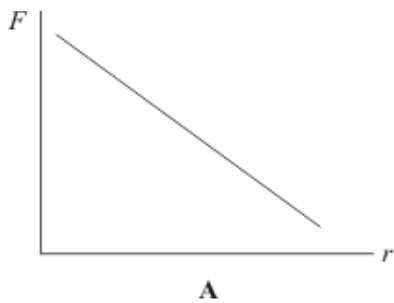
(Total 1 mark)

**Q28.** Two identical spheres exert a gravitational force  $F$  on each other. What is the gravitational force between two spheres, each twice the mass of one of the original spheres, when the separation of their centres is twice the original separation?

- A  $F$
- B  $2F$
- C  $4F$
- D  $8F$

(Total 1 mark)

**Q29.** Which one of the following graphs correctly shows the relationship between the gravitational force,  $F$ , between two masses and their separation  $r$ .



(Total 1 mark)

**Q30.** Two satellites, P and Q, of the same mass, are in circular orbits around the Earth. The radius of the orbit of Q is three times that of P. Which one of the following statements is correct?

- A The kinetic energy of P is greater than that of Q.
- B The weight of P is three times that of Q.
- C The time period of P is greater than that of Q.
- D The speed of P is three times that of Q.

(Total 1 mark)

**Q31.** An object on the surface of a planet of radius  $R$  and mass  $M$  has weight  $W$ . What would be the weight of the same object when on the surface of a planet of radius  $2R$  and mass  $2M$ ?

- A  $\frac{W}{4}$
- B  $\frac{W}{2}$
- C  $W$
- D  $2W$

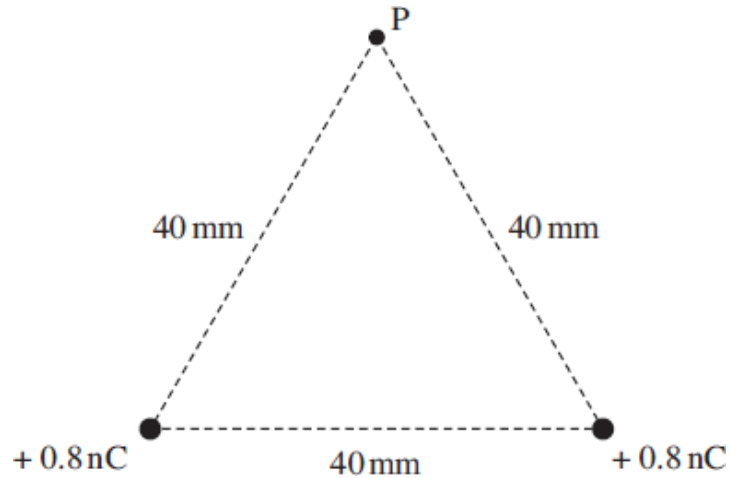
(Total 1 mark)

**Q32.** Two protons are  $1.0 \times 10^{-14}$  m apart. Approximately how many times is the electrostatic force between them greater than the gravitational force between them? (Use the Data and Formulae booklet)

- A  $10^{23}$
- B  $10^{30}$
- C  $10^{36}$
- D  $10^{42}$

(Total 1 mark)

- Q33.** Two charges, each of  $+0.8 \text{ nC}$ , are  $40 \text{ mm}$  apart. Point P is  $40 \text{ mm}$  from each of the charges.



What is the electric potential at P?

- A zero
- B  $180 \text{ V}$
- C  $360 \text{ V}$
- D  $4500 \text{ V}$

(Total 1 mark)

- Q34.** The repulsive force between two small negative charges separated by a distance  $r$  is  $F$ .

What is the force between the charges when the separation is reduced to  $\frac{r}{3}$ ?

- A  $\frac{F}{9}$
- B  $\frac{F}{3}$
- C  $3F$
- D  $9F$

(Total 1 mark)

**Q35.** The repulsive force between two small negative charges separated by a distance  $r$  is  $F$ .

What is the force between the charges when the separation is reduced to  $\frac{r}{3}$ ?

- A  $\frac{F}{9}$
- B  $\frac{F}{3}$
- C  $3F$
- D  $9F$

**(Total 1 mark)**

**M1.** C [1]

**M2.** D [1]

**M3.** A [1]

**M4.** D [1]

**M5.** C [1]

**M6.** A [1]

**M7.** B [1]

**M8.** C [1]



<b>M9.</b>	D	[1]
<b>M10.</b>	A	[1]
<b>M11.</b>	A	[1]
<b>M12.</b>	A	[1]
<b>M13.</b>	C	[1]
<b>M14.</b>	C	[1]
<b>M15.</b>	D	[1]
<b>M16.</b>	C	[1]

<b>M17.</b>	D	[1]
<b>M18.</b>	C	[1]
<b>M19.</b>	A	[1]
<b>M20.</b>	C	[1]
<b>M21.</b>	C	[1]
<b>M22.</b>	B	[1]
<b>M23.</b>	B	[1]
<b>M24.</b>	B	[1]
<b>M25.</b>	A	[1]

<b>M26.</b>	A	[1]
<b>M27.</b>	D	[1]
<b>M28.</b>	A	[1]
<b>M29.</b>	D	[1]
<b>M30.</b>	A	[1]
<b>M31.</b>	B	[1]
<b>M32.</b>	C	[1]
<b>M33.</b>	C	[1]
<b>M34.</b>	D	[1]

**M35.** D

[1]

- E1.** Gravitation was the subject being tested in this question, on the inverse square law, which had a facility of 61% but did not discriminate as well as it had when used in a previous AS level examination.
- E2.** This question demanded an understanding of the inverse square aspect of Coulomb's law. It showed that many candidates do not understand proportion when the relationship is not direct. 49% selected the correct response, but over 25% settled for distractor B ( $F/9r$ ) instead of D ( $F/9$ ).
- E3.** An unfortunate printing error, for which AQA apologises, meant that an erratum notice had to be issued for this question. This corrected the charge on Q from  $+6\mu\text{C}$  to  $-6\mu\text{C}$ . In the main, the candidates showed a good understanding of electric potential, causing the question to have a facility of 75%. With a 40:60 division of the 100 mm separation, it is not surprising that the most common wrong response was distractor D (60 mm) when the correct one was A (40 mm). This question was the weakest discriminator on this paper.
- E5.** This question, with a facility of 66%, examined the variations of electric field strength and electric potential with distance in a radial field. Distractor D was hardly ever chosen, with wrong answers divided mainly between distractors A and B.
- E6.** This question continued the theme of gravitation. At first sight, it should be easy. In fact it was the most demanding question in the test, with a facility of only 33%. Marginally more candidates chose the incorrect distractor D than the correct answer. This was a fairly simple test of inverse square proportion for force and inverse proportion for potential. Candidates made matters difficult by confusing the distance from an external point to the centre of the Earth with the distance to the surface of the Earth.
- E7.** Failure to realise that a negatively charged electron has an associated negative value of electric potential caused many candidates to go wrong in this question. As in gravitation, the force between an electron and a proton is attractive and so the potential is negative. 40% of the candidates made the correct selection, B. 26% selected distractor A; the only difference between A and B is the  $-$  sign in B.

- E8.** The gravitational field strength at the surface of a planet and its relation with radius and mass was the subject tested by this question. 61% of the candidates selected the correct response, a 10% improvement over the pre-test facility. Distractor B, the most common wrong response, was chosen by just over one in five of the candidates.
- E9.** This question, with a facility of 71%, required the angular speed of a satellite in circular orbit to be found and appeared to cause little difficulty.
- E11.** This question had a facility of 58%. It was a slightly more demanding type of question on Coulomb's law, where both the charges and separation of two point charges are altered. The 30% who chose distractor C are likely to have misunderstood the law of force by using inverse proportion instead of inverse square proportion.
- E12.** This was a fairly demanding calculation on the inverse square law of gravitation, in which candidates had to consider the effect of changing both the size of the attracting masses and their separation. Just over half reached the correct conclusion. No doubt it was errors in rearranging the arithmetic and/or algebra that caused 34% of candidates to opt for distractor B, where the new force was double what it ought to be.
- E14.** This question, on the gravitational field strength at the surface of a planet, made similar mathematical demands to the previous question but was answered more successfully. The facility was 72%, an improvement of over 10% on the result when this question last appeared in an examination. The question was also an effective discriminator.
- E15.** This question raised similar demands to the previous question, in that they required more than one concept to be combined to give an algebraic result. In this question, electrostatic and gravitational forces had to be considered together. The facility was 64%, and this question was the best discriminator in the test. Over one-fifth of the responses were for distractor A, which has  $(4\pi \epsilon_0)$  in the numerator instead of the denominator of the required expression.
- E16.** This question was also on electrostatics but, with a facility of 48%, was much more demanding. At first sight it appears necessary to solve a quadratic equation to answer the question, but this difficulty can be overcome by taking the square root of the expression obtained. Incorrect distractor D was chosen by 35% of the students and consequently the discrimination of the question was poor.

- E17.** This question was a fairly direct test of Coulomb's law for charges under changing circumstances; 70% of the students had the correct answer.
- E18.** This question on electrostatics, was concerned with field strength and potential. This was the worst discriminator in the test, and only 43% of candidates selected the correct response. A principal reason for as many as 24% of them choosing distractor A (potential is a scalar) must be that they had failed to notice that the question asked for the *incorrect* statement.
- E19.** This question three quarters of the students were successful when dealing with the algebra giving the velocity motion of a satellite in stable orbit of radius  $(R + h)$ . This question had appeared in a 2002 examination, when the students found it marginally harder and it was slightly less discriminating.
- E20.** The candidates found this question, with a facility of 41%, to be the most demanding on the test. The pre-test facility of this question had been rather higher. Candidates continue to have difficulty with algebraic questions such as this, which require two separate quantities (here field strength and density) to be combined. Practically half of the responses were divided almost equally between incorrect distractors A and B.
- E21.** This question which tested how  $g$  is connected to the diameter for two stars of similar density, was the most demanding question on the test – its facility was only 39%. Equating  $mg$  with  $GMm / R^2$  and then substituting  $(4/3) \pi R^3 \rho$  for  $M$  ought to have shown that  $g$  is proportional to the product  $R\rho$ . Consequently, if  $\rho$  is taken to be the same,  $g \propto R$ . Yet 33% of the students suggested that  $g$  would be 100 times smaller (distractor A), and not 100 times bigger, when the diameter was 100 times larger.
- E22.** This question required candidates to apply  $F = EQ$  in a charged parallel plate situation. 58% of them appreciated that the separation of the plates was  $d$  and that the field strength  $E$  would be  $V/d$ . However, 29% chose distractor A, for which the field strength must have been interpreted as  $V \div (d/2)$ .
- E23.** Appreciation that gravitational potential  $V$  is proportional to  $1/r$  was all that was required to arrive at the correct response in this question which had a facility of 71%. The most common incorrect choice was distractor A, where the students may have thought  $V$  is proportional to  $1/r^2$ .

- E24.** The algebra required to relate the density of a planet to its mass and gravitational field strength in this question did not prove to be an obstacle to most students because 79% of them gave the correct combination from the table.
- E25.** Coulomb's law had to be applied in this question. 66% of the candidates realised that doubling the separation would have the effect of reducing the force by a factor of four, whilst the changes to the charges would mean that they would become  $+2Q$  and  $-Q$ , so that the force would remain one of attraction. Distractor C was selected by 22% of candidates; this could be because they thought that  $F \propto 1/r$  instead of  $F \propto 1/r^2$ .
- E26.** This question required candidates to appreciate that, for the total potential to be zero at the chosen point, the magnitude of  $V$  due to the  $+4 \mu\text{C}$  charge should be the same as the magnitude of  $V$  due to the  $-16 \mu\text{C}$  charge. This required  $(Q/r)$  to be the same and should give a distance ratio of 1:4. 58% of the candidates were able to work this out correctly, which is 5% lower than when this question was last used in an examination. Almost one in four of the candidates chose distractor B, suggesting that the distance ratio would be 1:2. This question was the worst discriminator in this examination.
- E27.** This question moved on to electric fields. Question 15, a direct algebraic test of Coulomb's law, had appeared in a previous examination. The 2012 students dealt with it much better than their predecessors, causing the facility to increase from 49% to 80%.
- E28.** This question was about gravitational forces. Application of the inverse square law was completed successfully by 70% of the candidates in the former question.
- E29.** This question was a graphical test of inverse proportionality, as represented by the universal law of gravitation. The facility of the question was 65%, but one quarter of the candidates were tempted into choosing distractor C.
- E30.** This question with a facility of 41%, was also demanding. Here several factors - kinetic energy, weight, time period and speed - had to be considered for two satellites in different circular orbits. The three incorrect answers had a fairly even distribution of responses.



- E31.** This question which had a facility of 70%, was an algebraic test of the relationship between the weight of an object at the surface of a planet and the mass and radius of that planet. This question discriminated well and had no particularly strong distractor.
- E32.** Another reused question combined Coulomb's law with Newton's law of gravitation and needed candidates to take data from the *Data and Formulae Booklet*. The incorrect responses were distributed fairly evenly across the three remaining distractors.
- E33.** This question required students to understand that electric potential is a scalar, and that the potential at a point close to two charges is therefore the sum of the potentials due to each of them. This was understood by fewer than half of the candidates, and so the facility of the question was only 45%. Almost a third of responses were for distractor A (zero) and almost a fifth for distractor B (the potential due to one charge alone).
- E34.** Almost three quarters of the candidates chose the correct answer in this question, which was a fairly direct test of Coulomb's inverse square law.
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