T10 *[186 marks]*

1. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

2. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

3. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

4. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

5. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

6. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

7. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

8a. *[2 marks]*

Markscheme

total momentum does not change/is constant; } *(do not allow "momentum is conserved")*
provided external force is zero / no external forces / isolated system;

Examiners report

[N/A]

8b. *[4 marks]*

Markscheme

impulse is the same/similar in both cases / momentum change is same;
impulse is force × time / force is rate of change of momentum;
time to come to rest is longer for car B;
force experienced by car B is less (so less likely to be damaged);

Examiners report

[N/A]

8c. *[2 marks]*

Markscheme

electric force per unit charge;
acting on a small/point positive (test) charge;

Examiners report

[N/A]

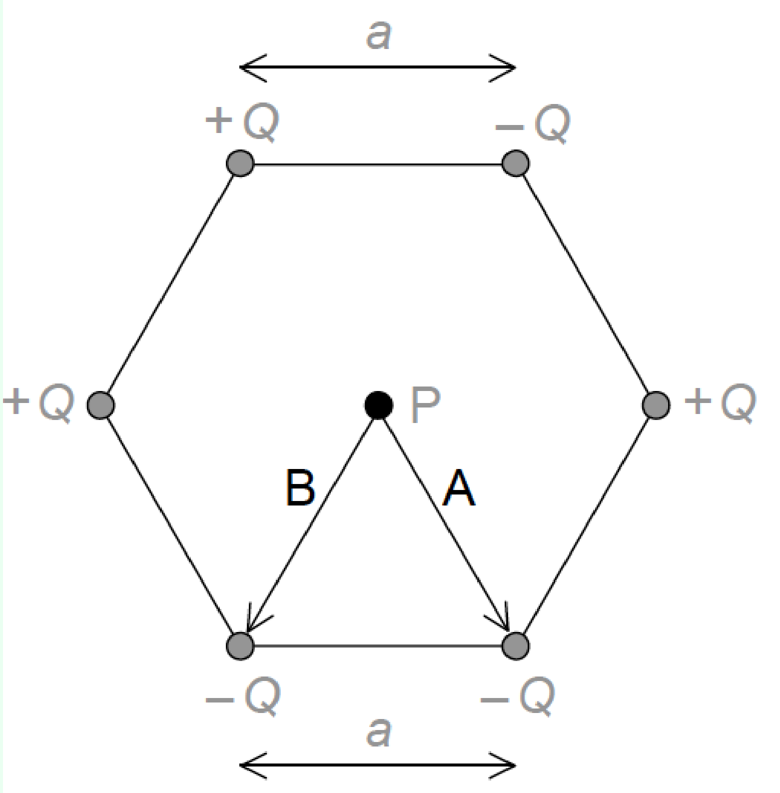
8d. *[8 marks]*

Markscheme

(i) states Coulomb's law as $\frac{kQq}{r^2}$ ***or*** $\frac{F}{q} = \frac{kQ}{r^2}$

states explicitly q=1;

states r=a;

(ii) 

arrow labelled A pointing to lower right charge;

arrow labelled B point to lower left charge;

Arrows can be anywhere on diagram.

(iii) overall force is due to +Q top left and -Q bottom right / top right and bottom left and centre charges all cancel; }

(can be seen on diagram)

force is therefore $\frac{2kQ}{a^2}$;

2.6×106 (N C^{-1}) ;

towards bottom right charge; *(allow clear arrow on diagram showing direction)*

Examiners report

[N/A]

9a. *[2 marks]*

Markscheme

gravitational potential energy is being gained;

this is at the expense of kinetic energy (and speed falls);

Examiners report

[N/A]

9b. *[2 marks]*

Markscheme

$\left(\text{acceleration} = \frac{(v-u)}{t} = \frac{4.25\times10^3 - 4.38\times10^3}{60} = \right) (-)\,2.17\,(\text{ms}^{-2})$;

gravitational field strength = acceleration of rocket (=2.17 N kg^{-1}); } *(allow g = a in symbols)*

or

computes potential difference from KE per unit mass change (5.61 $\times 10^5$),
computes distance travelled (0.259 Mm), uses $g = \frac{(-)\Delta V}{\Delta r}$;
g=($-$)2.17(ms^{-2});

Examiners report

[N/A]

9c. *[1 mark]*

Markscheme

the satellite has velocity/kinetic energy as it is orbiting with the space station;

Examiners report

[N/A]

10. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

11. *[1 mark]*

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.

12. *[1 mark]*

Markscheme

C

Examiners report

This is another case where candidates are required to learn a definition and identify it accurately.

13. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

14. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

15. *[1 mark]*

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.

16a. *[2 marks]*

Markscheme

power/energy per second emitted is proportional to surface area;
and proportional to fourth power of absolute temperature / temperature in K;
Accept equation with symbols defined.

Examiners report

The Stefan-Boltzmann law was poorly understood with few candidates stating that the absolute temperature is raised to the fourth power.

16b. *[2 marks]*

Markscheme

solar power given by $4\pi R^2\sigma T^4$;
spreads out over sphere of surface area $4\pi d^2$;
Hence equation given.

Examiners report

This question was poorly done with few candidates substituting the surface area of the sun or the surface area of a sphere at the Earth's radius of orbit.

16c. *[2 marks]*

Markscheme

$\left(\frac{\sigma R^2 T^4}{d^2}=\right)\frac{5.7\times10^{-8}\times\left[7.0\times10^{8}\right]^2\times\left[5.8\times10^{3}\right]^4}{\left[1.5\times10^{11}\right]^2}$;

=1.4×10^3(Wm^{-2});

*Award **[2]** for a bald correct answer.*

Examiners report

Despite not being able to state or manipulate the Stefan-Boltzmann law most candidates could substitute values into the expression and calculate a result.

16d. *[2 marks]*

Markscheme

some energy reflected;
some energy absorbed/scattered by atmosphere;
depends on latitude;
depends on time of day;
depends on time of year;
depends on weather (*eg* cloud cover) at location;
power output of Sun varies;
Earth-Sun distance varies;

Examiners report

This question was well answered at higher level.

16e. *[2 marks]*

Markscheme

power radiated=power absorbed;

$T=\sqrt[4]{\frac{240}{5.7\times10^{-8}}}\ (=250\mathrm{K})$;

Accept answers given as 260 (K).

Examiners report

To show the given value there is the requirement for an explanation of why the incident power absorbed by the Earth's surface is equal to the power radiated by the Earth, few candidates were successful in this aspect. Although most could substitute into the Stefan-Boltzmann equation they needed to either show that the fourth root was used or to find the temperature to more significant figures than the value given.

16f. *[3 marks]*

Markscheme

radiation from Sun is re-emitted from Earth at longer wavelengths;
greenhouse gases in the atmosphere absorb some of this energy;
and radiate some of it back to the surface of the Earth;

Examiners report

A surprising number of candidates could not explain the greenhouse effect. A common misunderstanding was that the Earth reflected radiation into the atmosphere and that the atmosphere reflected the radiation back to the Earth.

16g. *[4 marks]*

Markscheme

(i) gravitational force / gravitational attraction / weight; *(do not accept gravity)*

(ii) astronauts and spaceship have the same acceleration;
acceleration is towards (centre of) planet;
so no reaction force between astronauts and spaceship;

or

astronauts and spaceships are both falling towards the (centre of the) planet;
at the same rate;
so no reaction force between astronauts and spaceship;

Examiners report

(i) Most were able to state gravitational force, however a significant number stated gravity and consequently did not get the mark.

(ii) Many answers only discussed the astronauts and not the spaceship, missing points such as 'falling at the same rate' or 'with the same acceleration'.

16h. *[2 marks]*

Markscheme

gravitational force equated with centripetal force / $\frac{GmM}{r^2} = \frac{mv^2}{r}$;

$\Rightarrow v^2 = \frac{GM}{r} \Rightarrow \left(v = \sqrt{\frac{GM}{r}}\right)$;

Examiners report

This was well answered with candidates able to adequately show in their explanation where the expression comes from.

16i. *[4 marks]*

Markscheme

(i) thermal energy is lost;
total energy decreases;

(ii) since *E* decreases, *r* also decreases;
as *r* decreases *v* increases / E_k increases so *v* increases;

Examiners report

ji) Most appreciated that the effect of the force would be to decrease the total energy.

jii) Very few appreciated that they should use the equations above to answer this part of the question. As a consequence, the most common answer discussed a decrease in kinetic energy and a decrease in speed.

17. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

18. *[1 mark]*

Markscheme

D

Examiners report

The statistics suggest that many candidates were confused by this question. Field lines have to start and finish on a charge which means that only A and B could be correct if only two point charges are present. But the field lines will be in the same direction on leaving a charge, hence D is the only sensible solution.

19. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

20. *[1 mark]*

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 $4r$.

21. *[1 mark]*

Markscheme

D

Examiners report

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

22. *[1 mark]*

Markscheme

C

Examiners report

This questions proved to be somewhat difficult, especially for SL candidates. A number of different approaches could be used here, such as looking at the dimensions of the fundamental units, or by considering the cause and effect of increasing each one of the variable.

23. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

24. *[1 mark]*

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.

25. *[1 mark]*

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.

26. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

27a. *[3 marks]*

Markscheme

work done per unit mass;
in bringing (test) mass from infinity to point;
reference to small/point (test) mass;

Examiners report

[N/A]

27b. *[6 marks]*

Markscheme

(i) tangent construction attempted at $R=4.0\times10^8$ m;
triangle/pair of coordinates used in calculation;
attempt to calculate gradient;
2.5×10^{-3} ms^{-2}; *(accept answers in the range of 2.2 to 2.7)*
Award ***[1 max]*** *for*
$\frac{V}{R}$ *to give (–)2.1×10*$^{-3}$.

(ii) change in $V=0.45\times10^6$-0.50×10^6 Jkg^{-1};
change in PE = $(0.5\times10^6\times7.4\times10^{22}=)3.3$-$3.7\times10^{28}$ J;

Examiners report

[N/A]

27c. *[1 mark]*

Markscheme

work is done against the gravitational field of Earth / Moon is now closer to infinity/further from Earth / $\frac{-GMm}{R}$ means that as R increases potential increases/becomes less negative;

Examiners report

[N/A]

28. *[1 mark]*

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.

29. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

30. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

31.

[1 mark]

Markscheme

D

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.

32a.

[2 marks]

Markscheme

force per unit charge;

on a positive test charge / on a positive small charge;

Examiners report

(i) As this is worth two marks, candidates should see the signal that force per unit charge is unlikely to gain full marks; and so it proved. Although a mark was available for saying this there needed to be a reference to the charge being a positive test charge.

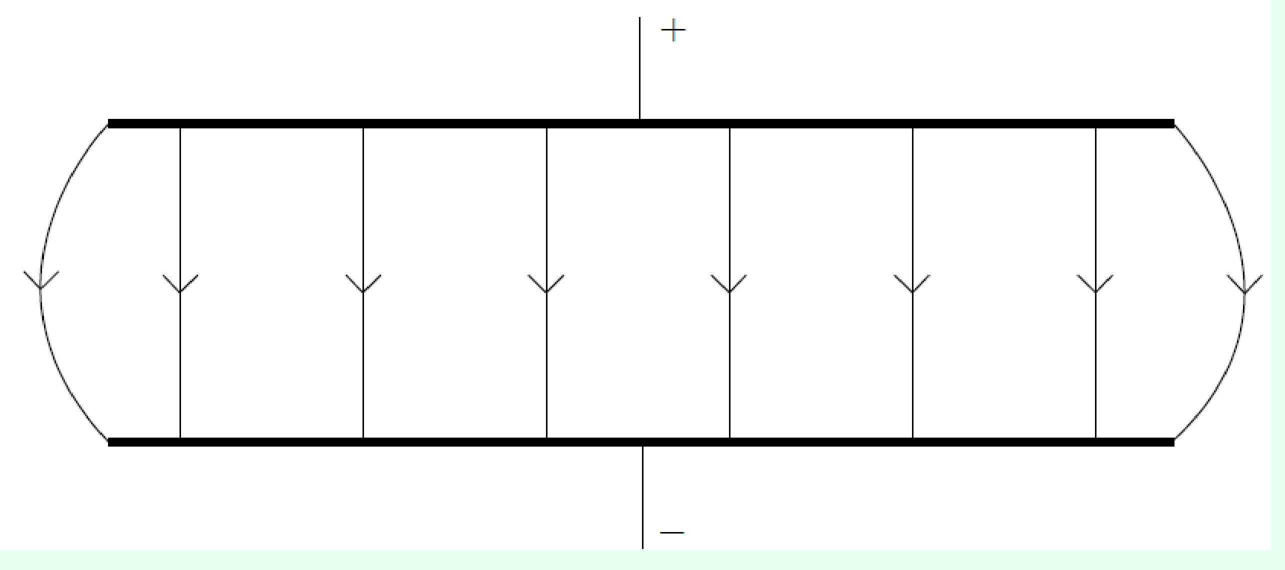
32b.

[5 marks]

Markscheme

(i) top plate positive and bottom negative (or +/- and ground);

(ii)



uniform (by eye) line spacing and edge effect, field lines touching both plates;

downward arrows (minimum of one and none upward);

(iii) $F=2.5\times10^{3}\times1.6\times10^{-19}$
4.0×10^{-16} (N);

*Award **[2]** for a bald correct answer.*

Examiners report

(i) G2 comments that the term ‘polarity’ was confusing to candidates proved to be unfounded and nearly all candidates marked in a positive and negative terminal – although the actual polarity was often incorrect.

(ii) With error carried forwards, the direction of the field was often correct but the drawing often was below an acceptable standard with line of force not bridging the plates, being very unevenly spaced and having no edge effect.

(iii) This calculation was almost invariably very well done.

32c. *[8 marks]*

Markscheme

(i) use of $F = \frac{(1.60\times10^{-19})^2}{4\pi\varepsilon_0(5.0\times10^{-3})^2}$ ***or*** $F = \frac{(1.60\times10^{-19})^2}{(5.0\times10^{-3})^2} \times 8.99 \times 10^9$;

9.2×10^{-24}(N);

(ii) 1.0×10^7 (ms^{-2}) (9.9×10^6 (ms^{-2}) if 9×10^{-24} (N) used);

(iii) electron will continue to accelerate;
speed increases with acceleration;
acceleration reduces with separation;
when outside the field no further acceleration/constant speed;
any reference to accelerated charge radiating and losing (kinetic) energy;

(iv) minimum of two concentric circles centred on Y;
anti-clockwise;

Examiners report

(i) In another ‘show that’ question it was expected that candidates would use Coulombs law and the data value for the electronic charge to give a value of more than one digit; often this was not the case but otherwise this was generally well done

(ii) Most candidates used their value for the force (or 9 x 10-24 N) and the mass of the electron on the data sheet to calculate a correct value for the acceleration.

(iii) This was an unusual opportunity for candidates to use Newton’s laws and many did say that the acceleration would decrease with distance. Too often they incorrectly believed that this meant that the electron would slow down – it continues to accelerate but at an ever decreasing rate.

(iv) Clearly, this part represented a simplification of a complex situation but as set up was not beyond the skills of most of the candidates. The electron represents an instant in which a conventional current would leave the page and the field at this instant would be that of concentric circles with an anti-clockwise (counter-clockwise) direction. Many candidates did draw this but diagrams were too frequently hurriedly drawn and of a poor standard.

33. *[1 mark]*

Markscheme

C

Examiners report

B was the most popular choice despite it clearly representing a force, rather than field strength. The field strength at a point is the acceleration of a mass placed at the point, so clearly C is the correct response.

34. *[1 mark]*

Markscheme

B

Examiners report

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

35.

[1 mark]

Markscheme

D

Examiners report

36.

[1 mark]

Markscheme

D

Examiners report

The majority of candidates chose option A that states that the electric field is the same everywhere in between the plates. The examining team felt that this deserved credit and so this option along with option D (field being weaker at the edges) were both accepted.

37.

[1 mark]

Markscheme

C

Examiners report

[N/A]

38a.

[2 marks]

Markscheme

the (attractive) force between two (point) masses is directly proportional to the product of the masses;
and inversely proportional to the square of the distance (between their centres of mass);
Use of equation is acceptable:
*Award **[2]** if all five quantities defined. Award **[1]** if four quantities defined.*

Examiners report

(a) Many candidates stated that the Newton's law force is proportional to the masses of the objects in question, rather than the product of the masses.

38b. *[3 marks]*

Markscheme

$G\frac{Mm}{R^2} = \frac{mv^2}{R}$ so $v^2 = \frac{Gm}{R}$;
$v = \frac{2\pi R}{T}$;
$v^2 = \frac{4\pi^2 R^2}{T^2} = \frac{Gm}{R}$;

or

$G\frac{Mm}{R^2} = m\omega^2 R$;
$\omega^2 = \frac{4\pi^2}{T^2}$;
$\frac{4\pi^2}{T^2} = \frac{GM}{R^3}$;
Award ***[3]*** *to a clear response with a missing step.*

Examiners report

This part was generally well done with most candidates coming to the correct outcome; too often steps were missed out in the derivations and this cost candidates mark. It is essential that they realise that a derivation must include every step. The presentation of this part left much to be desired in quite a large minority with mathematically incorrect statements being given.

38c. *[8 marks]*

Markscheme

(i) $R^3 = \frac{6.67\times10^{-11}\times5.97\times10^{24}\times6000^2}{4\times\pi^2}$;
R=7.13x10^6(m);
h=(7.13x10^6-6.37x10^6)=760(km);
Award ***[3]*** *for an answer of 740 with π taken as 3.14.*

(ii) clear use of $\Delta V = \frac{\Delta E}{m}$ and $V = -\frac{Gm}{r}$ **or** $\Delta E = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$;
one value of potential energy calculated (2.37×10^9 ***or*** 2.02×10^9);
3.5×10^8 (J);
Award ***[3]*** *for a bald correct answer.*
Award ***[2]*** *for 7.7x10^9. Award* ***[1]*** *for 7.7x10^{12}.*
Award ***[0]*** *for answers using mgΔh.*

(iii) increased;
further from Earth / closer to infinity / smaller negative value;
Award ***[0]*** *for a bald correct answer.*

Examiners report

(i) Most candidates were able to substitute values into the equation and rearrange it to find a value for R. Many then fail to subtract the radius of the Earth.

(ii) Very few candidates completed this part correctly. Confusion between potential and potential energy was common as were adding the height in kilometres to the radius of the Earth in metres. A sizeable minority of candidates attempted to use the mgh equation.

(iii) This part was quite well answered with most candidates realising that the increase in height meant an increase in potential energy. Several argued that the magnitude decreased but being a negative quantity this meant an increase.

39a. *[2 marks]*

Markscheme

the force between two (point) charges;
is inversely proportional to the square of their separation and (directly) proportional to (the product of) their magnitudes;

Allow ***[2]*** *for equation with F, Q and r defined.*

Examiners report

Many were able to state Coulomb's law or to give the equation with explanations of the symbols. Some candidates however failed to define their symbols and lost marks.

39b. *[7 marks]*

Markscheme

(i) $F = \left(k\frac{q_1 q_2}{r^2} =\right) \frac{9\times10^{9}\times\left[1.6\times10^{-19}\right]^{2}}{4\times10^{-20}}$;

$=5.8\times10^{-9}$(N);

*Award **[0]** for use of masses in place of charges.*

(ii) ($\frac{(b)(i)}{1.6\times10^{-19}}$ **or** 3.6×10^{10} (NC^{-1}) **or** (Vm^{-1});

(directed) away from the proton;

Allow ECF from (b)(i).

Do not penalize use of masses in both (b)(i) and (b)(ii) – allow ECF.

(iii) $H = \left(G\frac{m}{r^2} =\right) \frac{6.67\times10^{-11}\times1.673\times10^{-27}}{4\times10^{-20}} = 2.8 \times 10^{-18} \left(\mathrm{Nkg}^{-1}\right)$;

$\frac{H}{E} = \frac{2.8\times10^{-18}}{3.6\times10^{10}}$ **or** 7.8×10^{-29}(Ckg^{-1});

($\approx10^{28}Ckg^{-1}$)

Allow ECF from (b)(i).

(iv) 3.4(V);

Examiners report

(i) The electric force was calculated well by many.

(ii) The answer to (i) was well used to determine the magnitude of *E*. However, many candidates did not read the question and failed to state the direction of the field or gave it in an ambiguous way.

(iii) Calculations to show the order of magnitude of *H/E* were generally well done. The last step was often missing with the answer simply given as a fraction.

(iv) Many obtained this simple mark.

39c. *[6 marks]*

Markscheme

(i) power supplied per unit current / energy supplied per unit charge / work done per unit charge;

(ii) energy supplied per coulomb= $\frac{5.1\times10^{-19}}{1.6\times10^{-19}}$ ***or*** 3.19(V);
(≈3.2V)

(iii) pd across 5.0Ω resistor= $\left(\frac{4.0\times10^{-19}}{1.6\times10^{-19}}=\right)2.5\,(\mathrm{V})$;
pd across *r*=(3.2-2.5=)0.70(V);

and

either

current in circuit= $\left(\frac{2.5}{5.0}=\right)0.5\,(\mathrm{A})$;
resistance of *r*= $\left(\frac{0.70}{0.50}=\right)1.4\,(\Omega)$;

or

resistance of *r*= $\frac{0.70}{2.5}\times5.0$;
=1.4(Ω);

or

3.2=0.5(R+*r*);
resistance of *r*=1.4(Ω);
*Award **[4]** for alternative working leading to correct answer.*
*Award **[4]** for a bald correct answer.*

Examiners report

(i) Many candidates gave confused or incorrect definitions of the emf of a cell. Previous comments in this report on the memorizing of definitions apply. Too many had recourse to the next part and used this idea in their answer.

(ii) This was well done.

(iii) A large number of candidates completed this calculation stylishly, generally explaining steps (or at least writing down the algebra) in a logical way. There were many correct and original solutions that gained full marks.

40. *[1 mark]*

Markscheme

C

Examiners report

41. *[1 mark]*

Markscheme

A

Examiners report

42. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

43.

[1 mark]

Markscheme

B

Examiners report

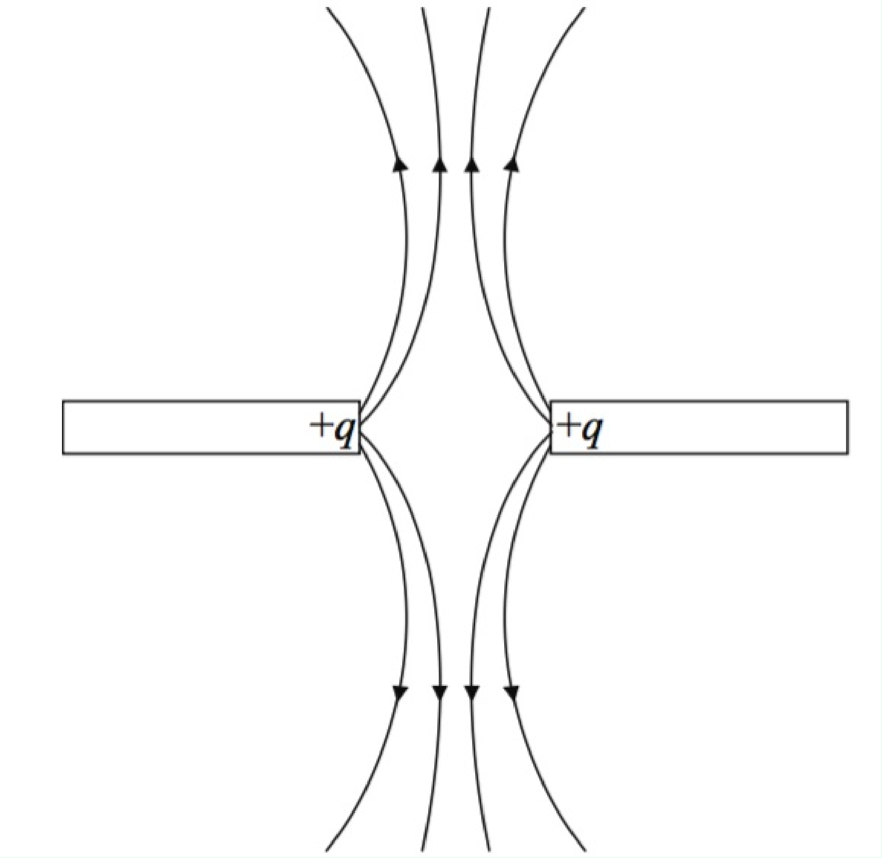
[N/A]

44.

[3 marks]

Markscheme

(i)



at least four field lines (minimum two per rod) to show overall shape of pattern; direction of lines all away from poles;
Ignore all working outside region.
Any field lines crossing loses first mark even if accidental.

(ii) any line labelled V perpendicular to the field lines it traverses; *(judge by eye)*
Ignore unlabelled lines as they could be field lines.

Examiners report

The shapes of possible equipotential surfaces were very poorly constructed. Candidates in their diagrams showed a poor understanding of the relationship.

45a. *[3 marks]*

Markscheme

$\frac{mv^2}{r} = \frac{GMm}{r^2}$;

$E_K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$;

$E_P = -\frac{GMm}{r}$ (hence magnitude of E_k=½ magnitude of E_P);

Examiners report

The deduction that the kinetic energy of a satellite is equal to half the magnitude of its potential energy was poorly shown by about half the candidates. The proof can begin with the equating of centripetal and gravitational forces for the satellite with a subsequent substitution into the kinetic energy equation, but many failed to remember this. Some got most of the way but failed to show the examiner the final step with the factor 1⁄2.

45b. *[6 marks]*

Markscheme

(i) total energy=(KE+PE=)$-\frac{Vm}{2}$;

$= \left(-\frac{4.0\times10^7\times8.2\times10^2}{2} =\right) - 1.6 \times 10^{10}\,\text{J}$;

(ii) $v=\sqrt{V}$; (or use of $E_k=½mv^2$)

$=6.3\times10^3\,\text{ms}^{-1}$;

(iii) total energy in new orbit=$\left(-\frac{2.0\times10^7\times8.2\times10^2}{2} =\right) - 0.82 \times 10^{10}\,(\text{J})$;

energy required=$(1.6\times10^{10}-0.82\times10^{10}=)7.8\times10^9$J;

or

total energy is proportional to E_P;

so energy required =−(b)(i)÷2=8 ***or*** 8.2×10^9J; *(allow ECF from (b)(i))*

Examiners report

(i) (ii) and (iii) This sequence of calculations of the total energy, the orbital speed and the energy change for the satellite was poor. This is standard work and candidates made little of it. The understanding of energy topics in gravitational fields was poorly demonstrated by the candidates throughout this question.

46a. *[3 marks]*

Markscheme

the work done per unit charge;

when a small/test/point positive charge; *(charge sign is essential)*

is moved from infinity to the point;

Examiners report

There were three marks for this question and most scored 1 or 2. The full definition of electric potential at a point was simply not well enough remembered. Many forgot that it is (i) the work done per unit charge on a (ii) positive (test) charge (iii) as the charge is moved from infinity to the point in question.

46b. *[6 marks]*

Markscheme

(i) perpendicular / at right angles / at 90° / normal;

(ii) $V = \frac{8.99\times10^{9}\times4.00\times10^{-6}}{2.78}$ ***or*** $1.2935 \times 10^{4}\mathrm{V}$; (*use of* $\frac{1}{4\pi\varepsilon_0}$ *gives 1.29378×10*^{4})
($\approx 1.29\times10^{4}$V)

(iii) difference in potential = ($7.20\times10^{4}-1.29\times10^{4}=$)$5.91\times10^{4}$;
required loss in kinetic energy/minimum kinetic energy to reach sphere = ($0.032\times10^{-6}\times5.91\times10^{4}=$)$1.89\times10^{-3}$J ;
available kinetic energy=($\frac{1}{2}\times1.20\times10^{-4}\times3.50^{2}=$)$7.35\times10^{-4}$J; not enough (initial) kinetic energy to reach sphere;
Response needs some statement of conclusion, e.g. so it does not reach sphere.
Allow answer in terms of minimum speed to reach sphere 5.61ms^{-1}.

Examiners report

(i) Most failed to read the question and did not realize that the question required the direction with respect to an equipotential surface. Most gave the direction relative to the diagram.
(ii) This was well done by a great many, however examiners did expect to see a full substitution, it was not acceptable to leave the permittivity of free space as a symbol in this "show that" question.
(iii) Even where candidates could negotiate a path through this testing question, solutions were seldom clear.

47a. *[2 marks]*

Markscheme

(minimum) speed of object to escape gravitational field of a planet/travel to infinity;
at surface of planet;
without (further) energy input;

Examiners report

[N/A]

47b. *[5 marks]*

Markscheme

(i) $-\frac{6.67\times10^{-11}\times3.5\times10^{21}}{8.0\times10^{5}}$;
-2.9×10^{5}Jkg^{-1}; *(allow Nmkg*$^{-1}$*)*
Award ***[1 max]*** *if negative sign omitted.*

(ii) $\frac{1}{2}mv^{2} = mV$;
speed== $\sqrt{2 \times 2.9 \times 10^{5}}$; *(allow ECF from (b)(i))*
7.6×10^{2}ms^{-1};
Ignore sign.
Award ***[3]*** *for a bald correct answer.*

Examiners report

[N/A]

47c. *[3 marks]*

Markscheme

time to hit surface $= \sqrt{\frac{2.0\times1.5}{0.37}}\ (= 2.85\mathrm{s})$;
distance to impact = 2.85×1.8;
5.1m;

Examiners report

[N/A]

48a.

[2 marks]

Markscheme

force is proportional to product of masses and inversely proportional to square of distance apart;
reference to point masses;

Examiners report

[N/A]

48b.

[3 marks]

Markscheme

(i) order of 1 cm;

(ii) $3\times10^{8}\times67\times10^{-3}$;
2.0×10^{7}m;

Examiners report

[N/A]

48c.

[8 marks]

Markscheme

(i) force required towards centre of Earth to maintain orbit;
force means that there is an acceleration / *OWTTE*;

or

direction changes;
a change in velocity therefore acceleration;

(ii) uses$=\frac{GM}{r^2}$ ***or*** $\frac{6.7\times10^{-11}\times6.0\times10^{24}}{\left[2.6\times10^{7}\right]^{2}}$;
0.57Nkg^{-1}; (allow ms^{-2})

(iii) $v=\sqrt{0.57\times\left(2.0\times10^{7}+6.4\times10^{6}\right)}$ by equating $\frac{v^2}{r}$ and g;
3900ms^{-1};

(iv) $T=2\pi\frac{2.6\times10^{7}}{3900}$;
11.9 hours;

Examiners report

[N/A]

49.

[1 mark]

Markscheme

B

Examiners report

[N/A]

50.

[1 mark]

Markscheme

C

Examiners report

[N/A]

51a.

[1 mark]

Markscheme

because the force is always at right angles to the velocity / motion/orbit is an equipotential surface;
Do not accept answers based on the displacement being zero for a full revolution.

Examiners report

[N/A]

51b.

[4 marks]

Markscheme

(i) equating gravitational force $\frac{GMm}{r^2}$;
to centripetal force $\frac{mv^2}{r}$ to get result;
(ii) kinetic energy is $\frac{GMm}{2r}$;
addition to potential energy $-\frac{GMm}{r}$ to get result;

Examiners report

[N/A]

51c.

[2 marks]

Markscheme

the total energy (at the new orbit) will be greater than before/is less negative;
hence probe engines must be fired to produce force in the direction of motion / positive work must be done (on the probe);
*Award **[1]** for mention of only potential energy increasing.*

Examiners report

[N/A]