**ANSWERS to Long Questions**

**M1.** (a) (i) Maximum **displacement** (of carriage/pendulum from rest position)

**(1)**

(ii) 6.0 (m)

**(1)**

(iii) Clear evidence of what constitutes period

4.8–4.9 (s)

**(2)**

(b) (i) Use of *v* = 2π*fA*

7.07 (ms–1)

**(2)**

(ii) Use of *a* = 4π2*f* 2*A*

11.1 (ms–2) ecf

**(2)**

(iii) Substitution into or rearrangement of *T* = 2π*√l/g*

3.98 (m)

**(2)**

(c) Applied frequency = natural frequency

Mention or clear description of resonance

**(2)**

(d) Resistive/frictional/damping/air resistance forces

due to friction in named place (eg in bearings)/air resistance acting on named part

(allow ride/gondola here)

low friction/large mass or inertia /streamline/smooth surface etc.

**(3)**

**[Total 15]**

**M2.** (a) amplitude (of bob) is small

[**or** (angular) amplitude is less than or = 10° ]

[**or** sin *θ* ≈ *θ* with *θ* explained ] ✔

***or*** *string is inextensible (or of negligible mass)*

***or*** *bob is a point mass*

*Ignore references to “air resistance”.*

**(1)**

(b) **The candidate’s writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate’s answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

**High Level (Good to excellent): 5 or 6 marks**

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

*The candidate describes the arrangement of the apparatus clearly. They identify correctly the measurements to be made, and indicate how these measurements would be made. They describe a valid method by which a straight line graph may be obtained and show how g would be calculated from their graph. They are also aware of precautions that should be taken during the experiment to ensure that the result is accurate.*

**Intermediate Level (Modest to adequate): 3 or 4 marks**

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

*The candidate is less clear about the experimental arrangement, gives a reasonable account of the measurements to be made and indicates a valid method by which a straight line graph may be obtained. They are less clear about how the result would be calculated from the graph, and they know the precautions less well.*

**Low Level (Poor to limited): 1 or 2 marks**

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

*The candidate gives a superficial account of the experimental arrangement, has some knowledge of the measurements to be made, but has only limited ability to show how a graphical method could be used to calculate the result. Some precautions may be known.*

**The description expected in a competent answer should include a coherent selection of the following points.**

* Diagram or description showing a bob suspended from a fixed point, on which the length *l* may be labelled correctly.
* Length *l* of pendulum measured by ruler from fixed point of support to centre of mass of bob.
* Period *T* measured by stopwatch, by timing a number of oscillations.
* Measurement of *T* repeated for the same *l* and a mean value of *T* calculated.
* Measurements repeated for at least five different values of *l*.
* Graph of *T*2 against *l* (or any other suitable linear graph) would be plotted.
* Graph is a straight line through origin, gradient is 4*π*2/g (or correct expression for g from their graph).

**Experimental measures such as the following are likely to be given:**

* Small amplitude oscillations.
* Measure *l* to centre of mass of bob.
* Measure *T* from a large number of oscillations.
* Repeat timing for each length.
* Begin counting oscillations at nought when *t* = 0.
* Measure complete oscillations.
* Use of fiducial mark at centre of oscillations.
* Pendulum should swing in a vertical plane.
* Avoid very small values of *l* when repeating the experiment.

**Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**

*A* ***high level*** *answer must include*

1. *a description of the apparatus,*
2. *a correct statement of the measurements to be made,*
3. *a correct graph plot,*
4. *a correct indication of how g would be found from the graph,*
5. *at least two precautions.*

*An* ***intermediate level*** *answer must include (at least)*

*1 and 2,* ***or*** *1 and 3,* ***or*** *2 and 3, above and at least one precaution.*

*A* ***low level*** *answer must include (at least) any one of 1,2,3,4 above.*

*An inappropriate, irrelevant or physically incorrect answer should be awarded* ***a mark of zero****.*

*If the experiment described relates to a* ***compound pendulum****, mark to max 2.*

*If a log graph is plotted and explained, it may gain credit.*

*If a correct graph is* ***not*** *used, then maximum mark awarded is 3.*

**(Max 6)**

(c) measured value of g will be 4× true value of g ✔

gradient of *T*2 against *l* graph will be ¼ of expected value [**or** reference to g ∞ 1/*T*2 or equivalent] ✔

(*T* is halved so) *T*2 is ¼ of true value ✔

*2nd and 3rd marks may be covered by an analysis of the period equation.*

**(3)**

**[Total 10]**

**M3.** (a) (i) toward B

**(1)**

(ii) 15 × 0.20 = 3 mm

**(1)**

(b) (i) period = 0.8 s

use of T = 2*π√L/g*

0.16 (0.159) m

**(3)**

(ii) lower initial displacement

lower inertia/more likely to begin moving as  
the Earth moves

no effect

period of a simple pendulum is independent of the  
mass of the bob/mass of bob is not in the formula  
for the period of a simple pendulum/period only  
depends on length (and *g*)

**(4)**

(c) (i) clearly states consistency of ratios of successive amplitudes as the test

one ratio of successive amplitudes correctly determined

two ratios correctly determined and conclusion

**(3)**

(ii) the oscillations are damped/air resistance mentioned/friction of pen against paper

energy is lost because of air resistance/work is done against air resistance/energy lost moving air out of the way/giving air kinetic energy

**(2)**

(iii) it will come to rest quicker

the bob loses a greater proportion of its energy during each oscillation

or pendulum has lower inertia so damping force has greater effect

or oscillating pendulum (initially) has less energy

or air resistance (initially) is unchanged

**(2)**

**[Total 16]**

**M4.** (a) (i) Tension minimum at extremities or maximum at middle / bottom

Tension depends on (component of) weight and required centripetal force / velocity

Increases as acrobat moves downwards

Tension at bottom = *mg* + *mv*2/*r* or Tension = weight + centripetal force

Tension at extremity = *mg/cosθ* (*θ* is angle between rope and vertical)

**(Max 3)**

(ii)     Use of *T* = 2*π*√(*l*/*g*)

3.6 (3.59) (m)

*Allow for change of subject for use*

**(2)**

(b) (i) Frequency of swing = 0.26 Hz

Use of *v* = 2*πfA*

3.0 or 2.97 (m s-1)

*alternative method*

*Change in pe = gain in ke*

*Calculating ∆h by geometry from swing = 0.48 m*

*3.1 or 3.06 (m s-1)*

**(3)**

(ii) Use of *s* = ½ *at*2

time to reach safety net = 1.11 s

*s* = their answer to **(b)(i)** × their time to reach the net = answer

(answer is 3.3 m if all correct)

*Allow for change of subject for use*

**(3)**

(c) (i) Attempt at valid test:

Fractional change in amplitude for same time interval

or use of ‘half life’ method

or use of exponential formula (*A = Aoe–kt*) to show that *k* is constant

Correct calculation for one pair of amplitudes

Correct for second pair and conclusion

*for half life method must see curve through peaks or other indication to find values between peaks*

**(3)**

(ii) Period shorter

Centre of mass of trapeze artist was lower than the bar

Effective length of the pendulum is lower

Bar likely to be low mass now have a pendulum with distributed mass / no longer a simple pendulum / centre of mass is half way along suspending rope

Calculates new effective length of the pendulum (2 m)

**(Max** **2)**

**[Total 16]**

**M5.** (a) (i) for one spring, change in force Δ*F* = *k*Δ*L* = 30 × 60 × 10–3

= 1.8 (N) 

resultant force (= [*F* + Δ*F*] – [*F* – Δ*F*]) = 2Δ*F* 🗸

(= 3.6 N)

**alternative** using answer from (b) (ii)

*a* = (2πf)2*x* = (2π × 1.38)2 × 60 × 10–3 = 4.51 (m s–2) 🗸

resultant force = *ma* = 0.80 × 4.51 (= 3.6 N)

**(2)**

(ii) acceleration *a* =  = 4.5(m s–2) 🗸

to the right 

**alternative** for first mark using answer from (b) (ii)

*a* = (2πf)2 *x* = (2π × 1.38)2 × 60 × 10–3 = 4.5 (m s–2) 🗸

**(2)**

(b) (i) acceleration is proportional to displacement (from equilibrium position) 🗸

acceleration is in opposite direction to displacement  
[**or** acceleration is towards a fixed point/equilibrium position] 🗸

**(2)**

(ii) 🗸 = (1.38 Hz)

period *T* = 0.73 (0.726) 🗸 [or 730]

s 🗸 [ms]

**(3)**

(c) (i) 1.0(1) x 1013 (Hz) 🗸

**(1)**

(ii) *v*max (= 2π *fA*) = 2π × 1013 × 10–11 = 630 (628) (m s–1) 🗸

**(1)**

(iii) max *E*K (= ½ *mv*max2) = ½ × 1.0 × 10–25 × 6282 = 2.0 × 10–20 (J) 🗸

[or using ½ *kA*2 approach]

**(1)**

**[Total 12]**

**M6.** (a) *forced vibrations:*

repeated upwards and downwards movement ✓  
vibrations at frequency of support rod ✓  
amplitude is small at high frequency **or** large at low frequency ✓  
correct reference to phase difference between displacements of driving and forced vibrations ✓

*Acceptable references to phase differences:*

*Forced vibrations − when frequency of driver » frequency of driven, displacements are out of phase by (almost) π radians or 180° (****or*** *½ a period)* ***or*** *when frequency of driver « frequency of driven, displacements are (almost) in phase. [Accept either].*

*[Condone >, < for », « ].*

*resonance:*

frequency of support rod **or** driver is equal to natural frequency of (mass-spring) system ✓  
large (or maximum) amplitude vibrations of mass ✓  
maximum energy transfer (rate) (from support rod to mass-spring system) ✓  
correct reference to phase difference between displacements of driving and driven vibrations at resonance ✓

*Resonance − displacement of driver leads on displacement of driven by π / 2 radians or 90°* ***or*** *¼ of a period (or driven lags on driver by π / 2 radians or 90°* ***or*** *¼ of a period).*

*[Condone phase difference is π / 2 radians or 90°].*

**(Max 4)**

(b) (i) cone oscillates without ring *(ticked) Only one box to be ticked.*

**(1)**

(ii) damping is caused by air resistance ✓  
area is the same whether loaded or not loaded ✓  
loaded cone has more kinetic energy **or** potential energy **or** momentum (at same amplitude) ✓  
smaller proportion (or fraction) of (condone less) energy removed per oscillation from loaded cone (or vice versa) ✓  
inertia of loaded cone is greater ✓

*Award marks for correct physics even when answer to (b)(i) is incorrect.*

**(Max 3)**

**[Total 8]**

**M7.** (a) (i) arrows to show *R* (or *N*) vertically up and *mg* (or *W*) vertically down and along the same line (within ± 2 mm) 🗸

**(1)**

(ii) *mg* – *R* = *R* = *mg* – 🗸 

**(1)**

(iii) **use** of *R* = *m* gives *R* = 12 (9.81 – ) 🗸

= 55 (54.6) (N) 🗸

**(2)**

(b) *R* decreases (as *v* increases) 🗸

because *mg* is unchanged but is larger 🗸

at higher speeds **R** becomes = 0 [**or** package is not in contact with the floor] 🗸

supported by calculation eg when *v* = 15 m s–1, *R* = 0.33 N (or ≈ 0) 🗸 **(Max 3)**

**[Total 7]**

**M8.** (a) (i) mass and energy have equivalent values

*E* = *mc*2 mentioned

MeV is energy unit (and kg that of mass)

**(Max 2)**

(ii) clear attempt to substitute amu values into equation

5.135 × 10–3 (u) or 4.78 (MeV) seen

mass of 1 lithium nucleus = 9.98 × 10–27 (kg)

total number of nuclei in 1 kg = 1.00 × 1026

total energy given out = 4.78 × 1026 MeV

**(5)**

(iii) neutrons needed (for the lithium reaction) can come from the other (deuterium-tritium) reaction

**(1)**

(b) (i) potential energy equation (*E* = ) quoted or used

correct substitutions

1.5(3) × 10–13 (J)

**3**

(ii) ke = 3/2 kT

0.75/0.765 × 10–13 (J) **or** half of (b) (i) or 4 × 109 (K) used

3.7 × 109 (K) **or** total energy 1.6 × 10–13 (J)

**3**

(iii) each nucleus carries a positive charge

(electrostatically) repel each other

strong nuclear force

this has a range of nucleus diameters

high temperature needed for high kinetic energy

**(Max 4)**

**[Total 18]**

**M9.** (a) (i) (Mass change in u=) 1.71× 10−3 (u)

**or** (mass Be−7) ‒ (mass He−3) ‒ (mass He−4) seen with numbers

2.84 × 10−30 (kg)  
**or** Converts their mass to kg

*Alternative 2nd mark:  
Allow conversion of 1.71 × 10−3 (u) to MeV by multiplying by 931 (=1.59 (MeV))* ***seen***

Substitution in E = mc2 *condone their mass difference in this sub but must have correct value for c2 (3×108)2 or 9×1016*

*Alternative 3rd mark:  
Allow their MeV converted to joules (× 1.6 × 10−13)* ***seen***

2.55 × 10−13 (J) to 2.6 × 10−13 (J)

*Alternative 4th mark:  
Allow 2.5 × 10−13 (J) for this method*

**(4)**

(ii) Use of *E=hc / λ* ***ecf***

Correct substitution in rearranged equation with *λ* *subject* ***ecf***

7.65 × 10−13 (m) to 7.8 × 10−13 (m) ecf

**(3)**

(b) (i) Use of Ep formula:

Correct charges for the nuclei **and** correct powers of 10

2.6(3) × 10−13 J

**(3)**

(ii) Uses K*E* = *kT:* ***or*** *halves KET, KE= 1.3 × 10−13 (J)* ***seen ecf***

Correct substitution of data **and** makes T subject   **ecf  
Or** uses KET value **and** divides T by 2

6.35 × 109 (K) or 6.4 × 109 (K) or 6.28 × 109(K) or 6.3 × 109 (K) **ecf**

**(3)**

(c) (i) Deuteron / deuterium / hydrogen−2

Triton / tritium / hydrogen−3

**(2)**

(ii) Electrical heating / electrical discharge / inducing a current in plasma / use of e−m radiation / using radio waves (causing charged particles to resonate)

**(1)**

**[Total 16]**

**M10.** (a) (i) neutron

**(1)**

(ii) p = 36

n = 144

**(2)**

1. (i) total energy produced = MJ each second

number of reaction = 4.2 × 1019 per second

**(2)**

(ii) 1 kg contains (1000/235) × 6.02 × 1023 atoms of uranium

total number of fissions = (1000/235) × 6.02 × 1023 × 2 × 104 (5.1 × 1028)

time = total fissions available/number per second or 1.2 × 109s, 38.7(39) years

**(4)**

(iii) too few neutrons produced to maintain the chain reaction

probability of a neutron colliding with a uranium nucleus too low

more absorption of neutrons in non–fission capture

**(2)**

(c) pressure = 150 × 105 (Pa) or *F = PA*

force on 1 cm 2 = 1500N

**(2)**

(d) energy removed each second   
*E* = MJ = 1.25 × 109 J or *E = mc∆θ*

1.25 × 109 = *m* 5000 × 40

mass per second = 6250 kg

volume per second = 8.6(8.56) m3

**(4)**

(e) **control rods**

neutrons are absorbed

by the nucleus of the boron/atoms

**moderator**

neutrons are slowed down

when colliding with the protons/hydrogen nucleus

**(4)**

**[Total 21]**

**M11.** (a) (i) Weight / *W / mg* − vertically downwards from some point on the body

Friction − vertically upwards and touching both the wall and the body

Centripetal force / normal reaction / R – horizontally to the left from the body

Each must be correct and correctly labelled

Minus one for each additional inappropriate force

**(3)**

(ii) Centripetal force / reaction / R is smaller

Frictional force reduces

Frictional force is less than weight

Resultant force is downward

Friction is proportional to (normal) reaction

**(2)**

(b) (i) *rω*2 = 29 or *v2 / r* = 29

Use of correct radius leading to 3.590 (rad s−1 ) to at least 3 sig figs

*2.54 using wrong r = 1 mark*

**(2)**

(ii) Angular acceleration, *α* = 3.6 / 20 OR 3.59 / 20 or 0.18 or 0.1795

3.8 (3.77, 3.78) × 104 cao

N m or kg m2 s−2

**(3)**

(iii) 2200 N cao

**(1)**

(c) (i) C

**(1)**

(ii) Speed greatest (as all PE turned to KE)

Total reaction force = *mrω2 + mg* or *v2 / r* + *mg* or *R* is largest or *R* = *ma* + *mg*OR  
Acceleration = *v*2 */ r*

**(2)**

**[Total 14]**

**M12.** (a) (i) elastic potential energy **and** gravitational potential energy ✓

*For elastic pe allow “pe due to tension”, or “strain energy” etc.*

**(1)**

(ii) elastic pe → kinetic energy → gravitational pe → kinetic energy → elastic pe ✓✓   
[**or** pe→ke→pe→ke→pe is ✓ only]   
[**or** elastic pe → kinetic energy → gravitational pe is ✓ only]

*If kinetic energy is not mentioned, no marks.*

*Types of potential energy must be identified for full credit.*

**(2)**

(b) (i) period = 0.80 s ✓   
during one oscillation there are two energy transfer cycles   
(or elastic pe→ke→gravitational pe→ke→elastic pe in 1 cycle)   
**or** there are two potential energy maxima per complete oscillation ✓

*Mark sequentially.*

**(2)**

(ii) sinusoidal curve of period 0.80 s ✓   
– cosine curve starting at *t* = 0 continuing to *t* = 1.2s ✓

*For 1st mark allow ECF from T value given in (i).*

**(2)**

(c) (i) use of *T* = gives 0.80 = ✓

∴ = 22 (21.6) ✓ N m–1 ✓

*Unit mark is independent: insist on N m–1.   
Allow ECF from wrong T value from (i): use of 0.40s gives 86.4 (N m–1).*

**(3)**

(ii) maximum ke = ( ½ *mv*max2) = 2.0 × 10–2 gives

*v*max2 = ✓ (= 0.114 m2s–2) and *v*max = 0.338 (m s–1) ✓

*v*max = 2*πfA* gives *A* = ✓

and *A* = 4.3(0) × 10–2 m ✓ i.e. about 40 mm

[**or** maximum ke = (½ *mv*max2) = ½ *m (*2*πfA*)2 ✓   
½ × 0.35 × 4*π*2 × 1.252 × *A*2 = 2.0 × 10–2 ✓

∴ *A*2 = ✓ ( = 1.85 × 10–3 )

and *A* = 4.3(0) × 10–2 m ✓ i.e. about 40 mm ]

[**or** maximum ke = maximum pe = 2.0 × 10–2 (J)   
maximum pe = ½ *k A2* ✓   
∴ 2.0 × 10–2 = ½ × 21.6 × *A*2 ✓   
from which *A*2 =  ✓ ( = 1.85 × 10–3 )   
and *A* = 4.3(0) × 10–2 m ✓ i.e. about 40 mm ]

*First two schemes include recognition that f = 1 / T i.e. f = 1 / 0.80 = 1.25 (Hz).*

*Allow ECF from wrong T value from (i) – 0.40sgives A = 2.15 × 10–2m but mark to max 3.*

*Allow ECF from wrong k value from (i) –86.4Nm–1 gives A = 2.15 × 10–2m but mark to max 3.*

**(4)**

**[Total 14]**

**M13.**(a) The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).

High Level − Good to Excellent  
An experiment with results and interpretation must be given leading to the measurement of absolute zero. The student refers to 5 or 6 points given below. However each individual point must stand alone and be clear.*The information presented as a whole should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.*

*6 clear points = 6 marks*

*5 clear points = 5 marks*

**5-6**

Intermediate Level − Modest to Adequate  
An experiment must be given and appropriate measurements must be suggested. For 3 marks the type of results expected must be given. 4 marks can only be obtained if the method of obtaining absolute zero is given.*The grammar and spelling may have a few shortcomings but the ideas must be clear.*

*4 clear points = 4 marks*

*3 clear points = 3 marks*

**3-4**

Low Level − Poor to Limited  
One mark may be given for any of the six points given below. For 2 marks an experiment must be chosen and some appropriate results suggested even if the details are vague. Any 2 of the six points can be given to get the marks.  
*There may be many grammatical and spelling errors and the information may be poorly organised.*

*2 clear points = 2 marks*

*Any one point = 1 mark*

**1-2**

**The description expected in a competent answer should include:**

1. Constant mass of gas (may come from the experiment if it is clear that the gas is trapped) and constant volume (or constant pressure).

*For (point 1) amount / quantity / moles of gas is acceptable.*

2. Record pressure (or volume) for a range of temperatures (the experiment must involve changing the temperature with pressure or volume being the dependent variable).

*For (point 2) no specific details of the apparatus are needed. Also the temperature recording may not be explicitly stated e.g. record the pressure at different temperatures is condoned.*

3. How the temperature is maintained / changed / controlled. (The gas must be heated uniformly by a temperature bath or oven − so not an electric fire or lamp).

4. Describe or show a graph of pressure against temperature (or volume against temperature) that is linear. The linear relationship may come from a diagram / graph or a reference to the Pressure Law or Charles’ Law line of best fit is continued on implies a linear graph).

5. Use the results in a graph of pressure against temperature (or volume against temperature) which can be extrapolated to lower temperatures which has zero pressure (or volume) at absolute zero, which is at 0 K or −273 °C (a reference to crossing the temperature axis implies zero pressure or volume).

*For (points 4 and 5) the graphs referred to can use a different variable to pressure or volume but its relationship to V or P must be explicit.*

*In (point 5) the graph can be described or drawn.*

6. Absolute zero is obtained using any gas (provided it is ideal or not at high pressures or close to liquification)  
**Or** Absolute temperature is the temperature at which the volume (or pressure or mean kinetic energy of molecules) is zero / or when the particles are not moving.

Discount any points that are vague or unclear

*(Second part of point 6) must be stated not just implied from a graph.*  **(6)**

1. (i)

* The motion of molecules is random.
* Collisions between molecules (or molecules and the wall of the container) are elastic.
* The time taken for a collision is negligible (compared to the time between collisions).
* Newtonian mechanics apply (or the motion is non-relativistic).
* The effect of gravity is ignored or molecules move in straight lines (at constant speed) between collisions.

✓✓ any two

*If more than 2 answers are given each wrong statement cancels a correct mark.*

**(Max 2)**

(ii) **If the numbers used are 4000, 5000 and 6000 giving 25666666 or similar.**

mean square speed (= (20002 + 30002 + 70002) / 3 = 20.7 × 106) = 2.1 × 107 (m2 s−2)

*Common correct answers*

*20.7 × 106*

*21 × 106*

*2.07 × 107*

*2.1 × 107*

*20 700 000*

*21 000 000.*

**(1)**

(c) **If the question and answer line requires a volume instead of a temperature.**

(using mean KE = 3*RT* / 2*N*A)  
*T* = 2*N*A × mean KE / 3*R*=2 × 6.02 ×1023 × 6.6 × 10−21 / 3 × 8.31✓  
= 320 (K) ✓ (318.8 K)  
Or  
(mean KE = 3*kT* / 2)  
*T* = 2 × mean KE / 3*k*=2 × 6.6 × 10−21 / 3 × 1.38 × 10−23 ✓  
= 320 (K) ✓ (318.8 K)

*First mark for substitution into an equation.*

*Second mark for answer*

*Answer only can gain 2 marks.*

**(2)**

**[Total 11]**

**M14.** (a) (use of Δ*Q* = *m c* Δ*T*)

30 × 98 = 0.100 × *c* × 14 🗸

*c* = 2100 (J kg–1 K–1) 🗸

**(2)**

(b) (use of Δ*Q* = *m l* + *m c* Δ*T*)

500 × 98 = 0.100 × 3.3 × 105  + 0.100 × 4200 × Δ*T* 🗸

(Δ*T* = 38 °C)

T = 38°C 🗸

**(3)**

(c) the temperature would be higher 🗸

as the ice/water spends more time below 25°C

**or** heat travels in the direction from hot to cold

**or** ice/water first gains heat then loses heat

any **one** line 🗸

**(2)**

**[Total 7]**

**M15.** (a) (i) *PV = NkT* **(1)**

223 × 105 Pa **(1)**

**(2)**

(ii) *pV* = const or repeat calculation from (i) **(1)**

3.5 × 10-3 m3 **(1)**

**(2)**

(iii) kinetic energy = 3/2 *kT* **(1)**

5.9(0) × 10-21 J **(1)**

**(2)**

(b) (i) volume increase **(1)**

time between collisions increases **(1)**

speed constant as temp constant **(1)**

rate of change of momentum decreases **(1)**

**(Max 3)**

(ii) volume smaller in cylinder **(1)**

molecules occupy significantly greater proportion of the volume **(1)**

molecules closer so intermolecular forces greater **(1)**

**(3)**

(c) internal energy stays the same **(1)**

gas does work in expanding so *W* is negative **(1)**

gas must be heated to make *U* positive **(1)**

*U* and *W* equal and opposite **(1)**

**(4)**

**[Total 16]**

**M16.** (a) (use of Δ*Q = mcT* gives)  
*ΔQ*1 = 1.5 × 4200 × 18 **(1)**= 1.134 × 105(J) **(1)***ΔQ*2 = 1.5 × 3.4 × 105 = 5.1 × 105(J) **(1)**total energy released (= 1.134 × 105+ 5.1 × 105)  
= 6.2 × 105J **(1)**(6.23 × 105J)

**(4)**

(b) (ice) requires energy to melt [or mention of latent heat] **(1)**stays at 0 °C (for longer) (or cools for longer) **(1)**(or extracts more energy from the drink)

**(2)**

**[Total 6]**

**M17.** (a) the number of atoms in 12g of carbon-12   
or the number of particles / atoms / molecules in one mole of substance ✓

*not – NA quoted as a number*

**(1)**

(b) (i) mean kinetic energy ( = 3 / 2 *kT*) = 3 / 2 × 1.38 × 10−23 × (273 + 22) = 6.1 × 10−21 (J) ✓

*6 × 10−21 J is not given mark*

**(1)**

(ii) mass of krypton atom = 0.084 / 6.02 × 10+23 ✓   
( = 1.4 × 10−25 kg)   
( = 2 × mean kinetic energy / mass = 2 × 6.1 × 10−21 / 1.4 × 10−25) = 8.7 - 8.8 × 104 ✓   
m2 s−2 or J kg−1 ✓

*1st mark is for the substitution which will normally be seen within a larger calculation.   
allow CE from (i)   
working must be shown for a CE otherwise full marks can be given for correct answer only   
no calculation marks if mass has a physics error i.e. no division by NA note for CE   
answer = (i) × 1.43 × 1025*

**(3)**

(c) (at the same temperature) the mean kinetic energy is the same   
**or**   
gases have equal   
**or**   
mass is inversely proportional to mean square speed / m ∝ ✓   
or mean square speed of krypton is less ✓

*1st mark requires the word mean / average or equivalent in an algebraic term   
2nd mark ‘It’ will be taken to mean krypton. So, ‘It is less’ can gain a mark   
allow ‘heavier’ to mean more massive’   
allow vague statements like speed is less for 2nd mark but not in the first mark*

**(2)**

**[Total 7]**

**M18.** (a) ω = or

= 1.1 × 10–3 (1.08 × 10–3) **(1)** [= 6.2 (6.19) × 10–2]

rad s–1 [accept s–1] **(1)** [degree s–1]

**(3)**

(b) (i) **or** **(1)**

gives *r*3 = **(1)**

*****r* = 6.99 × 106 (m) **(1)**

**(3)**

(ii) *F* (= *mω*2*r*) = 1.1 × 104 × (1.08 × 10–3)2 × 6.99 × 106 **(1)**

= 9.0 × 104 (8.97 × 104) (N) **(1)**

[**or**

**(1)**

= 9.0 × 104 (8.98 × 104) (N) **(1)**]

**(2)**

**[Total 8]**

**M19.** (a) (i) use of *mg* = *kΔL* or *F* = *kΔL* **and** *F = mg*

extension = 5.9 m

total length = 25.9 m (allow 20 + their extension)

**(3)**

(ii) 20 + twice (5.9) amplitude + 2.6; 34.4 m;  
allow ecf from ai

**(1)**

(b) (i) *T* = 2π√*m/k* and *T* = 1/*f* or *f* = 1/2*π* √*k/m*

correct substitution: allow for calculation of T (4.85 s)

0.21 or 0.206 (Hz)

**(3)**

(ii) substitutes data in *v*max = 2π*fA*

5.4 ms–1 (5.28 to 5.53)

**(2)**

(iii) two complete oscillations shown with positive and negative velocities and acceptable shape  
(condone more than 2)

**and two from**period of 5 s used in graph (allow ecf for T from earlier part)

start at 0 and positive velocity change at T = 0 with positive and negative velocities shown

max velocity shown decreasing

**(3)**

(c) (i) it would have to be raised

rest extension would be greater/rider would be nearer the ground if extension unchanged

the rider has to move down a distance = to the amplitude (5.9 m) from the new rest position

**or** with same initial extension/energy stored in rope, the rider would reach a lower height  
amplitude would be lower  
**or** due to the larger mass more energy (= mgh) is needed to reach the same height

so initial extension would have to be increased

**(3)**

(ii) the rope would become slack at the top of the ride so the rider would go into free flight/rider would overshoot the highest point

the rider would fall and, with negligible air resistance, the rope would again absorb the energy arriving back at the start point **or** rider is more likely to fail to reach the ground after one oscillation due to energy losses/air resistance

the PE gained (at the top of the flight) can (at most) only be converted back to the elastic energy that was stored in the rope at the start

(allow a statement to the effect that to hit the floor would contravene conservation of energy or require an energy input)

**(3)**

**[Total 18]**

**M20.** (a) (i) *ω* ( = 5.73 rad s−1) ✓

*θ*( = *ωt* ) = 5.73 × 0.40 = 2.3 (2.29) (rad) ✓

= × 360 = 130 (131) (degrees) ✓

[**or** s(( = *vt*) = 8.6 × 0.40 ( = 3.44 m) ✓

*θ* =  × 360 ✓ = 130 (131) (degrees) ✓ ]

*Award full marks for any solution which arrives at the correct answer by valid physics.*

**(3)**

(ii) tension *F* (=*mω*2*r*) = 0.25 × 5.732 × 1.5 ✓ = 12(.3) (N) ✓

[**or** *F* *=*  ✓ = 12(.3) (N) ✓ ]

*Estimate because rope is not horizontal.*

**(2)**

(b) maximum *ω* = (= 12.6) (rad s−1) ✓

maximum *f* = 2.01 (rev s−1) ✓

[**or** maximum *v =* *=* (= 19.0) (m s−1) ✓

maximum *f* *=* = 2.01 (rev s−1) ✓ ]

*Allow 2 (rev s−1) for 2nd mark.*

*Ignore any units given in final answer.*

**(2)**

(c) **The student’s writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The student’s answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

**High Level (Good to excellent): 5 or 6 marks**

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.  
*The student appreciates that the velocity of the ball is not constant and that this implies that it is accelerating. There is a comprehensive and logical account of how Newton’s laws apply to the ball’s circular motion: how the first law indicates that an inward force must be acting, the second law shows that this force must cause an acceleration towards the centre and (if referred to) the third law shows that an equal outward force must act on the point of support at the centre. The student also understands that the rope is not horizontal and states that the weight of the ball is supported by the vertical component of the tension.*

*A* ***high level*** *answer must give a reasonable explanation of the application of at least two of Newton’s laws, and an appreciation of why the rope will not be horizontal.*

**Intermediate Level (Modest to adequate): 3 or 4 marks**

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.  
*The student appreciates that the velocity of the ball is not constant. The answer indicates how at least one of Newton’s laws applies to the circular motion. The student’s understanding of how the weight of the ball is supported is more superficial, the student possibly failing to appreciate that the rope would not be horizontal and omitting any reference to components of the tension.*

*An* ***intermediate level*** *answer must show a reasonable understanding of how at least one of Newton’s laws applies to the swinging ball.*

**Low Level (Poor to limited): 1 or 2 marks**

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

*The student has a much weaker knowledge of how Newton’s laws apply, but shows some understanding of at least one of them in this situation. The answer coveys little understanding of how the ball is supported vertically.*

*A* ***low level*** *answer must show familiarity with at least one of Newton’s laws, but may not show good understanding of how it applies to this situation.*

*References to the effects of air resistance, and/or the need to keep supplying energy to the system would increase the value of an answer.*

**The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.**

* *First law:* ball does not travel in a straight line, so a force must be acting on it
* although the ball has a constant speed its velocity is not constant because its direction changes constantly
* because its velocity is changing it is accelerating
* *Second law*: the force on the ball causes the ball to accelerate (or changes the momentum of it) in the direction of the force
* the acceleration (or change in momentum) is in the same direction as the force
* the force is centripetal: it acts towards the centre of the circle
* *Third law*: the ball must pull on the central point of support with a force that is equal and opposite to the force pulling on the ball from the centre
* the force acting on the point of support acts outwards
* *Support of ball*: the ball is supported because the rope is not horizontal
* there is equilibrium (or no resultant force) in the vertical direction
* the weight of the ball, *mg*, is supported by the vertical component of the tension, *F* cos *θ*, where *θ* is the angle between the rope and the vertical and *F* is the tension
* the horizontal component of the tension, *F* sin *θ*, provides the centripetal force *m* *ω*2 *r*

**Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**

*A reference to Newton’s 3rd law is not essential in an answer considered to be a high level response. 6 marks may be awarded when there is no reference to the 3rd law.*

**(Max 6)**

**[Total 13]**

**M21.** (a) attempt to use power = *mgh/t* or *P* = *Fv* and *v* = *s/t*

7546/7550/7600

W (allow J s–1 and condone N ms–1)

**(3)**

(b) loss of GPE = 550 × 9.81 × 35 = 189 kJ

gain in KE = 0.5 × 550 × 222 = 133 kJ

resistance force = their difference/63 (890 N if correct)

answer to 2 sf (allow if answer is from working even if incorrect)

**(4)**

(c) air resistance varies/increases

frictional force varies/increases

further detail: air resistance increases with speed/v **or** normal reaction force varies with angle of the slope

**(3)**

(d) use of *F* = *mv*2/*r*

arrives at *r* = 12 m (ignoring the weight)

16.4 m

**(3)**

**[Total 13]**

**M22.** (a) T = power/*ω*

Torque = 2500/0.47

5320 N m value to 2 or more sf needed

**(3)**

(b) (i) Deceleration= 0.47/34= 0.0138 (rad s–2)

moment of inertia = torque / angular deceleration

=5000/0.0138 = 3.57 × 105

kg m2 (Allow N m s2)

*3.8 × 105 if 5320 used*

**(3)**

(ii) Suitable equation of motion used with correct data but omitted minus sign

8.0 radian Allow (their *ω*/2*π*)

1.27 revolutions

*Condone 1 revolution*

*(allowed for thinking question refers to complete revolutions)*

**(3)**

(c) (i) F = 65 × 2.2 × 0.472

32(31.6 N)

**(2)**

(ii) Force produced by friction between the feet and the roundabout

Centripetal force has to act through the centre of mass of the operator

**or**

The resultant of the frictional force and normal reaction has to pass through the centre of mass

*Any indication (eg on diagram) of wrong direction = 0*

**(2)**

(iii) Ticks 4th box

**(1)**

**[Total 14]**

**M23.** (a) molecules have negligible volume  
collisions are elastic  
the gas cannot be liquified  
there are no interactions between molecules (except during collisions)  
the gas obeys the (ideal) gas law / obeys Boyles law etc.  
at all temperatures/pressures  
any two lines  

*gas laws may be given as a formula*

**(2)**

(b) (i) *n (= PV / RT)* = 1.60 × 106 × 0.200 / (8.31 × (273 + 22)) 🗸  
= 130 or 131 mol 🗸 (130.5 mol)

**(2)**

(ii) mass = 130.5 × 0.043 = 5.6 (kg) 🗸 (5.61kg)

*allow ecf from bi*

density (= mass / volume) = 5.61 / 0.200 = 28  (28.1 kg m−3)  
kg m−3 

*a numerical answer without working can gain the first two marks*

**(3)**

(iii) *(V2 = P1 V1 T2 / P2 T1)  
V2 = 1.6 × 106 × .200 × (273 – 50) / 3.6 × 104 × (273 + 22) or 6.7(2) (m3)* 

*allow ecf from bii*

***[reminder must see bii]****look out for*

mass remaining = 5.61 × 0.20 / 6.72 = 0.17 (kg)   (0.167 kg)  
**or**  
*n* = (*PV* / *RT* = 3.6 × 104 × 0.200 / (8.31 × (273 − 50)) = 3.88(5) (mol) 

mass remaining = 3.885 × 4.3 × 10−2 = 0.17 (kg)   
2 sig figs 

*any 2 sf answer gets the mark*

**(3)**

**[Total 10]**

**M24.** (i) (heat supplied by glass = heat gained by cola)  
(use of *m*g *c*g *ΔT*g =*mc* cc *ΔT*c)

*1st mark for RHS or LHS of substituted equation*

0.250 × 840 × (30.0 – Tf) = 0.200 × 4190 × (Tf – 3.0) 🗸

*2nd mark for 8.4°C*

(210 × 30 – 210 *t*f = 838 *T*f – 838 × 3)  
*T*f = 8.4(1) (°C) 🗸

*Alternatives:*

*8°C is substituted into equation (on either side shown will get mark)*

*resulting in 4620J~4190J 🗸*

*or*

*8°C substituted into LHS 🗸 (produces ΔT = 5.5°C and hence)*

*= 8.5°C ~ 8°C 🗸*

*8°C substituted into RHS🗸*

*(produces ΔT = 20°C and hence)*

*= 10°C ~ 8°C 🗸*

**(2)**

(ii) (heat gained by ice = heat lost by glass + heat lost by cola)

*NB correct answer does not necessarily get full marks*

(heat gained by ice = *mcΔT* + *ml*)  
heat gained by ice = *m* × 4190 × 3.0 + *m* × 3.34 × 105 🗸  
(heat gained by ice = *m* × 346600)

*3rd mark is only given if the previous 2 marks are awarded*

heat lost by glass + heat lost by cola  
= 0.250 × 840 × (8.41 – 3.0) + 0.200 × 4190 × (8.41 – 3.0) 🗸  
(= 5670 J)

*(especially look for m × 4190 × 3.0)*

*the first two marks are given for the formation of the substituted equation not the calculated values*

*m* (=5670 / 346600) = 0.016 (kg) 🗸

*if 8°C is used the final answer is 0.015 kg*

or (using cola returning to its original temperature)  
(heat supplied by glass = heat gained by ice)  
(heat gained by glass = 0.250 × 840 × (30.0 – 3.0)) = 5670 (J) 🗸  
(heat used by ice = *mcΔT* + *ml*) = *m*(4190 × 3.0 + 3.34 × 105) 🗸 (= *m*(346600))

*m* (=5670 / 346600) = 0.016 (kg) 🗸

**(3)**

**[Total 5]**

**M25.** (a) using *Q* = *mc*Δ*θ*

= 3.00 × 440 × (84-27) **(1)**

7.5 × 104 (J) **(1)**

**(2)**

(b) using *Q* = *ml*= 1.20 × 2.5 × 104= 3.0 × 104 (J) **(1)**

**(1)**

(c) (heat supplied by lead changing state + heat supplied by cooling lead =  
heat gained by iron)

3.0 × 104 + heat supplied by cooling lead = 7.5 × 104 **(1)**

heat supplied by cooling lead = 4.5 × 104 = *mc*Δ*θ*

*c* = 4.5 × 104/(1.2 × (327 – 84) **(1)**

*c* = 154 (J kg–1 K–1) **(1)**

**(3)**

(d) any **one** idea **(1)**

no allowance has been made for heat loss to the surroundings

or the specific heats may not be a constant over the range of temperatures calculated

**(1)**

**[Total 7]**

**M26.** (a) the energy required to change the state of a unit mass of water to steam / gas ✓   
when at its boiling point temperature/100°C without a change in temperature) ✓

*allow 1 kg in place of unit   
allow liquid to vapour / gas without reference to water   
don't allow ‘evaporation’ in first mark*

**(2)**

(b) (i) thermal energy given by copper block ( = *mc*Δ*T*)   
= 0.047 × 390 × (990 – 100)   
= 1.6 × 104 (J) ✓   
2 sig figs ✓

*can gain full marks without showing working   
a negative answer is not given credit*

*sig fig mark stands alone*

**(2)**

(ii) thermal energy gained by water and copper container   
( = *mc*Δ*T*water + *mc*Δ*T*copper)   
= 0.050 × 4200 × (100 – 84) + 0.020 × 390 × (100 – 84)   
**or** = 3500 (J) ✓ (3485 J)   
available heat energy ( = 1.6 × 104 – 3500) = 1.3 × 104 (J) ✓

allow both 12000 J and 13000 J

*allow CE from (i) working must be shown for a CE   
take care in awarding full marks for the final answer – missing out the copper container may result in the correct answer but not be worth any marks because of a physics error   
(3485 is a mark in itself)   
ignore sign of final answer in CE (many CE’s should result in a negative answer)*

**(2)**

(iii) (using Q = *ml*)   
*m* = 1.3 × 104 / 2.3 × 106 = 0.0057 (kg) ✓   
Allow 0.006 but not 0.0060 (kg)

*allow CE from (ii)   
answers between 0.0052* ***→*** *0.0057 kg resulting from use of 12000 and 13000 J*

**(1)**

**[Total 7]**

**M27.** (a) 1. fixed mass or fixed number of molecules / moles ✔

2. constant temperature ✔

*Allow alternatives to fixed mass such as ‘sealed vessel’ or ‘closed system’.*

*Not amount of gas as this is ambiguous.*

*The temperature must not be specific.*

**(2)**

(b) (i)

**or**

V = 0.067 × 8.31 × 350 / (4.4 × 10−4) ✔

= 0.00044 (m3) ✔ (4.39 × 10−4 m3)

*1st mark comes from use of valid equation with substitutions.*

*In the alternative look out for 0.067 = 1 /15 = (0.0016 / 0.024)*

*And R = NA k*

*Correct answer gains full marks*

*If no other answer is seen then 1 sig fig is wrong.*

**(2)**

(ii) (proportion of a mole of trapped air

= volume of cylinder / volume of mole)

= 0.0016 / 0.024 = 0.067 (mol) ✔ (0.0667)

**or**

(use of *n = pV/RT*)

= 1.0 × 105 × 0.0016 / (8.31 × 290) = 0.066 (mol) ✔ (0.0664)

**or**

= 4.4 × 105 × 0.00044 / (8.31 × 350) = 0.067 (mol) ✔ (0.0666)

*Answers range between 0.066 − 0.067 mol depending on the volume carried forward.*

*(answer alone gains mark)*

*Working must be shown for a CE*

*Ans = V2 × 151*

**(1)**

(iii) (mass = molar mass × number of moles)

mass = 0.029 × 0.0667 ✔ (0.00193 kg)

(density = mass / volume) = 0.00193 / 0.0016 = 1.2(1) kg m–3 ✔

(no continuation errors within this question but allow simple powers of 10 arithmetic errors which will lose one mark)

*CE mass = 0.029 × (b)(ii)*

*CE density = (0.029 × (b)(ii)) / 0.0016*

*or (18.1 × (b)(ii)*

**(2)**

(c) the (average / mean / mean-square) speed of molecules increases (with absolute temperature) ✔

as the mean kinetic energy is proportional to the (absolute) temperature

Or

Reference to KEmean = 3/2 *kT* ✔ but mean or rms must feature in the answer somewhere.

**(2)**

**[Total 9]**

**M28.**(a) Tick in 4th box

**(1)**

(b) (i) (using heat energy = *ml*)

energy = 0.047 × 3.3 × 105 = 1.6 × 104 (J) ✔ (1.55 × 104 J)

*answer alone gains mark*

**(1)**

(ii) (heat in from water = heat supplied to melt and raise ice temperature)

1.8 × 104 = 1.6 × 104 + (energy to raise temp of ice)

energy to raise temp of ice = 2 × 103 (J) ✔

*answer alone gains mark allow 2, 2.5 or 3 × 103 J*

*allow CE if substitution is shown*

*1.8 × 104 – (b)(i)*

**(1)**

(iii) (using heat energy = *mc*∆*T*)

c = 2 × 103 / 0.047 × 25

= 2 × 103 ✔ (1.7 × 103) (note there is a large range of correct answers)

J kg-1 K-1 or J kg-1 oC-1 ✔ (allow use of dividing line but don’t allow oK and oC-1 is not the same as C-1)

*only allow CE if substitutions are seen*

*c = (b)(ii) / 0.047 × 25*

*= b(ii) × 0.851*

*allow 1 sig fig.*

*common answers:*

*for 2.5 × 103 J gives 2.1 × 103 or 2 × 103*

*for 3 × 103 J gives 2.6 × 103 or 3 × 103*

**(2)**

**[Total 5]**

**M29.** (a) (i) Use of *V = πr2L*

3.47 × 10–2 or 3.5 × 10–2 (m)

*Sub including V and L (condone L=18)*

*Or rearrangement to make r subject of correct equation*

*Condone power 10 error on L*

*1 mark for following answers*

*1.7 × 10–2, 1.7 × 10-3, 3.5 × 10-3 (m)*

**2**

(ii) Use of *pV = NkT* or *T* = 19 + 273 or *T* = 292 seen

Allow rearrangement making *N* subject

Correct use of *pV = NkT* substitution

4.26 × 1021 seen or 4.3 × 1021 seen

*Condone sub of 19 for T for 1st mark in either method*

*Or (N =) seen with pV = NkT seen*

*Alternative use of pV = nRT* ***and*** *N = nNA in first and second marks*

*First mark condone T = 19*

*Second mark pV = nRT seen with use of and 7(.08) × 10-3 × 6(.02) × 1023 seen*

**(3)**

(iii) (*NV*=)1.7 × 10-4 × 7 × 10-4 or 1.19 × 10-7 seen

2.76 × 10-29 to 3.0 × 10-29 (m3) condone 1 sf here

*Penalise where product does not equal 1.19 × 10-7*

**(2)**

(iv)

* + - the volume of molecule(s) is negligible **compared to** volume occupied by gas
    - the particles are far apart / large spaces between particles (compared to their diameter)
    - **Therefore** Time during collisions is negligible compared to time between collision
    - **Therefore** intermolecular forces are negligible

*Allow volume of one molecule is negligible compared to total volume*

**(Max 3)**

(b) Use of ½ *m*<*c*2> =3/2 *k*T sub or rearrangement

Condone crms as subject for 1 mark

Condone power 10 error

Condone T = 19 in 1st MP

Correct sub with <*c*2> as subject including correct power 10

2.57 × 105 or 2.6 × 105 (on answer line)

m2 s-2

*Alternatively:*

*use of pV=1/3 Nm<c2> sub or rearrangement*

*Condone crms as subject for 1 mark*

*Condone power of 10 error*

*Condone T = 19 in 1st MP*

*Correct sub with <c2> as subject including correct power 10*

*2.7(4) × 105 (from N = 4 × 1021) (on answer line)*

*2.57 × 105 for N = 4.26 × 1021*

*2.5(48) × 105 for N = 4.3 × 1021*

*m2 s-2*

*condone alternative units where correct:*

*Pa m3 kg-1*

*J kg-1*

**(4)**

(c) (i) *p1L1 = k1* and *p2L2=k2*

(consistent power 10)

i.e. 2 sets of **correct** data seen in sub

allow incomplete sub with 2 similar *k* (18 × 103) values seen

*p1L1 = k1 , p2L2 = k2 and p3L3 = k3*

(consistent power 10)

i.e. 3 sets of **correct data seen in sub**

Comparison of *k* values followed by conclusion

*Presents a factorial of L leading to an inverse of the factorial change in P (correct data)*

*Repeats this process for* ***second*** *data set for same factorial change (correct data)*

***States*** *the relationship seen and* ***states*** *the conclusion*

**3**

(ii) Temperature or internal energy

*Allow mass / number of particles / mean square speed (of molecules)*

**1**

(d) L decreases then volume decreases (therefore more particles in any given volume) / V = *πr2* L / V is (directly) proportional to L

Decreased volume Increases number of collisions (with walls every second)

Decreased volume causes Rate of change of momentum to increase

Increased rate of change of momentum causes force (exerted on walls) to increase (causing an increase in pressure)

*Allow converse argument but must be consistent*

*or equivalent*

*must be correct equation with V in terms of L with p as subject*

**(4)**

**[Total 22]**

**M30.** (a) The molecules (continually) move about in random motion✓

Collisions of molecules with each other and with the walls are elastic✓

Time in contact is small compared with time between collisions✓

The molecules move in straight lines between collisions✓

**ANY TWO**

*Allow reference to ‘particles interact according to Newtonian mechanics’*

**(2)**

(b) Ideas of pressure = F / A and F = rate of change of momentum✓

Mean KE / rms speed / mean speed of air molecules increases✓

More collisions with the inside surface of the football each second✓

*Allow reference to ‘Greater change in momentum for each collision’*

**(3)**

(c) Radius = 690 mm / 6.28) = 110 mm or *T* = 290 K ✓ seen

volume of air = 5.55 × 10-3 m3✓

*n* × 29(g) = 11.4 (g)✓ *n* = 0.392 mol

Use of *pV = nRT* = ✓

*p* = 1.70 × 105 Pa ✓

Conclusion: Appropriate comparison of their value for *p* with the requirement of the rule, i.e. whether their pressure above 1 × 105 Pa falls within the required band✓

*Allow ecf for their n V and T✓*

**(6)**

**[Total 11]**

**M31.** (a) (i) *Two examples (any order)*:

* when charged particle is at rest **or** not moving relative to field  
* when charged particle moves parallel to magnetic field  

**(2)**

(ii) 🗸 (gives *BQr = mv*)

*Acceptable answers must include correct force equation (1st point).*

*B* and *Q* are constant so *r* ∝ momentum (*mv*)  

*Insist on a reference to B and Q constant for 2nd mark.*

**(2)**

(b) (i) upwards (perpendicular to plane of diagram) 🗸

*Accept “out of the page” etc.*

**(1)**

(ii) 🗸 = 8.7(4) x 106 (ms-1)

**(2)**

(iii) length of path followed (= length of semi-circle) = 🗸

time taken = 6.8(3) x 10-8 (s)

*Allow ECF from incorrect v from (b)(ii).*

**Or**gives *🗸*

= 6.8(3) x 10-8 (s) 🗸

*Max 1 if path length is taken to be (gives 1.37 × 10−7s).*

**(2)**

(iv) *v* ∝ *r* (and path length ∝ *r* ) 🗸

*t* = (path length / *v*) **or** ( / *v* )

so *r* cancels (∴time doesn't depend on *r*) 🗸

**or** 🗸 = (because *r* cancels)

**or** *BQv* = *mω*2 *r* gives *BQωr* = *mω*2 *r* and *BQ* = *mω* = 2*πfm* 🗸

∴ frequency is independent of *r* 🗸 ]

**(2)**

1. = 2.16 x 107 (ms-1) 🗸

*1st mark can be achieved by full substitution, as in (b)(ii), or by use of data from (b)(i) and / or (b)(ii).*

*Ek* (= ½ *mv*max 2) = ½ × 1.67 × 10−27 × (2.16 × 107)2  ( = 3.90 × 10−13 J)



*Allow ECF from incorrect v from (b)(ii), or from incorrect t from (b)(iii).*

**(3)**

**(Total 14)**

**M32.** (a) emf = Δ*(BAN) / t  
Change in flux* = *A* × Δ*B* or 12 × (23 − 9) seen

Substitution ignoring powers of 10

1.2 V

**(3)**

(b) Reduced

Magnet will move (with the case)

Increased

Flux linkage increases or emf is proportional to *N*

**(2)**

(c) (i) Formula used, seen

0.348 / 0.349 seen to at least 3 sf

**(2)**

(ii) Period consistent at 0.35 s or *V*o = 8 V

Shape shows decreasing amplitude

At least 3 cycles starting at 8 V

**(3)**

**[Total 10]**

**M33.** (a) magnetic field direction: −*z* **(1)**

**1**

(b) direction changes meaning that velocity is not constant **(1)**

acceleration involves change in velocity  
(or acceleration is rate of change of velocity) **(1)**

[**alternatively**

magnetic force on electron acts perpendicular to its velocity **(1)  
 **force changes direction of movement causing acceleration **(1)**]

**(2)**

(c) (i) *BQv* = **(1)** gives *v*

= **(1)** (= 5.59 × 106 m s−1)

**(2)**

(ii) angular speed *ω* = 7.5(5) × 107 **(1)**

*unit*: rad s−1 **(1)** (accept s−1)

**(2)**

(iii) frequency of electron’s orbit *f* **(1)**

(= 1.20 × 107 s−1)

number of transits min−1 = 1.20 × 107 × 60 = 7.2 × 108 **(1)**

[**alternatively**

orbital period

[**or**] (= 8.32 × 10−8 s)

number of transits min−1 = = 7.2 x 108 **(1)**]

**(2)**

**[Total 9]**

**M34.** (a) (i) (vertically) downwards [**or** top to bottom, or down the page] **(1)**

**(1)**

(ii) force on sphere *F* (= *kx*) = 0.24 × 18 × 10−3 **(1)** (= 4.32 × 10−3 N)

**(1)**

(iii) **use of** *F = EQ* gives *E* = F/Q = 4.32 × 10−3/4.1 x 10-8 **(1)** (= 1.05 × 105 V m−1)

**use of** *E* = gives separation *d* = **(1)**

= 4.8 × 10−2 (m) **(1)** (4.76 × 10−2)

**(3)**

(b) (i) electric field becomes zero (or ceases to exist) **(1)**

flow of charge (or electrons) from one plate to the other  
[**or** plates discharge] **(1)**

(until) pd across plates becomes zero [**or** no pd across plates,  
**or** plates at same potential] **(1)**

**(Max 2)**

(ii) net downward force on sphere (when *E* becomes zero)  
[**or** gravitational force acts on sphere, **or** force is weight] **(1)**

this force extends spring **(1)**

force (or acceleration) is proportional to (change in) extension of spring **(1)**acceleration is in opposite direction to displacement (or towards equilibrium) **(1)**

for shm, acceleration ∝ (−) displacement  
[**or** for shm, force ∝ (−) displacement] **(1)**

**(Max 3)**

**[Total 10]**

**M35.** (a) (i) correct period read from graph or use of *f=1/T* 0.84±0.01

*2.4 Hz gets 1*

correct frequency 1.2 (1.18 − 1.25 to 3 sf)

**(2)**

(ii) correct shape (inverse)

Crossover PE = KE

**(2)**

(b) (i) Use of

48.7 (49) m

**(2)**

(ii) *v* = 120 000 / 3600 = 33(.3) m s−1

Use of *F = m v2/r* (allow *v* in km h−1)

Total tension = 6337 + (280 × 9.81) = 9.083 × 103 N  
Allow their central force

Divide by 4      2.27 × 103 N  
Allow their central force

**(4)**

(iii) *mgh = ½ mv2*

*Condone: Use of v = 2πfA (max2)*

9.8×44 = 0.5 *v2*      Allow 45 in substitution

*Condone 22 m s−1*

29.4 m s−1 (Use of 45 gives 29.7)

106 km h−1 (their m s−1 correctly converted)  
Or compares with 33 m s−1

**(4)**

(iv) 1/16th(0.625) % of KE left if correct

*Allow 1/8 (0.125)or 1/32(0.313)*

KE at start = 5.6 × 104 J or states energy ∝ speed2 so speed is ¼

*Allow for correct subn E =½ 280 × 202 x factor from incorrect number of swings calculated correctly*

Final speed calculated = 5 m s−1

*Must be from correct working*

**(3)**

**[Total 17]**

**M36.** (a) (i) heat water to 100 °C, energy (= 190 × 4200 × 79) = 63 (MJ) **(1)**vaporise water, energy (=190 × 2.3 × l06) = 440(MJ) **(1)** *(437MJ)*

energy transferred (per sec) = (437 + 63) MJ **(1)** (= 500 MJ)

(ii) mass of rocks (= 4.0 × 106 × 3200)

= 1.3 × 1010(kg) **(1)** *(1.28 × 1010)*

temperature fall of Δ*T* in one day, energy removed  
(= 1.28 ×1010 × 850 × Δ*T*) = 1.1 × 1013 Δ*T* **(1)** *(1.09 x 1013 ΔT)  
(allow C.E. for value of mass of rocks)*

energy transfer in one day (= 500 × 106 × 3600 × 24) = 4.3 × 1013 (J) **(1)**

in one day = 3.9(1) K **(1)**

**(7)**

(b) number of nuclei in 1 kg of 238 U = = 2.5(3) x 1024 **(1)**

activity of l kg of 238U = (**1)**

= 1.2(6) x 107 (s-1) **(1)**

energy released per sec per kg of 238 U

= 1.2(6) × 107 × 4.2 × 1.6 × 10–13(J) **(1)** *(8.47 × 10–6(J))*

mass of 238Uneeded = = 5.9(0) × 1013kg **(1)**

**(5)**

**[Total 12]**

**M37.** (a) kinetic energy = *mgh* **(1)** = 0.37 J **(1)**

(b) *υ* = **(1)** = 2.22 ms–1 **(1)**

(c) *Fc* = 2.9 N [or 3.0 N if *g* = 10 used] **(1)**

(d) *T* = *Fc* + *W* = 4.4 N **(1)**

**[Total 6]**

**M38.** (a) m = gradient = 0.035 ± 0.001 (cm2 °C−1) 🗸

c = intercept = 10.5 0.1 (cm2) 🗸

absolute zero = -c/m 🗸

= -300 ± 10 °C *some relevant working must be seen 🗸*

**or** a meaningful attempt to use similar triangles 🗸

an accurate value for the base found 🗸

adjustment to the base (if appropriate) 🗸

answer = -300  10 °C 🗸

**or** *relevant use of* V1/T1 = V2/ T2 🗸

valid introduction of **unknown** temperature 🗸

consistent solution of the equation 🗸

answer = -300  10 °C 🗸

**(4)**

(b) statement of *or use of* pV = nRT

accurate reading from the line

Celsius converted to Kelvin *(+273 or + answer to part (a))*

n = 4.52 × 10–4 **or** 4.11 × 10–4 *or 4.2 × 10–4 (*∆*V/*∆*T)* (mol)

m = n × 0.044 (m = 4.52 × 0.044 = 2.0 × 10–5 kg)

**(5)**

**[Total 9]**

**M39.** (a) 1/*C* = 1/500 + 1/1000 or

330 (333) µF

**(2)**

(b) (i) Q = VC *or* Q = *0.25 × 9*

2.3 or 2.25 C (c.a.o. unit essential)

(ii) *energy = ½ CV*2 or 0.5 × 0.25 × 92 or ½ *QV* used

10(.1) J (allow e.c.f. for *Q*)

(iii) *V = V*o e−*t/RC*

0.1 = 9 e−*t*/(8.5 x 0.25)

9.6 (9.56) s

**(7)**

(c) (i) *Q = mc*∆θ or mass = volume × density

correct substitution 10.1 = (2.2 × 10−7 × 8900 × 400 × ∆θ)

12 (12.3) K or °C ecf for energy from (b) (ii)

**(5)**

(ii) some energy raises temperature of the thermometer

energy/heat lost to (raise temperature of) surroundings

**[Total 14]**

**M40.** (a) a = v2/r

= (7.68 × 103)2/(6.760 × 106) **or** r = 6380 + 380

= 8.73 m s–2

**(3)**

(b) (the scientist is in) free-fall (owtte)

his/her **weight provides the centripetal force**

(to maintain) the same orbit/same radius **and** velocity/same acceleration (as the ISS)

his/her body experiences no motion/force relative to the ISS

**(Max 2)**

(c) (i) k = 4π2m/T2 **or** T = 2π(m/k)1/2 *and inferred transposition*

= 4 × (3.142)2 × 2.0/ (1.2)2

(= 54.8)

**(2)**

(ii) *use of* T = 2π(m/k)1/2 *and* f = 1/T

f = 5.4 × 1012 Hz

**(2)**

**[Total 9]**

**M41.** (a) lowest energy state/level that the electron can occupy

**or** state in which electron needs most energy to be released

**or** the level of an unexcited electron (not lowest orbit)

**(1)**

(b) (i) force = *mv*2/*r* or *mr*ω2 and *v = r*ω

8.1 × 10−8 = 9.1 × 10−31 × *v*2/5.3 × 10−11 **or** (*v*2 =) 4.72 × 1012 seen

2.17 × 106 (m s−1)

(ii) λ = *h/mv* or 6.6 × 10−34/9.1 × 10−31 × 2.2 × 106

3.3 × 10−10 m

(iii) circumference = 2π5.3 × 10−11 = 3.3 × 10−10 m

(allow e.c.f. from (ii))

**(7)**

(c) (i) 1.9(4) × 10−18 J

(ii) 5.6 × 10−19 J (e.c.f. 2.5 × 10−18 − their (i))

(iii) energy difference *E =* 3 × 10−19 J (condone any difference)

*E* = hc/λ *or E =* hf *and* c=fλ

**or** their E = 6.6 × 10−34 × 3.0 × 108/λ

6.6 or 6.7 × 10−7 m

**(5)**

**[Total 13]**

**M42.** (a) kinetic energy of ball = ½*mυ*2 = ½ × 0.060 × (50)2 = 75 J **(1)**

**(1)**

(b) kinetic energy of one atom *kT* **(1)** ( × 1.38 × 10–23 × *T*)

one gram contains × *NA* (= 1.5 × 1023) atoms **(1)**

total internal energy = 1.5 × 1023 × × 1.38 × 10–23 × 48 = 150 J **(1)**

**(3)**

(c) energy of helium gas at 48 K is twice that of tennis ball   
∴energies equal when helium gas has a temperature of 24 K **(1)**

**(1)**

**[Total 5]**

**M43.** (a) 2.2 s c.a.o.

(b) *exactly two* reasonable sine wave cycles drawn

displacement = 10 cm when time = 0

time = 2.2 s after one cycle

peaks decrease to approximately 7.0 cm after two cycles  
or 8.4 cm after one cycle

**award two marks if half-cycle confused with full cycle but otherwise correct**

**(4)**

(c) (i) the period would be decreased

(ii) there would be less damping/more oscillations before the pendulum comes to rest

**(2)**

**[Total 7]**

**M44.** (a) (i) period = 1.8 or 1.9 s or *f = 1/T*

0.56 (0.556)Hz or 0.53 (0.526) s if *T* = 1.9 s

(ii) 0.074 – 0.078 m

(iii) frequency remains constant

amplitude reduces

**(5)**

(b) attempt shows understanding of π/2 phase difference

(lag or lead)

constant phase difference and amplitude

(acceptable quality)

**(2)**

(c) (i) maximum acceleration = ω2*A* or ω = 2π*f*

0.91(3) m s−2 or 0.83 if *T =* 1.9 s

(ecf from (a) (i)) and (a) (ii))

(not allowed if period given as answer in (i))

(ii) (maximum) speed = ω*A* (0.267 m s−1)

use of KE = ½ *mv*2 with at least *m* (= 8 × 10−3) substituted

(2.5 to 3.0) × 10−4 J

**(5)**

**or**

maximum restoring force = 8.0 × 10−3 × 0.91

oscillator energy = ½ × *F* × *A* **or** 0.5 × 8.0 × 10−3 × 0.91 × 0.075

(2.5 to 3.0) × 10−4 J

**[Total 12]**

**M45.** (a) (i) energy/heat input needed to change liquid into gas/vapour when at its boiling point/without change of temperature

energy per unit mass/1 kg

(ii) idea that more energy has to be supplied to separate molecules than to break solid bond  
**or**for vaporisation work is done against atmospheric pressure  
**or**Idea that there is a greater change in PE in L-G than S-L

**(3)**

(b) (i) *ml = Mc*∆*θ* or energy gain by water = 89250 (J)  
*m* × 2.3 × 106 = 0.25 × 4200 × 85

*m =* 0.0388 kg

total mass = 0.289 (0.29) kg (0.25 + their *m*)

(ii) energy from steam is needed to raise temperature of the cup

**or**

energy/heat will be lost to the surroundings/cup/tube during the heating

**(4)**

**[Total 7]**

**M46.** (a) (i) *R*D = 1.3 × 21/3 = 1.64 fm **(1)** *RT* = 1.3 × 31/3 = 1.64 fm **(1)**

(ii) energy at ‘contact’ = **(1)**



= 6.56 × 10–14 J **(1)**

= 4.10 MeV **(1)**

**(Max 5)**

1. energy of nucleus = 3/2 *kT* **(1)**

6.56 × 10–14 = 3/2 × 1.38 × 10–23 × *T* **(1)**

gives *T* = 3.2 × 109 K **(1)** (marks available for alternative sensible use of energy data)

reference to range of speeds (or energies) of nuclei (or atoms) **(1)**

**(Max 3)**

**[Total 8]**

**M47.** (a) (i) *free:* system displaced and left to oscillate **(1)**

(ii) *forced:* oscillation due to (external) periodic driving force [or oscillation at the frequency of another vibrating system] **(1)**

**(2)**

(b) (i) *k* = = 6.0 × 104 Nm–1 **(1)**

(ii) T = 2*π* = 2*π*

giving 0.78 s **(1)**

**(3)**

(c) (i) *t* = = = 0.80 s **(1)**

(ii) time ≅ period of free oscillations, resonance **(1)**i.e. large amplitude oscillations **(1)**

**(3)**

**[Total 8]**

**M48.** (a) (i) **(1)** = 2.5 x 105 Vm-1 **(1)**

(ii) *F* = *Eq* = 2.5 × 105 × 3.2 × 10–19 **(1)** = 8.0 × 10–14 N **(1)**

(iii) **or** **(1)**

(= 3.1 × 105 m s–1)

**(Max 5)**

(b) (i) field into paper **(1)**

(ii) force **⊥**r motion in B-field **(1)**   
∴ directed towards centre of a *circular* path **(1)**

(iii) so **(1)**

for B, *q* constant *r* ∝ *mυ*, momentum **(1)**

*r* = = 0.33 m **(1)**

**(6)**

(c) greater mass, so smaller speed at Q **(1)**

greater momentum justified e.g. *E* = (*E* const) **(1)**

∴ greater radius **(1)**

**(Max 2)**

**[Total 13]**

**M49.** (a) (i) no net flow of (thermal) energy (between two or more bodies) **(1)**bodies at same temperature **(1)**

(ii) (kinetic) energy is exchanged in molecular collisions **(1)**until average kinetic energy of all molecules is the same **(1)**

**(Max 3)**

(b) (i) *crms* = **(1)**

= 1340m s–1 **(1)**

(ii) average k.e. of nitrogen molecules = average k.e. of helium molecules **(1)**

= × (1340)2 = 5.97× 10–21 J **(1)**

*alternative schemes for (ii)*:

average k.e. = *kT* **(1)**

= × 1.38 × 10–23 ×290 = 6.00 × 10–21 J **(1)**

**or**

average k.e. = **(1)**

= × = 6.00 × 10–21 J **(1)**

(iii) use of *p* = or equivalent [or, at same temperature, *p* ∝ no. of molecules] **(1)**

*p*He = × 120 = 80 kPa **(1)**

**(6)**

**[Total 9]**

**M50.** (a) (i) more collisions (with wall) per second **(1)**and more momentum change per collision **(1)**greater force because more momentum change per second (greater pressure) **(1)**

(ii) (same pressure) faster molecules so more momentum change per collision **(1)**greater volume, fewer collisions per second [or greater volume to maintain same pressure] **(1)**

**(Max 4)**

(b) (i) **(1)** = 5.94 × 10–3 m3 **(1)**

(ii) **(1)**

= 1000 K (727 °C) **(1)**

**(4)**

**[Total 8]**

**M51.** (a) (i) (use of Δ*Q* = *mc*Δ*θ* gives) *Q* = 30 × 1000 × 15 **(1)**= 4.5 × 105 J **(1)**

(ii) *P* × *t* = 4.5 × 105 **(1)**

*t* = = 225 s **(1)**

(allow C.E. for value of *Q* from (i)

**(4)**

(b) heat is lost to surroundings or other objects in room or to heater itself **(1)**more (thermal) energy required from heater **(1)**

[or because convection currents cause uneven heating]  
[or rate of heat transfer decreases as temperature increases]

**(2)**

**[Total 6]**

**M52.** (a) (i) *T* (=273 + 22) = 295 (K) **(1)**

(ii) *pV* = *nRT* **(1)**105 × 103 × 27 = *n* × 8.31 × 295 **(1)***n* = 1160 (moles) **(1) (**1156 moles)  
(allow C.E. for *T* (in K) from (i)

(iii) *N* = 1156 × 6.02 × 1023 = 7.0 × 1026 **(1)** (6.96 × 1026)

**(5)**

(b) (i) decreases **(1)**because temperature depends on mean square speed (or )  
[or depends on mean *E*k] **(1)**

(ii) decreases **(1)**as number of collisions (per second) falls **(1)**rate of change of momentum decreases **(1)**

[or if using *pV* = *nRT*decreases **(1)**as *V* constant **(1)**as *n* constant **(1)**]  
[or if using p = 1/3*ρ*decrease **(1)**as *ρ* is constant **(1)**as  is constant **(1)**]

**(Max 4)**

**[Total 9]**

**M53.** (a) (i) quantity of energy supplied to unit mass **(1)**

which raises temperature by 1°C [or 1K] **(1)**

(ii) quantity of energy required to change state of unit mass **(1)**

solid to liquid [or ice to water] **(1)**

without change of temperature **(1)**

**(Max 4)**

(b) (i) *Q* (= *mc*Δ*θ* ) = 0.15 × 1200 × (58 – 18) = 7200 (J) **(1)**

P = = 24 W **(1)**

(ii) *Q* = 24 × 7 × 60 = 10080 (J) **(1)**

10080/0.15 gives *l* = 67200 J kg–1 **(1)**

(iii) 24 × 4 × 60 = 0.15 × *sL* × (94 – 58) **(1)**

gives *sL* = 1070 J kg–1 K–1 **(1)**

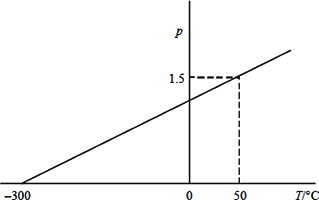
**(6)**

**[Total 10]**

**M54.** (a) **(1)** = (6.71 × 104 mol)

number of molecules = *nNA* **(1)**= 6.71 × 10–4 × 6.02 × 1023= 4.04 × 1020 **(1)**[or equivalent solution using *pv* = *NkT*]

**(3)**

(b)

straight line with positive gradient **(1)**through (50, 1.5) **(1)**crosses temperature axis between –250 and –300°C **(1)**

**(3)**

(c) number of moles left in container after valve opens

**(1)** (= 5.04 × 10–4 mol)

∴ number of molecules left in container = 5.04 × 10–4 × 6.02 × 1023 = 3.03 × 1020 **(1)**∴ number of molecules that escape = 4.04 × 1020 – 3.03 × 1020 = 1.01 × 1020 **(1)**

**or**∴ number of moles that escape (= 6.71 × 10–4 – 5.04 × 10–4) = 1.67 × 10–4 **(1)**∴ number of molecules that escape= 1.67 × 10–4 × *NA* = 1.01 × 1020 **(1)**

**(3)**

**[Total 9]**

**M55.** (a) adequate scale **(1)**   
points plotted correctly **(1)**   
best fit line (at least a point to right and left of line) **(1)**

**(3)**

(b) use of triangle for at least half line **(1)**

gradient = = 0.056 ± 0.004 (°C / s) **(1)**

**(2)**

(c) gives 48 = *c* × (1.0) × 0.056 **(1)**

*c* = 860 ± 60 J kg-1K-1 (or J kg-1 °C-1) **(1)**

**(2)**

(d) (use of *E*th = *ml* gives) 48 × 200 = 32 ×10-3 × *l* **(1)**   
*l* = 3.0 × 105 J kg-1 **(1)**   
sensible assumption, e.g. no heat lost to surroundings or temperature does not change or heat is transferred to ice **(1)**

**(3)**

**[Total 10]**

**M56.** (a) (i) graph:

scales (points spread over at least half graph paper, each) **(1)**   
correct points (plotted within ½ square) **(1)**   
best fit line (if origin shown, line must pass through it) **(1)**

*Ek* at 350 K = 7.22 × 10–21J (accept 7.23 to 7.27) **(1)**

(ii) gradient = = 2.07 × 10–23(JK–1) (accept 2.00 to 2.15)

(use of *kT* = *Ek* gives) gradient = *k* **(1)** (accept C.E for gradient)

*k* = = 1.38 ×10–23 **(1)** J K–1 **(1)**

**(8)**

(b) (i) kinetic energy is conserved **(1)**

(ii) time of collision is negligible (compared to time between collisions)   
[or large number of molecules,   
volume negligible (compared to volume of container),   
no intermolecular forces,   
rapid random motion] **(1)**

(iii) temperature proportional to *Ek* **(1)**   
at 0 K, *Ek* would be zero **(1)**   
[or sketch graph of *Ek* vs *T / K* to give straight line through origin **(1)**   
graph explained **(1)**]

**(4)**

**[Total 12]**

**M57.** (a) *p*: pressure and *V*: volume **(1)**   
*N*: number of molecules **(1)**   
*m*: mass of one molecule / particle / atom **(1)**   
: mean square speed **(1)**

**(4)**

(b) (i) molecules have a range of speeds **(1)**   
they have no preferred direction of movement **(1)**

(ii) elastic collisions   
intermolecular forces are negligible (except during collisions)   
volume of molecules negligible (compared to volume of container)   
time of collisions negligible (compared to time between collisions)   
all molecules identical   
laws of statistics apply or large number of molecules   
Newtonian laws apply any two **(1)** **(1)**

**(Max 3)**

(c) molecules collide (with the walls) **(1)**   
walls exert a force on the molecules **(1)**   
molecules exert an (equal) force (on the walls) **(1)**   
creating pressure **(1)**   
molecule momentum changes

**(Max 4)**

**[Total 11]**

**M58.** (a) (i) (in 1 s), *E* = 0.045 × 4200 × (47 – 15) **(1)**= 6050 J

(ii) *P=* = 6.0 kW **(1)**

**(3)**

(b) (i) (use of *P = VI* gives) *I* = = 26 A **(1)** (26.3 A)

(allow C.E. for value of P from (a))

(ii) radius = 1.2 × 10-3 (m) **(1)**   
cross-sectional area = *π*(1.2 × 10-3)2 (or 4.5 × 10-6(m2)) **(1)**

**(1)**

= **(1)**

= 3.8 × 10-3 Ω m-1

(allow C.E. for value of A)

(iii) = 26 x 3.8 x 10-3 = 0.1 (V m–1) (per wire)

two wires per cable gives pd per metre = 2 × 0.1 **(1)**  
(= 0.20 V m–1) **(1)**

1. maximum length = = 30 m **(1)**

**(9)**

**[Total 12]**

**M59.** (a) (i) *p V* = *nR T* **(1)***V* = **(1)** (gives *V* = 7.2 × 10–2m3)

(ii) (use of *E*k = *kT* gives) *E*k = × 1.38 × 10–23 × 290 **(1)**

= 6.0 × 10–21 (J) **(1)**

**(4)**

(b) (use of *pV* = *nRT* gives) **(1)**

[or use *p* *n*]

*n =* 13 moles **(1)** (12.5 moles)

**(2)**

(c) pressure is due to molecular bombardment [or moving molecules] **(1)**when gas is removed there are fewer molecules in the cylinder [or density decreases] **(1)**

(rate of) bombardment decreases **(1)**molecules exert forces on wall **(1)**

****is constant **(1)**

[or *pV* = *Nm (c2)* **(1)**

*V* and *m* constant **(1)**

*(c2)* constant since *T* constant **(1)**

*p*  *N* **(1)**]

[or *p* = *ρ*(c2) **(1)**

explanation of *ρ* decreasing **(1)**

*(c2)* constant since *T* constant **(1)**

*p* (c2) *ρ* **(1)**]

**(Max 4)**

**[Total 10]**

**M60.** (a) (i) (use of ΔQ = *mc*Δθ gives) energy lost by water = 0.20 × 4200 × 20 **(1)**= 1.7 × 104 J  **(1)** (1.68 × 104 J)

(ii) rate of loss of energy = = 28 (W) **(1)** (allow C.E. for value of energy lost in (i))

**(3)**

(b) (i) (use of Δ*Q* = *ml* gives) (28 × *t*) = 0.20 × 3.3 × 105 **(1)***t* = 2.4 × 103 s **(1)** (2.36 × 103 s)  
(allow C.E. for value of rate of loss of energy in (a)(ii)

(ii) e.g. constant rate of heat loss **(1)**ice remains at 0°C **(1)**

**(Max 3)**

**[Total 6]**

**M61.** (a) (i) *pV* = *nRT* **(1)**

(ii) all particles identical or have same mass **(1)**collisions of gas molecules are elastic **(1)**inter molecular forces are negligible (except during collisions) **(1)**volume of molecules is negligible (compared to volume of container) **(1)**time of collisions is negligible **(1)**motion of molecules is random **(1)**large number of molecules present   
(therefore statistical analysis applies) **(1)**monamatic gas **(1)**Newtonian mechanics applies **(1)**

**(Max 4)**

(b) *E*k = or  **(1)**

= **(1)**

= 6.1 × 10–21 J **(1)** (6.07 × 10–21 J)

**(3)**

(c) masses are different **(1)**hence because Ek is the same, mean square speeds must be different **(1)**

**(2)**

**[Total 9]**

**M62.** (a) (i) (use of *E = Pt* gives) *E* = 3000 × 320 = 960 kJ **(1)**

(ii) (use of *Q = mc*Δθ gives) *Q* = 2.4 × 4200 (100 - 16) **(1)**   
= 850 kJ **(1)**

(iii) energy needed to heat the kettle material **(1)** [or heat loss to surroundings]

**(4)**

(b) (i) (use of *I* = gives) *I* = = 13 (A) **(1)**

(use of *V = IR* gives) *R=* = 18 Ω **(1)**  (17.7 Ω)

(allow C.E. for value of *I*)  
[or correct use of *R* = to give correct *R*]

(ii) *A* = (m2) **(1)** (= 3.32 ×10–7(m2))

(use of *ρ* = gives) **(1)**

= 2.3 × 10-5 Ω m **(1)**    (2.35 × 10-5 Ωm)   
(use of R = 18 Ω gives *ρ* = 2.4 × 10-5 Ω m)  
(allow C.E. for value of *R* from (i) and value of *A*)

**(5)**

**[Total 9]**

**M63.** (a) (use of *E*k = ½*mv2* gives) *E*k = × 95 × 8.02 **(1)**

= 3040 J **(1)**

**(2)**

(b)     (i)      Δ*Q* = 0.60 × 3040 = 1824 (J) **(1)**          (allow C.E. for *E*k from (a))  
(use of Δ*Q* = *mc* Δ*θ* gives)       1824 = 0.12 × 1200 Δ*θ* **(1)**Δ*θ* = 13 K **(1)      (**12.7 K)  
          (allow C.E. for Δ*Q*)

(ii)     no heat is lost to the surroundings **(1)**

**(4)**

**[Total 6]**

**M64.** (a) (i) (use of gives) **(1)**

= 40(.1) moles **(1)**

(ii) = 9.8**(1)** moles **(1)**

**(3)**

(b) (total) = (40 × 6 × 1023) − (9.8 × 6 × 1023) = 1.8(1) ×1025 **(1)**

(allow C.E. for incorrect values of *n* from (a))

(oxygen molecules) = 0.23 × 1.8 ×1025 = 4.2 × 1024 **(1)**

**(2)**

**[Total 5]**

**M65.** (a) (i) curve A below original, curve B above original **(1)**

(ii) both curves correct shape **(1)**

**(2)**

(b) (i) (use of *pV* = *nRT* gives) 130 × 103 × 0.20 = *n* × 8.31 × 290 **(1)**

*n* = 11 (mol) **(1)** (10.8 mol)

(ii) (use of *E*k = *kT* gives) *E*k =  × 1.38 × 10–23 × 290 **(1)**

= 6.0 × 10–21 J **(1)**

(iii) (no. of molecules) *N* = 6.02 × 1023 × 10.8 (= 6.5 × 1024)  
total k.e. = 6.5 × 1024 × 6.0 × 10–21 = 3.9 × 104 J **(1)**(allow C.E. for value of *n* and *E*k from (i) and (ii))  
(use of *n* = 11 (mol) gives total k.e. = 3.9 (7) × 104 J)

**(5)**

**[Total 7]**

**M66.** (a) attractive **force** between point masses **(1)**proportional to (product of) the masses **(1)**inversely proportional to square of separation/distance apart **(1)**

**(3)**

(b) *mω*2*R* = (–) **or**  **(1)**

(use of *T* = gives) **(1)**

*G* and *M* are constants, hence *T*2  *R*3 **(1)**

**(3)**

(c) (i) (use of *T*2  *R*3 gives) **(1)**

*T*m = 87(.5) days **(1)**

(ii) **(1)** (gives *R*N = 4.52 × 1012 m)

ratio = = 30(.1) **(1)**

**(4)**

**[Total 10]**

**M67.** (a) reasons:  
α particle has much more mass/momentum than β particle  
α particle has twice as much charge as a β particle  
α particle travels much slower than a β particle any **two** **(1)** **(1)**

**(2)**

**(QWC 1)**

(b) (i) energy absorbed per sec (= energy released per sec)  
= 3.2 × 109 × 5.2 × 106 ×1.6 ×10–19 **(1)**= 2.7 ×10–3 (J) **(1)** (2.66 × 10–3 (J))

(ii) temperature rise in 1 minute =

(for numerator) **(1)** (for denominator) **(1)**

= 0.90 K (or °C) **(1)**

(allow C.E. for incorrect value in (i))

**(5)**

**[Total 7]**

**M68.** (a) (i) change of momentum (= 0.44 × 32) = 14(.1) kg m s1 **(1)**

(ii) (use of *F* = gives) *F* = **(1)**

= 1.5(3) × 103N **(1)**

(allow C.E. for value of Δ(*mv*) from (i)

**(3)**

(b) (i) deceleration = = 9.8 × 102m s–2 **(1)** (9.78 × 102m s–2)

(ii) (use of *a* = gives)

centripetal acceleration = = 9.3 × 102m s–2 **(1)**

(9.29 × 102 m s–2)

(iii) before impact: radial pull on knee joint due to centripetal acceleration of boot **(1)**during impact: radial pull reduced **(1)**

**(4)**

**[Total 7]**

**M69.** (a) (i) a collision in which kinetic energy is conserved **(1)**

(ii) molecules of a gas are identical [or all molecules have the same mass] **(1)**molecules exert no forces on each other except during impact **(1)**motion of molecules is random [or molecules move in random directions] **(1)**

volume of molecules is negligible (compared to volume of container)  
[or very small compared to volume of container or point particles] **(1)**time of collision is negligible (compared to time between collisions) **(1)**Newton‘s laws apply **(1)**large number of particles **(1)** (any two)

**(3)**

(b) (i) the hot gas cools and cooler gas heats up  
until they are at same temperature  
hydrogen molecules transfer energy to oxygen molecules  
until **average k.e.** is the same  
(any two **(1)** **(1)**)

(ii) (use of *E*k = *kT* gives) *E*k = × 1.38 × 10–23 × 420 **(1)**

= 8.7 × 10–21 J (8.69 ×10–21 J)

**(4)**

**[Total 7]**

**M70.** (a) acceleration is proportional to displacement **(1)**acceleration is in opposite direction to displacement, or towards a fixed point,  
or towards the centre of oscillation **(1)**

**(2)**

(b) (i) *f* = = 1.1 Hz (or s–1) **(1)** (1.09 Hz)

(ii) (use of *a* = (2π*f*)2*A* gives) *a* = (2π × 1.09)2 × 76 × 10–3 **(1)**= 3.6 m s–2 **(1)** (3.56 m s–2)  
(use of *f* = 1.1 Hz gives *a* = 3.63 m s–2)  
(allow C.E. for incorrect value of *f* from (i))

(iii) (use of *x* = *A* cos(2π*ft*) gives) *x* = 76 × 10–3 cos(2π × 1.09 × 0.60) **(1)**= (–)4.3(1) × 10–2m **(1)** (43 mm)  
(use of *f* = 1.1 Hz gives *x* = (–)4.0(7) × 10–2 m      (41 mm))  
direction: above equilibrium position or upwards **(1)**

**(6)**

(c) (i) graph to show:  
correct shape, i.e. cos curve **(1)**correct phase i.e. –(cos) **(1)**

(ii) graph to show:  
two cycles per oscillation **(1)**correct shape (even if phase is wrong) **(1)**correct starting point (i.e. full amplitude) **(1)**

**(Max 4)**

**[Total 12]**

**M71.** (a) ½ *Fx* or ½ *kx*2

29.4 mJ

**(2)**

(b) (i) amplitude clearly marked on diagram - must touch lines or be an accurately drawn equivalent distance

**(1)**

(ii) idea of interchange of p.e. and k.e.

appropriate use of elastic p.e. at start of cycle and of gravitational p.e.at highest point  
+ some k.e. in between.

**(2)**

**[Total 5]**

**M72.** (a) 2π/*T* or 2π*f* **or** angular speed/velocity/frequency/Δθ ÷ Δ*t with symbols defined*

displacement direction opposite to acceleration vector/  
acceleration towards central point/equilibrium point

**(2)**

(b) (i) ω = 2π/*T* = 2.86 rad/s *can appear as* (2π/2.2) in subst  
F = 0.053(1) N

**(2)**

(ii) to centre of turntable/rotation/circle *not* ‘towards centre’

**(1)**

(c) (i) *l* = [*T*2*g*/4π2] = 1.20 m

**(1)**

(ii) correct use of *a = ω2A*

or accel = *v*2/*r* or *F/m* approach  
*a* = 1.0 / 1.1 / 1.04 / 1.06 m s–2 [cao]

**(2)**

(d) *a* origin at zero

*a* in antiphase

k.e always positive and start at maximum

k.e. twice *f* and good shape

**(4)**

**[Total 12]**

**M73.** (a) *pV* = *constant* seen

p = 88 kPa

**(2)**

(b) completes correct shape curve to (0.85,88 000 **or** 90000),

then horizontal to 0.35 m3

**(2)**

(c) attempts to measure area [graph evidence or words]

correct use of graph scale

answer in range (80 – 91) Kj

**(3)**

(d) done **on** gas because it is compressed

**(1)**

**[Total 8]**

**M74.** (a) Max to zero to max with zero at 0 displacement and correct amplitude correct shape drawn with reasonable attempt to keep total energy constant, crossing at 1 × 10–2 J

**(2)**

(b) (i) 0.044 m

**(1)**

(ii) *x* = 0.044 cos 2π3.5*t* (0.044 cos 22*t*) or *x* = 0.044 sin 2π3.5*t* etc

ecf for A

**(1)**

(iii) *α*max = (2π3.5)2 0.044

21 (21.3) m s–2 ecf for A and incorrect 2π*f* from (ii)

(0.042 gives 20.3; 0.04 gives 19.4)

**(2)**

**[Total 6]**

**M75.** (a) (i) 1 N per A per m  
**or** 1 Wb m–2**or** quotes: *B* = *F*/*IL* with terms defined  
**or** induced *EMF* = Δ*BAN*/*t* with terms defined  
**or** a slightly flawed attempt at the definition in statement form

It is the flux density (perpendicular to a wire) that produces a force of 1N per m on the wire when the current is 1A  
**or***B* = *F*/*IL* **and** 1 T is flux density when *F* = 1N; *I* = 1A and *L* = 1 m  
**or** induced *EMF* = Δ*BAN* /*t* and 1 T is the flux change when emf = 1V for *A*=1 *N* =1 and *t* =1 or similar

**(2)**

(ii) force on charge due to *E* field , *F*E= *Eq* **or** *Vq*/*d* **and** force due to *B* field, FB = *Bqv***or** *Eq*=*Bqv,* cancels *q* **and states explicitly** *v* = **or** *v* =

**(2)**

(iii) *v* = 20000/0.14 (seen) **or** 143 × 103 m s–1

**(1)**

(b) (i) *Bqv* =*mv*2/*r* or *r* = *mv*/*Bq* ( allow *e* instead of *q*)  
mass of ion = 1.7 × 10–27 × 58 (may be in equation)  
**or** (9.86 × 10–26 kg seen)

**or**radius = 0.14 m (may be in equation)

Substitutes and arrives at 0.62 to 0.63 T

**(3)**

(ii) Calculates new radius (0.145 m) or diameter (0.288 m)  
using *r* *m* or otherwise **allowing ecf**

0.010 m (condone 0.01 m) or 0.0096 – 0.0097 m  
(Allow 0.0079 m or 0.008 m due to use of different s.f.s for *B* and *v* )

**(2)**

**[Total 10]**

**M76.** (a) energy required to heat the ice up

2100 J needed to **raise** / extracted to lower temperature  
of 1 kg by 1 deg (K or °C)

**(2)**

(b) (i) **either** water @ 18 to water @ 0 = 75600 J **or** ice @ 0 to ice at –5 = 10500 J

water @ 0 to ice @ 0 = 330000 J

total = 416100 J

**(3)**

(ii) their bi × 1.5 **or** their bi/300

power = 2080 W  
[0.4 MJ yields 2 kW condone 1 sf; J s–1]

**(2)**

**[Total 7]**

**M77.** (a) displacement negative cosine

velocity consistent with first graph

acceleration consistent with first or second graph

at least one cycle, constant amplitude (condone small decay ), include *A* for   
displacement, reasonably drafted

(b) use of *T* = 2π i.e. substituted values or 0.74 seen

use or implied use of *T* =

1.34 Hz

**[Total 7]**

**M78.** (a) force is needed toward the centre or there is acceleration toward the centre

movement to the left/toward A/away from the centre (or indicated on diagram)

right hand spring (attached to **B)** has to stretch to provide force

**(3)**

(b) (i) acceleration = *v*2/r or speed = 12.5 m s–1or a *=* *r* *ω2* and *v* *=* *rω* or *ω* *=* 0.52 rad s–1 or 452/0.024

6.5 m s–2 8.4 × 104 km h–2 unit essential

**(2)**

(ii) Force on mass = 0.35 × (i) (2.28 N if correct)  
or use of F = *mrω*2 (0.35 × 24 × 0.522)

0.82mm or 0.83 mm if (i) is correct  
Movement = 12.6 × (i) mm

**(2)**

(c) (i) T *=* *2π* or a = (*2πf*)2*A* or *f* = 1.4Hz or   
ω *=* 8.9 rad s–1

*k* = 27.8 N m–1 use of *T* *=* 1/*f* or *2π*/*ω*

0.71 s (allow 0.70 s to 0.72 s)

**(3)**

(ii) sketch showing amplitude reducing with time starting at max ignore changing period

labelled consistently with answers to (b)(ii) and (c)(i).  
(0.71 s and initial displacement 82 mm)  
condone only one period shown correctly

**(2)**

**[Total 12]**

**M79.** (a) (i) collisions with/bombardment by air molecules (condone particles)

**(1)**

(ii) motion of air molecules (“they are“) random (in all directions)

**fast moving**

air molecules small or much smaller than smoke particles

**(Max 2)**

(b) (i) 3/2kT or substituted values (independent of powers)

*do not allow all equations written*

6.21 × 10–21 J

**(2)**

(ii) pV = 1/3 Nm<c2>

relates Nm/V to *ρ*

2.4 × 105 m2s–2

(allow compensation of ½ m<c2> for 1)

**(3)**

(iii) there will be a range of speeds

there will be molecules with lower speeds  
than mean /average  
means higher and lower values

**(2)**

**[Total 10]**

**M80.** (a) (i) Unchanged

**(1)**

(ii) ½ OWTTE

**(1)**

(iii) *T* = 2π√ (*M/k*)

*T*2 = 4π2 × *M/k*  (square and re-arrange)

**(2)**

(iv) *T* = 1/0.91 [= 1.1 s]

1.12 × 190000 /4π2

So *m*platform = (cand ans for *M* –5300) leading to correctly evaluated answer

**(3)**

(b) *v* shape correct [*cos* graph]

**or** *v* shape inverted [*-cos* graph]

k.e. always +ve

k.e. freq doubles

k.e. shape acceptable

**(5)**

(c) **max 4 from**:  
mention of forced oscillation  
platform frequency always matches lorry’s frequency  
mention of resonance  
small amplitude when well away from resonant frequency  
large amplitude at resonance          [do not infer small amp  
point from this] resonant freq close to 0.91 Hz

**(4)**

**[Total 16]**

**M81.** (a acceleration/force is directed toward a (fixed) point/the centre/the equilibrium position  
**or***a* = –*kx* + ‘–’ means that *a* is opposite direction to *x*

acceleration/force is proportional to the distance from the point/displacement  
**or***a* = –*kx* where *a* = acceleration; *x* = displacement and *k* is constant

**(2)**

(b) (i) 3.2 = 2π√*l*/9.8 (condone use of *g* = 10 m s2 for C mark)  
(use of *a* = –*ω*2*x* is a PE so no marks)

2.5(4) m

**(2)**

(ii) Correct value at 0.5 m and correct curvature

Energy at 1 m = 160 J

**(2)**

**[Total 6]**

**M82.**(a) (i) 15 rev / s = 30π rad / s **or** *v* = 51 / 52 m s–1 [could appear in subst]

*F* = *mw*2*r* [or *mv*2 / *r* & *v* = *ωr*]

appropriate sub leading to 7.33 kN [2+sf evaluation mandatory]

(ii) to centre of rotor OWTTE

(iii) *stress* = *F* / *A*

correct substitution from ai

(iv) 0.55 × 2.09 × 107 / 6 ×1010 [or ε = 3.3 × 10–4 ]

= 0.192 mm

(v) ½ × 7.32 × 103 × 1.92 × 10–4 [ecf]

= 0.702 J

(b) (i) volume pushed down [per second] = *Av* [mass = ρ × volume]

Change of momentum [per second] = mass pushed down per second × *v*

(ii) Upward force = 900 N OWTTE [penalise use of 900*g*]   
OR area swept out by blades = π × 0.552

900 = (0.55)2 π1.3*v*2

= 27 m s–1

**(3)**

**[Total 15]**

**M83.** (a) Time for one cycle

One cycle defined correctly in terms of diagram, can be on diagram

**(2)**

(b) B

Mention of air resistance, allow drag OR bob faster in centre of motion

Links two ideas

**(3)**

**[Total 5]**

**M84.**(a) (i) acceleration (not *a*) and displacement (not *x*) are in opposite directions  
OR restoring force/acceleration always acts toward rest position

**(1)**

(ii) (+) sine curve consistent with *a* graph

**(1)**

(b) (i) statement that *E*K = *E*P

statement of max values considered

*E*P = ½ *k*(Δ*l*)2 or *E*Pmax = ½ *kA*2

correctly substituted values

*E*K = 3.7 × 10–2 J

OR  
*f* = 1/*T* or *T* = 3.97 s or period equation

leading to *f* = 0.252 Hz

ωmax = 1.58 rad s–1 or *v*max = 0.055ms–1 (seen or used)

substituted values into *E*K = ½*mA*2ω2 or *E*K = ½mv2

*E*K = 3.7 × 10–2 J

**(5)**

(ii) any attenuation from *t* = 0 seen

10 mJ or *E*0/4 at either 4s or third hump

consistent period values minima at 1 and 3s; maxima at 0 and 4s

**(3)**

**[Total 10]**

**M85.** (a) (i) 230 × √2 = 325 (V) ✔

(2 × 325 =) 650 to 651 V ✔

*allow doubling their incorrect peak voltage (162.6 × 2) by use of 2 as an attempt to find peak-to-peak for 1 mark but not just 2 × 230*

**(2)**

(ii) *(use of P = V2/R)*

*P* = 2302/12 ✔

*P* = 4.4 × 103 (W)✔ cao

2 sig. figs. Incorrect answer must be supported by working ✔

*Allow their incorrect answer (a)(i)2 ÷ 12*

***Or*** *3252 ÷ 12 as a use of for 1 mark*

*Alternative*

*For first mark*

*I =* ***and*** *P=VI allowing their incorrect answer*

*(a)(i) or 325 as sub for V for 1 mark*

*Answers 8.8 kW (325V) and 35 kW (650V)*

**(3)**

(b) (i) there is a pd / voltage across the cable ✔

pd / voltage across cooker is 230 V minus this pd / voltage ✔

2nd mark depends on 1st mark in all

*The current is lower due to the resistance of cable / The current is lower as circuit resistance increases ✔*

*pd across oven is lower since V=I × Resistance of element ✔*

***or***

*Resistance of the cable is in series with element ✔*

*Voltage splits (in ratio ) across these resistances ✔*

**(2)**

(ii) resistance of cable = 2 × 3.15 × 0.0150 = 0.0945 ✔

*Allow power 10 error here*

✔

**Or** **and**

=228 V ✔ cao

*Allow their incorrect Rcable correctly substituted for 2nd marking*

**(3)**

(iii) 230 − their (b) (ii) or 19 (A) quoted for current or equivalent seen in equation

(230 / 12.0945) ✔

(*P* =) 34.2 to 42.3(W) ✔ correct working

ecf as P = (230- (b)(ii))2 / their Rcable

**(2)**

(iv) minimise power loss / maximise efficiency of oven / ensure element gets as hot as possible ✔

avoid overheating / fires ✔

*not just to carry a large current / larger pd across element*

*Either order*

**(2)**

**[Total 14]**

**M86.** (a) (i) energy released when the separate nucleons combine to form the nucleus

**or** energy needed to separate the nucleus into individual nucleons owtte

**(1)**

(ii) BE in J = 8 × 1.1314027 × 10–12 (9.05122 × 10–12)

BE in eV = 5.6570135 × 107 eV or BE/nucleon = 7.07 × 106 MeV

56.570135 (MeV) (condone 3 sf consistent with electron charge)

**(3)**

(b) (i) change in BE = 0.0147120 (× 10–12) J

use of *E = mc2* with their energy 1.635 × 10–31 kg

**(2)**

(ii) use of charge on alpha particles = 2 *e*

attempt to substitute in PE =

2.4(2.39) × 10–13 J

**(3)**

(ii) the mass of Be > mass of 2 He nuclei

explains that when they touch there is zero KE only mass available is that of the two alpha particles

extra KE provides the increase in mass of the beryllium-8 compared with the 2 He nuclei

**(3)**

**[Total 12]**

**M87.** (a) (i) force per unit mass ✓   
a vector quantity ✓

*Accept force on 1 kg (or a unit mass).*

**(2)**

(ii) force on body of mass *m* is given by ✓

gravitational field strength ✓

*For both marks to be awarded, correct symbols must be used for M and m.*

**(2)**

(b) (i) ✓

= 2.45 × 103 (N) ✓ to **3SF** ✓

*1st mark: all substituted numbers must be to at least 3SF.   
If 1.39 × 107 is used as the complete denominator, treat as AE with ECF available.   
3rd mark:* ***SF mark is independent.***

**(3)**

(ii) *F* = *mω2 (R + h)* gives *ω*2 = ✓

from which *ω* = 2.19 × 10–4 (rad s–1) ✓

time period **or**= 2.87 ✓ 104 s ✓

[**or** *F* =

gives *v*2 ✓

from which *v* = 4.40 ✓ 103 (m s–1) ✓

time period *T =*  **or** = 2.87 × 104 s ✓ ]

[**or** *T*2 = ✓

= ✓

gives time period T = 2.87 × 104s ✓ ]

= = 7.97 (hours) ✓

number of transits in 1 day = = 3.01 ( ≈ 3) ✓

*Allow ECF from wrong F value in (i) but mark to max 4 (because final answer won’t agree with value to be shown).*

*First 3 marks are for determining time period (or frequency). Last 2 marks are for relating this to the number of transits.*

*Determination of f = 3.46 × 10–5 (s–1) is equivalent to finding T by any of the methods.*

**(5)**

(c) acceptable use ✓   
satisfactory explanation ✓   
e.g. monitoring weather **or** surveillance:   
whole Earth may be scanned **or** Earth rotates under orbit   
**or** information can be updated regularly   
**or** communications: limited by intermittent contact   
**or** gps: several satellites needed to fix position on Earth

*Any reference to equatorial satellite should be awarded 0 marks.*

**(2)**

**[Total 14]**

**M88.** (a) work done [or energy needed] per unit charge[**or** (change in) electric pe per unit charge] 

on [or of] a (small) positive (test) charge 

in moving the charge from infinity (to the point) 

[**not** from the point to infinity] 

**(3)**

(b) (i) *V* =

gives Q (= 4π*ε0rV*) = 4π × 8.85 × 10–12 × 0.30 × 3.0 

= 1.0 × 10–10 (C) 

to **2 sf** only 

**(3)**

(ii) use of V ∝ gives VM =  (= (+) 1.0 V)

**(1)**

(iii)  (= 2.50 V m–1)

**(1)**

(c) (i) uniformly spaced vertical parallel lines which start and end on plates 

relevant lines with arrow(s) pointing only downwards 

**(2)**

(ii) = 3.3(3) (V m–1) 

**(1)**

(iii) part (b) is a radial field whilst part (c) is a uniform field 

[**or** field lines become further apart between **L** and **M** but are equally spaced between **R** and **S**]

**(1)**

**[Total 12]**

**M89.** (a) time to halve = 0.008 s or two coordinates correct

*C = T1/2*/(0.69 × 150) or eg 0.4 = 1.4 e–0.015/150C

77 μF (consistent with numerical answer)

**(3)**

(b) as capacitor discharges: **🗸**

pd decreases **🗸**

current through resistor decreases (since *I* ∝ *V*) **🗸**

rate at which charge leaves the capacitor decreases (since *I = ∆Q/∆t*) **🗸**

rate of change of charge is proportional to rate of change of pd (since *VQ*) **🗸**

condone quicker discharge when pd is larger **🗸**

**(Max 3)**

(c) energy stored ∝ *V 2* or use of ½ *CV 2*   
**or** initial energy = 78.4 (or 75.5) μJ   
**or** final energy using V = 0.38–0.4 0 V   
(answer in range 5.6 – 6.4 μJ)

fraction remaining = (0.4/1.4)2 or 0.072 – 0.081   
**or** energy lost = 72 μJ

91.8 to 92.8% lost

**(3)**

(d) (i) charge = 77 μC to 82 μC

**(1)**

(ii) charge required = 77 × 10–6 × 5 × 3.15 × 107 (= 12128 C) or 1A–h =3600 C

3.36(3.4) Ah

**(2)**

**[Total 12]**

**M90.** (a) work done per unit mass in bringing object from infinity to point

potential at infinity zero by definition

work has been done by the field so potential at all points closer than  
infinity negative

**(3)**

(b) use of point on graph allow within ± small square

substitution into *V* = −

range from 590 – 6.90 × 1024 (kg)

**(3)**

(c) (i) ∆Ep =

addition of radius of Earth to give 7.25 × 106 (m)

1.54 × 1010 (J)

**(3)**

(ii) equates and

to give ∆EK =

1.25 × 109 J

positive or increase

**(4)**

(iii) (lower altitude so) gpe decreases ke increases

loss of gpe is twice gain in ke

**(2)**

**[Total 15]**

**M91.** (a) charge (stored)  per unit potential difference 

[**or** *C* = *Q*/*V* where *Q* = charge (stored by one plate)  *V* = pd (across plates) ]

**(2)**

(b) (i) == 2.2 × 10–6 (F)  (or 2.2 μF)

**(2)**

(ii) when *t* = time constant *Q* = 0.63 × 13.2 = 8.3 (μC)  

[**or** = 0.63 × 13(.0) (from graph) = 8.2 (μC)]

reading from graph gives time constant = 15 (± 1) (ms) 

**(2)**

(iii) resistance of resistor = = = 6820 (Ω) 

**(1)**

(iv) gradient = current 

**(1)**

(c) (i) maximum current = = = 0.88 (mA) 

[**or** value from initial gradient of graph: allow 0.70 – 1.00 mA for this approach]

**(1)**

(ii) curve starts at marked *l*max on *l* axis and has decreasing negative gradient 

line is asymptotic to *t* axis and approaches ≈ 0 by *t* = 60 ms 

**(2)**

**[Total 11]**

**M92.** (a) (magnetic) field is applied perpendicular to path **or** direction **or** velocity of charged particles 

(magnetic) force acts perpendicular to path **or** direction **or** velocity of charged particles 

force depends on speed of particle **or** on *B* [or *F* ∝ *v* or *F* = *BQv* explained] 

force provides (centripetal) acceleration towards centre of circle [**or** (magnetic) force is a centripetal force] 

*BQv* = **or** shows that *r* is constant when *B* and *v* are constant 

**(4)**

(b) (i) radius *r* of path = = = 4.30 × 103 (m) (allow 4.3km) 

centripetal force = 3.50 × 10–16(N) 

**(3)**

(ii) magnetic flux density B 

= 7.29 × 10-5  T 

**(3)**

(c) magnetic field must be increased 

to increase (centripetal) force **or** in order to keep *r* constant 

[**or** otherwise protons would attempt to travel in a path of larger radius]

[**or**, referring to , *B* must increase when *v* increases to keep r constant ]

**(2)**

**[Total 12]**

**M93.** (a) (i) horizontal arrow to the left 

**(1)**

(ii) the electrostatic force is unchanged 

because electric field strength is constant 

**(2)**

(b) (i) forces are equal in magnitude but opposite in direction 

(*E* is the same for both and) *Q* has same magnitude but opposite sign 

**(2)**

(ii) acceleration of proton is (much) smaller (than acceleration of electron   
because mass of proton is (much) greater (than mass of electron) 🗸

**(2)**

(iii) acceleration of proton increases and acceleration of electron decreases 

correct reference to changing strength of electric field (for either or both) 

**(2)**

(c) (i) energy of photon E 

= 3.06 × 10–19 (J) 

energy required = = 1.91 (eV) 

**(3)**

(ii) electric field strength = = 2.50 × 104 (V m–1) 

distance = 

= 7.64 10–5(m) 

**(3)**

**[Total 15]**

**M94.** (a) force between two (point) charges is proportional to (product of) charges    
and inversely proportional to the square of their distance apart 

*Formula not acceptable. Accept “charged particles” for charge****s****. Accept separation for distance apart.*

**2**

(b) (i) lines with arrows radiating outwards from each charge    
more lines associated with 6nC charge than with 4nC    
lines start radially and become non-radial with correct curvature   
further away from each charge  correct asymmetric pattern (with neutral pt closer to 4nC charge)

**(Max 3)**

(ii) force = = 

= 4.6(7) × 10−5 (N) 

*Treat substitution errors such as 10−6(instead of 10−9) as AE with ECF available.*

**(2)**

(c) (i) *E*4 = (= 3.11 × 104 V m−1) (to the right) 

*For both of 1st two marks to be awarded, substitution for* ***either*** *or both of E4* ***or*** *E6 (or a substitution in an expression for E6 - E4) must be shown.*

*E*6 = = (4.67 × 104 V m −1) (to the left) 

*If no substitution is shown, but evaluation is correct for E4 and E6, award one of 1 st two marks.*

*E*resultant = (4.67 − 3.11) × 104 = 1.5(6) × 104 

Unit: V m−1 (or N C−1) 

*Use of r = 68 × 10−3 is a physics error with no ECF.  
Unit mark is independent.*

**(4)**

(ii) *direction:* towards 4 nC charge **or** to the left 

**(1)**

**[Total 12]**

**M95.** (a) zero potential at infinity (a long way away)

energy input needed to move to infinity (from the point)  
work done by the field moving object from infinity   
potential energy falls as object moves from infinity

**(2)**

(b) Any pair of coordinates read correctly *±1/2 square*

Use of *Ep* or *V* = *and rearrange for M*

6.4 (±0.5) × 1023 kg

**(3)**

(c) Reads correct potential at surface of Mars = −12.6 (MJ)

*or reads radius of mars correctly (3.5 × 106)*

equates to ½ v2 (condone power of 10 in MJ)

*use of v = √(2GM/r) with wrong radius*

5000 ± *20* m s−1 (condone 1sf e.g. 5 km s−1)

*e.c.f. value of M from (b) may be outside range for other method 6.2 × 10−9x √their M*

**(3)**

(d) Attempts 1 calculation of *Vr*

*Many values give 4.2.... so allow mark is for reading and using correct coordinates but allow minor differences in readings  
Ignore powers of 10 but consistent*

Two correct calculation of *Vr*

Three correct calculations with conclusion

**(3)**

**[Total 11]**

**M96.** (a) direction of induced emf (or current)   
opposes change (of magnetic flux) that produces it 

**(2)**

(b) (i) (volumes are equal and mass of Q is greater than that of P) density of steel > density of aluminium 

*Allow density of Q greater (than density of P).*

**(1)**

(ii) use of *s =½ g t*2 gives *t 2* = (from which *t* = 0.45 s) 

*Backwards working is acceptable for 1st mark*

(vertical) acceleration [**or** acceleration due to gravity] is independent of mass of falling object v [**or** correct reference to *F = mg = ma* with *m* cancelling ] **🗸**

*2 nd mark must refer to mass.  
Do not allow “both in free fall” for 2nd mark.*

**(2)**

(c) (i) moving magnet [**or** magnetic field] passes through tube there is a change of flux (linkage) (in the tube) **🗸**

[**or** flux lines are cut **or** appropriate reference to *ɛ = N (Δɸ / Δt)]* 

*In this part marks can be awarded for answers which mix and match these schemes.*

[**Alternative:**(conduction) electrons in copper (or tube) acted on by (moving) magnetic field of Q   
induced emf (or current) is produced by redistributed electrons ]

**(2)**

(ii) emf produces current (in copper)   
this current [*allow* emf] produces a magnetic field   
this field opposes magnetic field (or motion) of Q  
[**or** acts to reduce relative motion **or** produces upward force]   
no emf is induced by P because it is not magnetised (or not magnet)  
[**or** movement of P is not opposed by an induced emf or current] 

***Alternative*** *to 3 rd mark:   
current gives heating effect in copper and energy for this comes from ke of Q *

**(Max 3)**

(d) time for P is unaffected because there is still no (induced) emf  
[**or** because P is not magnetised  
**or** because there is no repulsive force on P]  
time for Q is shorter (than in (c))  
current induced by Q would be smaller   
because resistance of brass ∝ resistivity and is therefore higher  
[**or** resistance of brass is higher because resistivity is greater]   
giving weaker (opposing) magnetic field  
[**or** less opposition to Q’s movement]

*Condone “will pass through faster” for 2nd mark.  
If emf is stated to be smaller for Q, mark (d) to max 2.*

**(Max 3)**

**[Total 13]**

**M97.** (a) thermionic emission / by heating

cathode heated / heating done by electric current / overcoming work function

*Must mention anode for third mark*

anode which is positive wrt cathode / accelerated by electric field between anode and cathode

**(3)**

(b) (i) one relevant equation seen: *E = V/d / F = Ee / a = F/m*

*Equation should be in symbols*

or F = 2.88 x 10-15

*Substitution may be done in several stages*

3.16 × 1015 (m s−2)

*Must be more than 2 sf*

**(3)**

(ii) *s* = *(ut)*+ *at*2 or *v* = *u* + *at* and *s* = *v*avt OR *s* = *vt* used

*Appropriate symbol equation seen and used for 1st mark*

3.56 × 10−3m

*Expect at least 3 sf but condone 3.6 for candidates who use a = 3.2 × 1015*

**(2)**

(iii) *v* = *u* + *at* / *v* = at v2 = *u*2 + 2*as* used

*May also use eV= ½mv2*

4.74 × 106 m s−1 to at least 3 sf

*Allow 4.8 (2 or more sf) – consistent with use of a = 3.2 × 1015*

**(2)**

(iv) *t* = 7.5 × 10−9 s seen or used

*May use ratios for 1st 2 marks: SV/Sh = VV/Vh*3.53 × 10−2 (m) **ecf** for wrong *t*

adds 3.56 × 10−3 (m) to their 3.53 × 10−2

clipped with b(i) and b(ii)

*Allow reasonable rounding*

**(3)**

**[Total 13]**

**M98.** (a) (i) 60 (degrees) 

**(1)**

(ii) angle required is 150 

which is 5π / 6 [**or** 2.6(2)] (radians) 

*Correct answer in radians scores both marks.*

**(2)**

(b) (i) (magnitude of the induced) emf 

*Accept “induced voltage” or “rate of change of flux linkage”, but not “voltage” alone.*

**(1)**

(ii) frequency **🗸** (= 25 Hz)

no of revolutions per minute = 25 × 60 = 1500 

*1500 scores both marks.*

*Award 1 mark for 40s → 1.5 rev min−1.*

**(2)**

(iii) maximum flux linkage *(=BAN)* = 0.55 (Wb turns) 



peak emf (= *BANω*) = 0.55 × 157 = 86(.4) (V)

**M99.** (a) (i) *Two examples (any order)*:

when charged particle is at rest **or** not moving relative to field 

when charged particle moves parallel to magnetic field 

**(2)**

(ii) **🗸** (gives *BQr = mV*)

*Acceptable answers must include correct force equation (1st point).*

*B* and *Q* are constant so *r* ∝ momentum (*mv*)  

*Insist on a reference to B and Q constant for 2nd mark.*

**(2)**

(b) (i) upwards (perpendicular to plane of diagram) 

*Accept “out of the page” etc.*

**(1)**

(ii) *v*  **🗸** = 8.7(4) x 106 (ms-1)

**(2)**

(iii) length of path followed (= length of semi-circle) = *πr* 

time taken 6.8(3) x 10-8 s **🗸**

*Allow ECF from incorrect v from (b)(ii).*

[**or** gives **🗸**

= 6.8(3) x 10-8 s ]**🗸**

*Max 1 if path length is taken to be 2πr (gives 1.37 × 10−7s).*

**(2)**

(iv) *v* ∝ *r* (and path length ∝ *r* ) 

*t* = (path length /*v*) **or** (*π* / *v* )

so *r* cancels (∴time doesn't depend on *r*) 

[**or** (because *r* cancels) **🗸**]

[**or** *BQv* = *mω*2 *r* gives *BQωr* = *mω*2 *r* and *BQ* = *mω* = 2*πfm* 

∴ frequency is independent of *r*  ]

**(2)**

(c) = 2.16 x 107 (ms-1) **🗸**

*1st mark can be achieved by full substitution, as in (b)(ii), or by use of   
data from (b)(i) and / or (b)(ii).*

*Ek* (= ½ *mv*max 2) = ½ × 1.67 × 10−27 × (2.16 × 107)2     
( = 3.90 × 10−13 J)



*Allow ECF from incorrect v from (b)(ii), or from incorrect t from (b)(iii).*

**(3)**

**(Total 14 marks)**

**M100.** (a) (i) 128 V

**(1)**

(ii) 64 V

*CE from (i)*

**(1)**

(iii) Vrms= 64 / √2 =45.3 V 

*CE from (ii)*

**(2)**

(iv) frequency = 1 / 0.01 = 100  Hz 

*do not accept kHz for unit mark unless correct for candidate value  
if use 10 s instead of 10 ms then can score second two marks*

**(3)**

(b) horizontal line   
through y = 45 (44 − 48) x =0 

*CE from (a)(iii)+ / - half square  
straight line must extend to at least to 6.0 ms*

**(2)**

(c) connect to *y-input*   
adjust / change time base   
so that each division is 2.0 ms OR 20 ms across screen   
reference to y-gain / sensitivity 

*if inappropriate numbers quoted for y gain then lose last mark*

**(Max 3)**

**[Total 12]**

**M101.** (a) (i) *Q*(= *It*) 4.5 × 10–6 × 60 **or** = 2.70 × 10–4 (C) ✓

*C*✓ = 6.1(4) × 10–5 = 61 (μF) ✓

**(3)**

(ii) since *V*C was 4.4V after 60s, when *t* = 30s *V*C = 2.2 (V) ✓   
 [ **or** by use of *Q = It* and *VC = Q / C* ]   
∴ pd across R is (6.0 – 2.2) = 3.8 (V) ✓

*R*= 8.4(4) × 105 (Ω) ✓ (=844 kΩ)

*In alternative method,   
Q = 4.5 × 10–6 × 30 = 1.35 × 10–4 (C)   
VC = 1.35 × 10–4 / 6.14 × 10–5 = 2.2 (V)   
(allow ECF from wrong values in (i)).*

**(3)**

(b) **The candidate’s writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**   
The candidate’s answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

**High Level (Good to excellent): 5 or 6 marks**   
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

*The candidate gives a coherent and logical description of the flow of electrons taking place during the charging and discharging processes, indicating the correct directions of flow and the correct time variations. There is clear understanding of how the pds change with time during charging and during discharging. The candidate also gives a coherent account of energy transfers that take place during charging and during discharging, naming the types of energy involved. They recognise that the time constant is the same for both charging and discharging.*

*A* ***High Level*** *answer must contain correct physical statements about at least* ***two*** *of the following for* ***both*** *the charging and the discharging positions of the switch:-*

* *the direction of electron flow in the circuit*
* *how the flow of electrons (or current) changes with time*
* *how VR and / or VC change with time*
* *energy changes in the circuit*

**Intermediate Level (Modest to adequate): 3 or 4 marks**   
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

*The candidate has a fair understanding of how the flow of electrons varies with time, but may not be entirely clear about the directions of flow. Description of the variation of pds with time is likely to be only partially correct and may not be complete. The candidate may show reasonable understanding of the energy transfers.*

*An* ***Intermediate Level*** *answer must contain correct physical statements about at least* ***two*** *of the above for* ***either*** *the charging or the discharging positions of the switch.*

**Low Level (Poor to limited): 1 or 2 marks**   
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

*The candidate is likely to confuse electron flow with current and is therefore unlikely to make effective progress in describing electron flow. Understanding of the variation of pds with time is likely to be quite poor. The candidate may show some understanding of the energy transfers that take place.*

*A* ***Low Level*** *answer must contain a correct physical statement about at least* ***one*** *of the above for* ***either*** *the charging or the discharging positions of the switch.*

**Incorrect, inappropriate or no response: 0 marks**   
No answer, or answer refers to unrelated, incorrect or inappropriate physics.

**The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.**

***Charging***

* electrons flow from plate **P** to terminal **A** and from terminal **B** to plate **Q** (ie. from plate **P** to plate **Q** via **A** and **B**)
* electrons flow in the opposite direction to current   
  plate **P** becomes + and plate **Q** becomes –
* the rate of flow of electrons is greatest at the start, and decreases to zero  
  when the capacitor is fully charged
* *V*R decreases from E to zero whilst *V*C increases from zero to *E*
* at any time *V*R + *V*C = *E*
* time variations are exponential decrease for *V*R and exponential increase for *V*C
* chemical energy of the battery is changed into electric potential energy  
  stored in the capacitor, and into thermal energy by the resistor (which passes to the surroundings)
* half of the energy supplied by the battery is converted into thermal energy and half is stored in the capacitor

***Discharging***

* electrons flow back from plate **Q** via the shorting wire to plate **P**
* at the end of the process the plates are uncharged
* the rate of flow of electrons is greatest at the start, and decreases to zero  
  when the capacitor is fully discharged
* *V*C decreases from –*E* to zero and *V*R decreases from *E* to zero
* at any time *VC* = – *V*R
* both *V*C and *V*R decrease exponentially with time
* electrical energy stored by the capacitor is all converted to thermal energy by the  
  resistor as the electrons flow through it and this energy passes to the surroundings
* time constant of the circuit is the same for discharging as for charging

*Any answer which does not satisfy the requirement for a Low Level answer should be awarded 0 marks.*

**(Max 6)**

**[Total 12]**

**M102.** (a) (i) force acts towards left or in opposite direction to field lines ✓   
because ion (or electron) has negative charge   
(∴ experiences force in opposite direction to field) ✓

*Mark sequentially.   
Essential to refer to negative charge (or force on + charge is to right) for 2nd mark.*

**(2)**

(ii) (use of *W = F* s gives) force *F* = ✓   
= 6.3(5) × 10–15 (N) ✓

*If mass of ion m is used correctly* ***using algebra*** *with F = ma, allow both marks (since m will cancel). If numerical value for m is used, max 1.*

**(2)**

(iii) electric field strength *E* = 1.3(2) ✓ 104 (N C-1) ✓

[**or** *ΔV* (833 V)

*E* = 1.3(2) ✓ 104 (V m-1) ✓ ]

*Allow ECF from wrong F value in (ii).*

**(1)**

(b) (i) (vertically) downwards on diagram ✓   
reference to Fleming’s LH rule **or** equivalent statement ✓

*Mark sequentially.   
1st point: allow “into the page”.*

**(2)**

(ii) number of free electrons in wire = *A* × *l* × number density   
 = 5.1 × 10–6 × 95 × 10–3 × 8.4 × 1028 = 4.1 (4.07) × 1022 ✓

*Provided it is shown correctly to at least 2SF, final answer alone is sufficient for the mark. (Otherwise working is mandatory).*

**(1)**

(iii) *B* ✓ = 0.16 (0.159) (T) ✓

[**or** B ✓ = 0.16 (0.158) (T) ✓ ]

*In 2nd method allow ECF from wrong number value in (ii).*

**(2)**

**[Total 10]**

**M103.** (a) (i) capacitance *C* ✔

= 8.1 (μF) ✔ (± 0.2 μF)

*1 mark only if correct value of C is found from a single point.*

*2 marks if correct value of C is found from at least 2 points and a mean value, or from gradient. (Check graph.)*

*Accept 8 (μF) if from correct working.*

**(2)**

(ii) additional energy = area between line and *Q* or *V* axis ✔

= {½ × (98.2 − 73.9) × 3.0} + {(98.2 − 73.9) × 9.0} ✔

= {36.5 + 218.7) = 255 J or 2.6 10−4 (J) ✔

[**or**, using ½ *QV*:

additional energy = ½ *Q*2*V*2 − ½ *Q*1*V*1 ✔

= ½ {(98.2 × 12) − (73.9 × 9)} ✔

= 257 μJ or 2.6 × 10−4 (J) ✔ ]

[**or**, using ½ *CV*2:

additional energy = ½ *CV*22 – ½ *CV*12 ✔

= ½ 8.1 × (122 – 92) ✔

= 255 μJ or 2.6 × 10−4 (J) ✔ ]

[**or**, using ½ *Q*2/*C*:

additional energy = ½ *Q*22/C – ½ *Q*12/*C* ✔

= (98.22 – 73.92) ÷ (2 × 8.1) ✔

= 258 μJ or 2.6 × 10−4 (J) ✔ ]

*First scheme: alternative for 2nd mark*

*= {½ × (98.2 − 73.9) × 3.0} + {73.9 × 3.0} ✔*

*All schemes:*

*second mark subsumes the first mark.*

*In all methods, allow tolerance of ± 10 μJ in final answer to allow for variation in graph measurements.*

*Allow ECF for incorrect C value from (a)(i).*

**(3)**

(b) (i) (*V* = *V*0e*–t/RC* gives) 0.2*V*0 = *V*0e*–t/RC*

and 0.2 = e–45/RC ✔

*Condone use of 0.8 for 0.2 in first mark only.*

In 0.2 – **or** In 5 = ✔

time constant *RC* = **or** In 5 = = 28.(0) (s) ✔

**(3)**

(ii) resistance of R = ✔

= 5.96 × 104 (Ω) or 60 kΩ ✔

*Allow ECF for incorrect RC value from (b)(i).*

**(2)**

(ii) tick in 4th box **only**

**(1)**

**[Total 11]**

**M104.** (a) (i) 7.5 × 10−6 (C) or 7.5 µ(C)

**(1)**

(ii) Suitable scale and charge from (i) correctly plotted at 2.5 V

*Large square = 1 or 2 µC* ***or****With false origin then large square = 0.5 µC*

Only a Straight line drawn through or toward origin

Line must be straight, toward origin **and** only drawn between 2.5 V and 1.2 V (± 1 / 2 square on plotted points)

**(3)**

(b) Attempted use of E= ½ *CV*2 Or attempted use of E=½ *QV*

9.38 (µJ) − 2.16 (µJ) seen  
**or** E = ½ *× 3 × 10−6 × 2.52 ‒* ½ *× 3 × 10−6 × 1.22 seen***or** E = ½ *× 3 × 10−6 × (2.52 ‒ 1.22) seen***or** E =½ *× 7.5 × 10−6 × 2.5 ‒* ½ *× 3.6 × 10−6 × 1.2 seen*

7.2 × 10−6 (J) c.a.o

**(3)**

(c) (i) *Use of V* =

*or equivalent with*

*Q =*

R = − or R = −

636 or 640 (Ω)

**3**

(ii) Current decreases (I = V / R) / describes rate of flow of electrons decreasing / rate of flow of charge decreases

Charge lost more slowly so pd falls more slowly because V∝Q or Q=CV where C is constant

**(Max 2)**

**[Total 12]**

**M105.** (a) (i) (Mass change in u=) 1.71× 10−3 (u)  
**or** (mass Be−7) ‒ (mass He−3) ‒ (mass He−4) seen with numbers

2.84 × 10−30 (kg)  
**or** Converts their mass to kg

*Alternative 2nd mark:  
Allow conversion of 1.71 × 10−3 (u) to MeV by multiplying by 931 (=1.59 (MeV))* ***seen***

Substitution in E = mc2 *condone their mass difference in this sub but must have correct value for c2 (3×108)2 or 9×1016*

*Alternative 3rd mark:  
Allow their MeV converted to joules (× 1.6 × 10−13)* ***seen***

2.55 × 10−13 (J) to 2.6 × 10−13 (J)

*Alternative 4th mark:  
Allow 2.5 × 10−13 (J) for this method*

**(4)**

(ii) Use of *E=hc / λ* ***ecf***

Correct substitution in rearranged equation with *λ* *subject* ***ecf***

7.65 × 10−13 (m) to 7.8 × 10−13 (m)    ecf

**(3)**

(b) (i) Use of Ep formula:

Correct charges for the nuclei **and** correct powers of 10

2.6(3) × 10−13 J

**(3)**

(ii) Uses K*E* = 3 / 2 *kT:* ***or*** *halves KET, KE= 1.3 × 10−13 (J)* ***seen ecf***

Correct substitution of data **and** makes T subject **ecf**Or uses KET value **and** divides T by 2

6.35 × 109 (K) or 6.4 × 109 (K) or 6.28 × 109(K) or 6.3 × 109 (K) **ecf**

**(3)**

(c) (i) Deuteron / deuterium / hydrogen−2

Triton / tritium / hydrogen−3

**(2)**

(ii) Electrical heating / electrical discharge / inducing a current in plasma / use of e−m radiation / using radio waves (causing charged particles to resonate)

**(1)**

**[Total 16]**

**M106.** (a) emf = Δ*(BAN) / t  
Change in flux* = *A* × Δ*B* or 12 × (23 − 9) seen

Substitution ignoring powers of 10

1.2 V

**(3)**

(b) Reduced

Magnet will move (with the case)

Increased

Flux linkage increases or emf is proportional to *N*

**(2)**

(c) (i) Formula used  
 seen

0.348 / 0.349 seen to at least 3 sf

**(2)**

(ii) Period consistent at 0.35 s or *V*o = 8 V

Shape shows decreasing amplitude

At least 3 cycles starting at 8 V

**(3)**

**[Total 10]**

**M107.** (a) (i) *M* =

combined with *g*s = gives *gs* = ✔

*Do not allow r instead of R in final answer but condone in early stages of working.*

*Evidence of combination, eg cancelling R2 required for second mark.*

**(2)**

(ii) *R =* = ✔

gives *R* = 6.06 × 106 (m) ✔

answer to **3SF** ✔

*SF mark is independent but may only be awarded after some working is presented.*

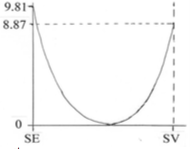
**(3)**

(b) line starts at 9.81 and ends at 8.87 ✔

correct shape curve which falls and rises ✔

falls to zeo value near centre of and to right of centre of distance scale ✔

[*Minimum of graph in 3rd point to be >0.5 and <0.75 SE-SV distance]*

**

*For 3rd mark accept flatter curve than the above in central region.*

**(3)**

**[Total 8]**

**M108.** (a) (i) (Minimum) Speed (given at the Earth’s surface) that will allow an object to leave / escape the (Earth’s) gravitational field (with no further energy input)

*Not gravity*

*Condone gravitational pull / attraction*

**(1)**

(ii) *mv*2 =

Evidence of correct manipulation

*At least one other step before answer*

**(2)**

(iii) Substitutes data and obtains *M* = 7.33 × 1022(kg)  
**or**  
Volume = (1.33 × 3.14 × (1.74 × 106)3 or 2.2 × 1019

*or ρ =*

3300 (kg m-3 )

**(2)**

(b) (Not given all their KE at Earth’s surface) energy continually added in flight / continuous thrust provided / can use fuel (continuously)

Less energy needed to achieve orbit than to escape from Earth’s gravitational field / it is not leaving the gravitational field

**(2)**

**[Total 7]**

**M109.** (a) Idea that both astronaut and vehicle are travelling at same (orbital) speed or have the same (centripetal) acceleration / are in freefall

*Not falling at the same speed*

No (normal) reaction (between astronaut and vehicle)

**(2)**

(b) (i) Equates centripetal force with gravitational force using appropriate formulae  
E.g. = or *mrω2*

Correct substitution seen e.g. *v2* =

(Radius of) 7.28 × 106 seen or 6.38 × 106 + 0.9 × 106

7396 (m s−1) to at least 4 sf **or** v2 = 5.47 × 107 seen

**(4)**

(ii) ΔPE = 6.67 × 10−11 × 5.97 × 1024 × 1.68 × 104 (1 / (7.28 × 106) − 1 / (6.78 × 106) )

−6.8 × 1010 J

ΔKE =0.5 × 1.68 × 104 ×(77002−74002) = 3.81 × 1010J

ΔKE − ΔPE = (−) 2.99 × 1010 (J)

**or**

Total energy in original orbit shown to be (−)*GMm* / *2r*or *mv*2 / 2 − *GMm / r*

Initial energy  
= − 6.67 × 10−11 × 5.97 × 1024 × 1.68 × 104 / (2 × 7.28 × 106) = 4.59 × 1011

Final energy  
= − 6.67 × 10−11 × 5.97 × 1024 × 1.68 × 104 / (2 × 6.78 × 106) = 4.93 × 1011

3.4 × 1010(J)

*Condone power of 10 error apart from answer*

**(4)**

**[Total 10]**

**M110.** (a) (i) meter deflects then returns to zero ✓

current produces (magnetic) field / flux ✓  
change in field / flux through Q induces emf ✓  
induced emf causes current in Q (and meter) ✓

*Deflection to right (condone left) then zero is equivalent to 1st mark.*

*Accept momentary deflection for 1st point.*

*“Change in field / flux induces current in Q” is just ✓ from the last two marking points.*

**(Max 3)**

(ii) meter deflects in opposite direction (or to left, or ecf) ✓  
field / flux through P is reduced ✓  
induces emf / current in opposite direction ✓

*Ignore references to magnitude of deflection.*

**(Max 2)**

(b) (i) flux linkage (= *nΦ* = *nBA*) = 40 × 0.42 × 3.6 × 10 −3= 6.0(5) × 10−2 ✓

*Unit mark is independent.*

*Allow 6 × 10−2.*

Wb turns ✓

*Accept 60 mWb turns if this unit is made clear.*

*Unit: allow Wb.*

**(2)**

(ii) change in flux linkage = *Δ*(*nΦ*)= 6.05 × 10−2 (Wb turns) ✓  
induced emf = = 0.12(1) (V) ✓

*Essential to appreciate that 6.05 × 10−2 is change in flux linkage for 1st mark. Otherwise mark to max 1.*

**(2)**

**[Total 9]**

**M111.** (a) (i) determine area under the graph  
[**or** determine area between line and time axis] ✓

**(1)**

(ii) *as seen*

line starts at very low current (within bottom half of first square) **🗸**  
**either** line continuing as (almost) horizontal straight line to end **🗸🗸**  
**or** very slight exponential decay curve **🗸**  
which does not meet time axis **🗸**

**or** suitable verbal comment that shows appreciation of difficulty of  
representing this line on the scales involved **🗸🗸🗸**

*Use this scheme for answers which treat the information in the question literally.*

**(3)**

*as intended*

line starts at half of original initial current ✓  
slower discharging exponential (ie. smaller initial gradient) than the original curve ✓  
correct line that intersects the original curve (**or** meets it at the end) ✓

*Use this scheme for answers which assume that both resistance values should be in Ω or kΩ.*

*½ initial current to be marked within ±2mm of expected value.*

**(3)**

(b) (i) energy stored (= ½ *CV2*) = ½ × 0.12 × 9.02  ✓ ( = 4.86 (J) )  
4.86 = 3.5 Δ*h* ✓  
gives Δ*h* = (1.39) = 1.4 (m) ✓  
to 2SF only ✓

*SF mark is independent.*

*Students who make a PE in the 1st mark may still be awarded the remaining marks: treat as ECF.*

**(4)**

(ii) energy is lost through heating of wires **or** heating the motor (as capacitor discharges) ✓

*Allow heating of circuit* ***or*** *I2 R heating.*

energy is lost in overcoming frictional forces in the motor  
(or in other rotating parts) ✓

*Location of energy loss (wires, or motor, etc) should be indicated in each correct answer.*

[**or** any other well-expressed sensible reason that is valid  
e.g. capacitor will not drive motor when voltage becomes low ✓ ]

*Don’t allow losses due to sound, air resistance or resistance (rather than heating of) wires.*

**(Max 2)**

**[Total 10]**

**M112.** (a) force between two (point) charges is proportional to product of charges ✓  
inversely proportional to square of distance between the charges ✓

*Mention of force is essential, otherwise no marks.*

*Condone “proportional to charges”.*

*Do not allow “square of radius” when radius is undefined.*

*Award full credit for equation with all terms defined.*

**(2)**

(b) *V* is inversely proportional to *r* [**or** *V* ∝ (−)1 / *r* ] ✓  
(*V* has negative values) because charge is negative  
[**or** because force is attractive on + charge placed near it  
**or** because electric potential is + for + charge and − for − charge] ✓  
potential is defined to be zero at infinity ✓

*Allow V × r = constant for 1st mark.*

**(Max 2)**

(c) (i) *Q*(= 4π*ɛ*0 *rV* ) = 4π*ɛ*0 × 0.125 × 2000

***or*** *gradient = Q / 4πɛ0 = 2000 / 8 ✓*

(for example, using any pair of values from graph) ✓  
= 28 (27.8) (± 1) (nC) ✓

*(gives Q = 28 (27.8) ±1 (nC) ✓*

**(2)**

(ii) at *r* = 0.20m *V* = −1250V and at *r* = 0.50m *V* = −500V  
so pd Δ*V* = −500 − (−1250) = 750 (V) ✓  
work done Δ*W* (= *Q*Δ*V*) = 60 × 10−9 × 750  
= 4.5(0) × 10−5 (J) (45 μJ) ✓

(final answer could be between 3.9 and 5.1 × 10−5)

*Allow tolerance of ± 50V on graph readings.*

*[Alternative for 1st mark:*

*ΔV =*  *(****or*** *similar substitution using 60 nC instead of 27.8 nC:  
use of 60 nC gives ΔV = 1620V) ]*

**(2)**

(iii) *E* = ✓ = 1600 (1560) (V m−1) ✓  
[or deduce *E* =  by combining *E* = with *V* = ✓  
from graph *E* = = 1600 (1560 ± 130) (V m−1) ✓ ]

*Use of Q = 30 nC gives 1690 (V m−1).*

*Allow ecf from Q value in (i).*

*If Q = 60 nC is used here, no marks to be awarded.*

**(2)**

**[Total 10]**

**M113.** (a) *(Faraday’s law)*

(induced) emf ∞ rate of change of flux (linkage) ✔

*(Lenz’s law)*

direction of induced emf (or current) ✔

is such as to oppose the change (in flux) producing it ✔

*In either order.*

*Allow “(induced) emf = rate of change of flux linkage”.*

*Ignore incorrect reference to names of laws.*

**(3)**

(b) (i) current in coil produces magnetic field or flux

(that passes through disc) ✔

rotating disc cuts flux inducing / producing emf **or** current (in disc) ✔

induced (eddy) currents (in disc) interact with magnetic field ✔

force on (eddy) currents slows (or opposes) rotation (of disc) ✔

***Alternative*** *for last two points:*

*(eddy) currents in disc cause heating of disc ✔*

*energy for heating comes from ke of disc or vehicle (which is slowed) ✔*

**(Max 3)**

(ii) *Advantage*: any one ✔

• no material (eg pads or discs or drums) to wear out

• no pads needing replacement

• no additional (or fewer) moving parts

*Disadvantage*: any one ✔

• ineffective at low speed **or** when stationary

• dependent on vehicle’s electrical system remaining in working order

• requires an electrical circuit (or source of electrical energy) to operate whereas pads do not

*Answers must refer to advantages and disadvantages of the electromagnetic brake.*

*Only accept points from these lists.*

**(2)**

**[Total 8]**

**M114.** (a) Equatorial orbit ✓

Moving west to east ✓

Period 24 hours✓

**ANY TWO**

**(2)**

(b) *T* = 2.5 × 104 s ✓

**(1)**

(c) *λ* =0.27 (3)m )✓

*θ*  = 0.16(1) rad = 92 ✓

(linear) width = *Dθ* = 12000 km 0.16(1) rad ) = 1.9(3) × 103 km ✓

**(3)**

(d) Angle subtended by beam at Earth’s centre

= beam width / Earth’s radius = 1.9(3) × 103 / 6400 ✓

0.30 rad (or 17°) ✓

Time taken = *α / ω* = 0.30 / 2.5(4) × 10-4 = 1.18 × 103 s

= 20 mins ✓

***Alternative****:*

*Speed of point on surface directly below satellite = ωR*

*= 2.5(4) × 10-4 × 6400 × 103 )*

*= 1.63 × 103 m s-1✓*

*Time taken = width / speed*

*= 1.93 × 106 m / 1.63 × 103 m s-1 ✓*

*= 1.18 × 103 s*

*(accept 1.2 × 103 s or 20 mins) ✓*

***or***

*Satellite has to move through angle of 1900 / 6400 radian = 0.29 rad✓*

*Fraction of one orbit = 0.30 / 2 × 3.14✓*

*Time = 0.048 × 2.5 × 104 = 1.19 × 103 s✓*

*Time= × 2.5 × 104 = 1.18 × 103 s*

***or***

*Circumference of Earth = 2π × 6370 ✓*

*= 40023 km*

*Width of beam at surface = 1920 km ✓*

*Time = ×2.48×104*

*= 1180 s = 19.6 min ✓*

**(3)**

(e) Signal would be weaker ✓ (as distance it travels is greater)

Energy spread over wider area/intensity decreases with increase of distance ✓

Signal received for longer (each orbit) ✓

Beam width increases with satellite height/satellite moves at lower angular speed ✓)

**(4)**

**[Total 13]**

**M115.** (a) Total mass of spacecraft = 3050 kg

Change in PE =

1.9 × 1011(J)

2 sf

*condone errors in powers of 10 and incorrect mass for payload*

*Allow if some sensible working*

**(4)**

(b) Chemical combustion of propellant / fuel or gases produced at high pressure

Gas is expelled / expands through nozzle

Change in momentum of gases escaping

equal and opposite change in momentum of the spacecraft

Thrust = rate of change of change in momentum

*N3 in terms of forces worth 1*

**(Max 3)**

(c) 0.031(4) (m s-2)

**(1)**

(d) Use of rocket equation

*v* = 1200 ln

996 (m s–1)

*Condone 1000 (m s–1)*

**(3)**

(e) (i) Use of correct mass 108 kg

F =

0.0198 N

*Allow incorrect powers of 10 and mass*

**(3)**

(ii) Use of *v* =

Correct substitution *v* =

0.86 (m s-1)

*Recognisable mass – condone incorrect power of 10*

**(3)**

(iii) Impulse = 25 N × 4.8 = 120 N s

(120 = 108 *v* so) Velocity = 1.1 m s-1

Clear conclusion

ie explanation/comparison of calculated velocity with escape velocity from **(e)(ii)**

*May use F = ma approach*

**(3)**

**[Total 20]**

**M116.** (a) (i) graph showing two pulses one at start and the other at the end with no emf between the pulses

Positive and negative pulses shown

Similar shaped ‘curved’ pulses : negative between 0 and 0.22 ± 0.02 s and positive pulse 0.58 ± 0.02 and 0.8

**3**

(ii) emf induced when the flux is changing or induced emf depends on the rate of change of flux

emf induced when flux changes between 0 and 0.2(2) s and / or between 0.6(0.58)s and 0.8 s

**or**

no change in flux between 0.2 and 0.6 so no induced emf

Induced emf / current produces a field to oppose the change producing it.

Flux linking bracelet increases as the bracelet enters the field produced by C and decreases as it leaves so opposite emfs

**(4)**

(b) (Takes 0.21 s or 0.22 s for flux to change from 0 to maximum so)

diameter = 0.28 × 0.21 = 0.059 (0.588) (m)

or 0.28 × 0.22 = 0.062 (0.616) (m)

*must be to at least 2sf*

**(1)**

(c) Area of bracelet = 3.14 × 0.0312

*B* = 1120 × 10-6 / (3.14 × 0.0312) = 0.38 (T)

*B* = 0.40 T if 3 cm used for radius

*Condone incorrect power of 10*

*Allow answers in range 0.38T to 0.41 T (depends on value used for r)*

**(2)**

(d) Use of steepest gradient of graph or tangent drawn on Figure 2

Correct data from tangent or points on the steepest part of the graph

10 to 11 mV

**(3)**

**[Total 13]**

**M117.** (a) *d* = ✓

1.4 ×10–3 m (1.4 (1.38) mm) ✓

*Data substitution – condone incorrect powers of 10 for C and A ✓*

**(2)**

(b) New capacitance = 161 pF✓

New *V* = 0.13 nC / 161pF = 81 V✓

**(2)**

(c) Energy stored = ½ × 161 × 10-12 × 812 ✓

0.53 μJ✓

**(2)**

(d) Energy increases because:

In the polar dielectric molecules align in the field with positive charged end toward the negative plate (or WTTE).✓

Work is done on the capacitor separating the positively charged surface of the dielectric from the negatively charged plate (or vice versa).✓

**(2)**

**[Total 8]**

**M118.** (a) Induced current such as to opposes the change producing it✓

**Switch on** current increases the flux through Y✓

Current opposite direction / anticlockwise to create opposing flux✓

**Switch off** flux thorough Y due to X decreases so current travels clockwise to create flux to oppose the decrease✓

*one marks for Lenz’s law statement*

*two for explaining what happens at switch on* ***OR*** *switch off adequately*

*one for completing the argument for switch on and off adequately*

**(4)**

(b) Determines correctly in the calculation two of *V*pk( 5.6±1 μV) , *A* (0.096 m2) and  
*ω*(9.4 rad s-1)β✓

Substitutes all three in *v = BAnω* ignoring powers of 10 and calculation errors for *A* and / or ω provided they have been attempted with working shown✓

BH = 12.4 nT✓

*Allow 2 or 3 sf*

**(3)**

**[Total 7]**

**M119.** (a) *t* = or 4.5 = × 9.81 × *t* 2 ✓

*t* = 0.96 s✓

**(2)**

(b) Field strength = 186000V m–1✓

Acceleration = *Eq / m*

or 186 000 × 1.2 × 10–6 ✓

0.22 m s–2 ✓

**(3)**

(c) 0.10(3)m (allow ecf from (i))✓

**(1)**

(d) Force on a particle = *mg* and acceleration = *F / m* so always = *g*✓

Time to fall (given distance) depends (only) on the distance and acceleration✓

**or**

*g = GM / r2* ✓

Time to fall = √2*s / g*

so no *m* in equations to determine time to fall✓

**(2)**

(e) Mass is not constant since particle mass will vary✓

Charge on a particle is not constant✓

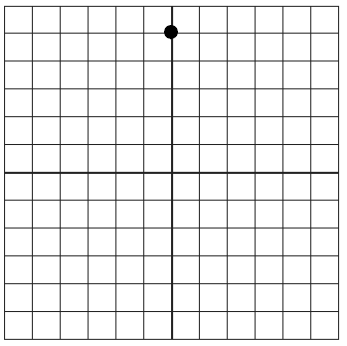
Acceleration = *Eq / m* or (*V / d*) (*q / m*) or *Vq / dm✓*

*E* or *V / d* constant but charge and mass are ‘random’ variables so *q / m* will vary (or unlikely to be the same)✓

**(4)**

**[Total 12]**

**M120.** (a)



**(1)**

(b) (i) the **voltage reverse**/**changes** direction/sign 

this makes **the spot** move up and down **or** correct explanation of lack of horizontal movement 

**(2)**

(ii) length of line = 8 divisions

peak to peak = 8 × 0.5 = 4.0 V 

**(2)**

(iii) (peak = 2.0 V)

rms = 2.0/√2 = 1.4 V 

**(2)**

**[Total 7]**

**M121.** (a) *E* ∝ V2 (or *E* =1/2*CV*2) **(1)**

pd after 25 s = 6 V **(1)**

**(2)**

(b) (i) use of *Q* = *Q*0 e−*t/RC* or *V* = *V*0 e−*t/RC* **(1)**

(e.g. 6 = 12e−25/*RC*) gives and **(1)**

(*RC* = 36(.1) s)

[alternatives for (i):

*V* = 12 e−25/36 gives *V* = 6.0 V **(1)** (5.99 V)

or time for pd to halve is 0.69*RC*

*RC* = **(1)** = 36(.2) s]

(ii) *R* = **(1)** = 5.3(0) × 104 Ω**(1)**

**(4)**

**[Total 6]**

**M122.** (a) (i) out of plane of diagram **(1)**

(ii) circular path **(1)**in a horizontal plane [or out of the plane of the diagram] **(1)**

**(1)**

radius of path, *r* **(1)**

= 0.91(4) m **(1)**

**(Max 5)**

(b) (i) radius decreased **(1)**halved **(1)**[or radius is halved **(1) (1)**]

(ii) radius increased **(1)**doubled **(1)**[or radius is doubled **(1) (1)**]

**(Max 3)**

**[Total 8]**

**M123.** (a)

|  |  |  |
| --- | --- | --- |
| **quantity** | **SI unit** |  |
| (gravitational potential) | J kg–1 or N m kg –1 | scalar |
| (electric field strength) | N C–1 or V m–1 | vector |
| (magnetic flux density | T or Wb m–2 or N A–1 m–1 | vector |

6 entries correct **(1) (1) (1)**4 or 5 entries correct **(1) (1)**2 or 3 entries correct **(1)**

**(3)**

(b) (i) *mg* = *EQ* **(1)**

= 1.32 × 104 (V m–1) **(1)**

(ii) positive **(1)**

**(3)**

**[Total 6]**

**M124.** (a) deflects one way **(1)**then the other way **(1)**

**(2)**

(b) (i) acceleration is less than *g* [or reduced] **(1)**suitable argument **(1) (**e.g. correct use of Lenz’s law)

(ii) acceleration is less than *g* [or reduced] **(1)**suitable argument **(1) (**e.g. correct use of Lenz’s law)

**(4)**

(c) magnet now falls at acceleration *g* **(1)**emf induced **(1)**but no current **(1)**no energy lost from circuit **(1)**[or no opposing force on magnet, or no force from magnetic field or no magnetic field produced]

**(3)**

**(QWC 2)**

**[Total 9]**

**M125.** (a) (i) (use of *V*rms = gives) *V*0 = 7.1√2 = 10 V **(1)**

(ii) *T* = 10 (ms) **(1)**

(use of *f*  gives) *f* = = 100 Hz **(1)**

**(3)**

(b)     control 1: time base **(1) (**or time period)

(use of *T* =gives) *T* = = 5 × 10–3 (s) **(1)**

setting = 2.5 ms (div–1) **(1)**

control 2: voltage sensitivity or Y-plate setting (or Y-gain) **(1)**setting = 20 V (div–1) **(1)**

**(5)**

**[Total 8]**

**M126.** (a) (i) *h* (= *ct*) (= 3.0 × 108 × 68 × 10–3) = 2.0(4) × 107 m **(1)**

(ii) *g* = (–) **(1)***r* (= 6.4 × 106 + 2.04 × 107) = 2.68 × 107 (m) **(1)**(allow C.E. for value of *h* from (i) for first two marks, but not 3rd)

*g* = **(1)** (= 0.56 N kg–1)

**(4)**

(b) (i) *g* = **(1)**

*v* = [0.56 × (2.68 × 107)]½ **(1)**

= 3.9 × 103m s–1 **(1)** (3.87 × 103 m s–1)

(allow C.E. for value of *r* from a**(**ii**)**

[or v2 = = **(1)**

*v* = **(1)**

= 3.9 × 103 m s–1 **(1)**]

(ii)  **(1)**

= 4.3(5) × 104s **(1)** (12.**(1)** hours)  
(use of *v* = 3.9 × 103 gives *T* = 4.3**(1)** × 104 s = 12.0 hours)  
(allow C.E. for value of *v* from (I)

[alternative for (b):

(i) **(1)**

= 3.8(6) × 103 m s–1 **(1)**]

(allow C.E. for value of *r* from (a)(ii) and value of *T*)

(ii) **(1)**

= (1.90 × 109 **(**s2**)** **(1)**

*T* = 4.3(6) × 104 s **(1)**

**(5)**

**[Total 9]**

**M127.** (a) (*V* = *IR* gives)    *V*rms = (5.3 × 10–3 × 2 × 103) = 10.6 (V) **(1)***V*0 = *V*rms √2 = 10.6√2 = 15 V **(1)** (14.99 V)  
[or calculate *I*0 (= 7.5 mA) and then *V*0]

**(2)**

(b) (use of *T* = gives) *T* = = 2 × 10–3 = 2 0(ms) **(1)**

trace to show:  
correct wave shape (sinusoidal) **(1)**correct amplitude (3 divisions) **(1)**correct period (8 divisions) **(1)**

**(4)**

**[Total 6]**

**M128.** (a) Φ (= *BA*) = 45 × 10–3 × π × (70 × 10–3)2 **(1)**= 6.9 × 10–4 Wb **(1)** (6.93 × 10–4 Wb)

**(2)**

(b) (i) *NΔΦ* ( = *NBA* – 0) = 850 × 6.93 × 10–4 **(1)**

= 0.59 (Wb turns) **(1)** (0.589 (Wb turns))

(if Φ = 6.9 × 10–4, then 0.587 (Wb turns))

(allow C.E. for value of Φ from (a))

(ii) induced emf ( = *N*) = **(1)**

= 4.9 V **(1)** (4.91 V)

(allow C.E. for value of Wb turns from (ii)

**(4)**

**[Total 6]**

**M129.** (a) work done/energy change (against the field) per unit mass **(1)**when moved from infinity to the point **(1)**

**(2)**

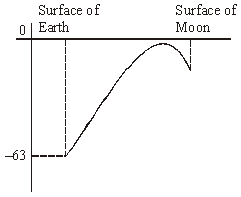
(b) *V*E = – and *V*M = – **(1)**

*V*M = – *G* × × = = *V*E **(1)**

= 4.57 × 10–2 × (–63) = –2.9 MJ kg–1 **(1)** (2.88 MJ kg–1)

**(3)**

(c)



limiting values (–63,–*V*M) on correctly curving line **(1)**rises to value close to but below zero **(1)**falls to Moon **(1)**from point much closer to M than E **(1)**

**(Max 3)**

**[Total 8]**

**M130.** (a) attractive **force** between point masses **(1)**proportional to (product of) the masses **(1)**inversely proportional to square of separation/distance apart **(1)**

**(3)**

(b) *mω*2*R* = (–)= **(1)**

(use of *T* = gives) **(1)**

*G* and *M* are constants, hence *T*2 ∝ *R*3 **(1)**

**(3)**

(c) (i) (use of *T*2 ∝ *R*3 gives) = **(1)**

*T*m = 87(.5) days **(1)**

(ii) = **(1)** (gives *R*N = 4.52 × 1012 m)

ratio = = 30(.1) **(1)**

**(4)**

**[Total 10]**

**M131.** (a) (i) magnetic field (or B) must be at right angles to velocity (or *v*) 

**(1)**

(ii) *F* = (magnetic) force (on a charged particle or ion)

*B* = **flux density** (of a magnetic field)

*Q* = charge (of particle or ion)

*v* = velocity [**or** speed] (of particle or ion)

*all four correct *

**(1)**

(b) (i) into plane of diagram 

**(1)**

(ii) magnetic **force** = electric **force** [or *BQv* = *EQ*] 

these forces act in opposite directions [**or** are balanced  
**or** **resultant** vertical force is zero] 

**(2)**

(iii) *BQv* = *EQ* gives flux density *B* = 

(= 738 V m–1)

= 4.3 × 10–3 T 

**(4)**

(c) ions would be deflected upwards 

magnetic force increases but electrostatic force is  
unchanged [**or** magnetic force now exceeds electrostatic force] 

**(2)**

**[Total 11]**

**M132.** (a) (i) straight line through origin **(1)**

(ii) **(1)**

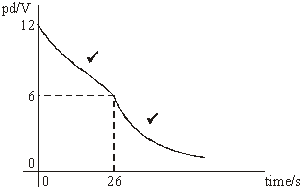
(iii) energy (stored by capacitor) **(1)** (or work done (in charging capacitor))

**(3)**

(b) (i) *RC* = 5.6 × 103 × 6.8 × 10–3 **(1)** (= 38.1 s)  
*V*(= *V*0 e–*t/RC*) = 12 e–26/38.1 **(1)** = 6.1 V **(1)** (6.06 V)  
[or equivalent using *Q* = *Q*0e–*t/RC* and *Q* = *CV*]

(ii) (*RC*)’ = 2.8 × 103 × 6.8 × 10–3 **(1)** (= 19.0 s)  
*V* (= 6.06 e–14/19) = 2.9(0) V **(1)**(use of *V*’ = 6.1 V gives *V* = 2.9(2) V)

(iii)



**(7)**

**[Total 10]**

**M133.** (a) + *α* → + 

**(1)**

(b) kinetic energy lost by the α particle approaching the nucleus is equal to the potential energy gain 

2.18 × 10–12 = 

*r* = 2.75 × 10–15 (m) 

**(3)**

**[Total 4]**

**M134.** (a) (i) relationship between them is *E*p = *mV* (allow Δ*E*p = *m*Δ*V*) [or *V* is energy per unit mass

(or per kg)] **(1)**

**(1)**

(ii) value of *E*p is doubled **(1)**

value of *V* is unchanged **(1)**

**(2)**

(b) (i) use of *V* = - gives *r*A = **(1)**

= 3.3(2) × 107 (m) **(1)**

**(2)**

(ii) since *V* **(1)**

(which is ≈ 1.1 × 104 km)

**(1)**

(iii) centripetal acceleration *g*B = **(1)**

[allow use of 1.1 × 107 m from (b)(ii)]

= 3.2 (m s–2) **(1)**

[**alternatively**, since *g*B = (–) , **(1)**

= 3.2 (m s–2) **(1)**]

**(2)**

(iv)    use of Δ*E*p = *m*Δ*V* gives Δ*E*p = 330 × (–12.0 – (–36.0)) × 106 **(1)**

(which is 7.9 × 109 J or ≈ 8 GJ)

**(1)**

(c) *g* is not constant over the distance involved

(**or** *g* decreases as height increases  
**or** work done per metre decreases as height increases  
**or** field is radial and/or not uniform) **(1)**

**(1)**

**[Total 10]**

**M135.** (a) (i) *T* = 40(ms) **(1)**

*f = 25* Hz **(1)**

*(allow C.E. for value of T)*

(ii) peak voltage (= 3 × 15) = 45 (V) **(1)**

rms voltage = =32 V **(1)** (31.8 V)

**(4)**

(b) (i) *I*rms = 59mA **(1)** (58.9mA)  
(use of 32 V gives 59(.2) mA)

*(allow C.E. for value of Vrms from (a))*

(ii)*V*rms= 59 × 10–3 × 90 = 5.3(1) V **(1)**

*(allow C.E. for value of Irms from (i)) [or V2 =V1 ]*

**(2)**

(c) *V*peak = 5.31× =7.5(1) (V) **(1)**best choice: 5 V per division **(1)**

*(allow C.E. for incorrect Vrms and for suitable reason)*

reason: others would give too large or too small a trace **(1)**

**(3)**

**[Total 9]**

**M136.** (a) (i) charge stored per unit volt or equation with terms defined **(1)**

(ii) 0.108 C or 0.11 C c.a.o. **(1)**

**(2)**

(b) (i) 1.7 s **(1)**

(ii) correct curvature **(1)**

intercept on *V* axis, asymptotic to *t* axis **(1)**

initial voltage, time constant and *V* after *RC* seconds shown **(1)**

**(4)**

(c) initially no pd across C so rate of charging is high **(1)**

Pd across C increases as the capacitor charges **(1)**

rate of charging reduces **(1)**

**(3)**

**[Total 9]**

**M137.** (a) technique one **(1)**

information derived from it **(1)**

technique two **(1)**

information derived from it **(1)**

**(4)**

(b) (i) gravitational **attraction** to… **(1)**

**…centre of gravity** (mass) of mountain **(1)**

(ii) cancellation of some systematic errors **(1)**

**(3)**

(c) (i) calculates volume of cone **(1)**

mass = density × volume seen **(1)**

2.2 × 1012 kg **(1)**

(ii) sideways force/mg = tan (0.0011) **(1)**

sideways force = Gmsch 0.5/(1400)2 subst seen **(1)**

2.4 × 1024 kg **(1)**

(iii) his density estimate was too low **(1)**

or mean density of the Earth is higher than that of the mountain **(1)**

**(7)**

**[Total 14]**

**M138.** (a) (i) use of 1.5 cycles **(1)**

conversion to time eg time for 1.5 cycles = 10 × 1.5 = 15ms **(1)**

calculation of frequency eg frequency = 1 / 0.010 = 100 ± 3Hz **(1)**

(ii) peak voltage = 1.5 × 2 **(1)** = 3.0V **(1)**

(iii) rms voltage = 3.0/√2 **(1)** (ce from (a) (i))

rms voltage = 2.12V **(1)**

**(7)**

(b) vertical line is formed **(1)**

of length equal to twice the peak voltage **(1)**

because trace no longer moves horizontally  
**or** spot moves **just** up and down **(1)**

**(Max 2)**

**[Total 9]**

**M139.** (a) (i) primary coil with more turns than secondary coil **(1)**

(wound around) a core **or** input is ac **(1)**

**(2)**

(ii) the mark scheme for this part of the question includes an overall  
assessment for the Quality of Written Communication

|  |  |  |
| --- | --- | --- |
| **QWC** | **descriptor** | **mark range** |
| good- excellent | Two causes of energy losses are clearly identified, correct measures to indicate how these two losses may be reduced are stated and a detailed physical explanation of why these measures are effective is given.  eg **any two** from the following four  1      When a transformer is in operation, there are ac currents in the primary and secondary coils. The coils have some resistance and the currents cause **heating of the coils**, causing some energy to be lost. This loss may be reduced by using **low resistance wire** for the coils. This is most important for the high current winding (the secondary coil of a step-down transformer). Thick copper wire is used for this winding, because thick wire of low resistivity has a low resistance.  2      The ac current in the primary coil magnetises, demagnetises and re-magnetises the core continuously in opposite directions. Energy is required both to **magnetise and to demagnetise the core** and this energy is wasted because it simply heats the core. The energy wasted may be reduced by choosing a material for the core which is easily magnetised and demagnetised, ie a **magnetically soft material** such as iron, or a special alloy, rather than steel.  3      The magnetic flux passing through the core is changing continuously. The metallic core is being cut by this flux and the continuous change of flux induces emfs in the core. In a continuous core these induced emfs cause currents known as **eddy currents**, which heat the core and cause energy to be wasted. The eddy current effect may be reduced by laminating the core instead of having a continuous solid core; the laminations are separated by very thin layers of insulator. Currents cannot flow in a conductor which is discontinuous (or which has a very high resistance).  4      If a transformer is to be efficient, as much as possible of the magnetic flux created by the primary current must pass through the secondary coil. This will not happen if these coils are widely separated from each other on the core. **Magnetic losses** may be reduced by adopting a design which has the two coils close together, eg by **better core design**, such as winding them on top of each other around the same part of a common core which also surrounds them. | **5**-**6** |

|  |  |  |
| --- | --- | --- |
| modest- adequate | Up to two sources of energy losses are stated and there is an indication of how these may be minimised by suitable features or materials. There is no clear appreciation of an understanding of the physical principles to explain why these measures are effective. | **3**-**4** |
| poor- limited | Up to two sources of energy losses are given, but the answer shows no clear understanding of the measures required to minimise them. | **1**-**2** |
| incorrect, inappropriate- or no - response | There is no answer or the answer presented is irrelevant or incorrect. | **0** |

Answers which address only **one** acceptable energy loss should  
be marked using the same principles, but to max 3.

**(6)**

(b) (i) power wasted internally (= *I V*) = 0.30 × 9.0 = 2.7 (W) **(1)**

**(1)**

(ii) input power = 3.0 (W) **(1)**

mains current **(1)** (= 1.30 × 10–2 A)

**(2)**

(iii) energy wasted per year (= *P t*) = 3.0 × 0.80 × 3.15 × 107= 7.5(6) × 107 (J) **(1)**

**(1)**

(iv) energy wasted = = 21.0 (kWh) **(1)**

cost of wasted energy = 21.0 × 20 = 420p (£4.20) **(1)**

**(2)**

(c) answers should refer to:

an advantage of switching off **(1)**

* cost saving, saving essential fuel resources, reduced global warming etc

a disadvantage of switching off **(1)**

* inconvenience of waiting, time taken for computer to reboot etc

risk of computer failure increased by repeated switching on and off

energy required to reboot may exceed energy saved by switching off

**(2)**

**[Total 16]**

**M140.** (a) (i) initial discharge current = 6.0 × 10–5 (A) **(1)**

**(1)**

(ii) time constant is time for *V* to fall to (1/e) [or 0.368] of initial value **(1)**

pd falls to (6.0/e) = 2.21 V when *t* = time constant **(1)**

reading from graph gives time constant = 22 (± 1) **(1)**

unit: s **(1)** (ΩF not acceptable)

[**alternatively** accept solutions based on use of *V* = *V*0e–t/*RC*

eg 1.5 = 6.0 e–30/*RC* **(1)** gives *RC* = **(1)** = 22 **(1)** s **(1)**]

**(4)**

(iii) capacitance of capacitor *C* = = 2.2 × 10–4 (F) = 220 (µF) **(1)**

**(1)**

(iv) energy ∝ *V*2 (or energy = ½ *CV*2) **(1)**

= 0.10 gives = (0.10)1/2 **(1)** (= 0.316)

*V*2 = 0.316 × 6.0 = 1.90 (V) **(1)**

reading from graph gives *V*2 = 1.90 V when *t* = 25 s **(1)**

[**alternatively** accept reverse argument:

ie when *t* = 25 s, *V*2 = 1.9 V from graph **(1)**

final energy stored = ½ × 2.2 × 10–4 × 1.92

= 3.97 × 10–4 (J) and initial energy stored = 3.96 × 10–3 (J) **(1)**

which is 10 × greater, so 90% of initial energy has been lost **(1)**]

[**alternatively**, using exponential decay equation:

use of *V* = *V*0e–*t*/*R* with *t* = 25 s and *RC* = 22 s gives *V* = 1.93 V **(1)**

energy ∝ *V*2 (or energy = ½ *CV*2) gives = 0.103 **(1)**

****fraction of stored energy that is lost = = 0.90 **(1)**]

**(3)**

(b) (i) initial energy stored is 4 × greater **(1)**

because energy ∝ *V*2 (and *V* is doubled) **(1)**

**(2)**

(ii) time to lose 90% of energy is unchanged because time constant  
is unchanged (or depends only on R and C) **(1)**

**(1)**

**[Total 12]**

**M141.** (a) mass depends only on the amount of matter present owtte

weight is force between body and Earth/depends on *g/mg*/  
gravitational field strength or answers in terms of Newton’s  
gravitational law

*g* (etc) varies at different points on and above the Earth or is  
different on different planets etc

**(3)**

(b) (i) reference is ‘infinity’ where potential is 0

energy has to be put in/work has to be done to move  
mass to infinity or a bodies energy/PE decreases as  
a body moves from infinity towards the Earth

**(2)**

(ii) need to show *Vr* to be constant, clear from algebra  
or final statement

two sets of data used correctly

all three sets of data used correctly (4.02, 4.025, 4.028)

**(3)**

(iii) energy change per kg = (5.36 – 3.22) × 107 (J)

total change = 963 (960) × 107 J

**(2)**

(c) (i) *GMm*/*r*2 = *mv*2/r or *v* = (*GM/r*)

*v*2 = 3.2 × 107m2s–2 or *v* = 5670 ms–1

use of KE = ½ *mv*2 using their *v*

7.2 GJ

**(4)**

(ii) KE changes by 4.8 GJ (allow ecf, 12 – their c(i))

**(1)**

(iii) total energy (supplied) = (4.8) GJ (cnao)

(allow 5.2 GJ using 10 GJ for change in Ep)  
(allow variations due to rounding off if physics  
is correct in previous parts)

**(1)**

**[Total 16]**

**M142.** (a) flux linkage (= *NΦ* = *BAN* cos *θ*)

= 2.8 × 10−2 × 1.9 × 10−3 × 50 × cos 35° **(1)**

= 2.2 × 10−3 (Wb turns) **(1)**

answer must be to **2 sf** only **(1)**

**(3)**

(b) (i) reasonable sine curve drawn on axes, showing just one cycle, starting at emf = 0 **(1)**

**(1)**

(ii) the flux linkage in these positions is **zero** **(1)**

**(1)**

(iii) induced emf  (or =) rate of change of flux (linkage) **(1)**

flux (linkage) through the coil changes as it is rotated **(1)**

from maximum at *θ* = 0, 180° to zero at 90° and 270° **(1)**

rate of change is greatest when plane of coil is parallel to *B* [**or** reference to *ε = BANω* sin *ωt*, **or** *ε* = *BANω* sin *θ*] **(1)**

because coil then cuts flux lines perpendicularly [**or** *ε* = *BANω* sin *ωt* shows *ε* is greatest  
when *ωt* = 90° or 270°] **(1)**

**(Max 3)**

**[Total 8]**

**M143.** (a) (i) *g* gravitational field strength, *G* gravitational constant

*g* force on 1 kg (on or close to) Earth’s surface

*G* universal constant relating attraction of any two masses to their separation  
or constant in Newton’s law of gravitation

**(3)**

(ii) equates *w* and cancels *m*

**(1)**

(iii) substitutes values into equation

correct calculation 5.99 × 1024

answer to two significant figures 6.0 × 1024 (kg)

**(3)**

(b) (i) 1 day/24 hours/86400 (s)

**(1)**

(ii) 4.24 × 107 (m)

**(1)**

(iii) *v* = 2π*r*/*T* or equivalent

conversion of period to seconds (allow in (b)(i))

3.08 (cao)

**(3)**

(iv) communication/specific example of communication (eg satellite TV/weather)

**(1)**

(v) avoids dish having to track/stationary **footprint**

**(1)**

**[Total 14]**

**M144.** (i) 10.0 (V) **(1)**

**(1)**

(ii) Vrms = 10.0/√2 = 7.1 (V) **(1)**

**(1)**

(iii) time period = 3 × 2 = 6 (ms) **(1)**

**(1)**

(iv) frequency = 1/0.006 or 1/6 **(1)**

frequency = 167 **(1)** (Hz)

**(2)**

**[Total 5]**

**M145.** (a) (i) tangent drawn at *t* = 0

coordinates correct and manipulated correctly  
0.015 to 0.020 (A) 15 mA – 20 mA  
**or** *V* = 4000 V as in (ii) then *I* = 18 mA

**(2)**

(ii) *V* = 220 × their (i) condoning powers of 10

about 4000 V (3300 – 4400 V)

**or** use of *V* = *Q*/*C*; *V* = 100 mC/25 µF

4000 V

**(2)**

(iii) more charge leads to increased potential difference across the capacitor

pd = *V*R + *V*C

**or** if *V*C increases then *V*R decreases

(if *V*R falls) so *I* falls

**(3)**

(b) (i) use of energy = ½ *Q*2/*C* or use of *C* = *Q/V* and ½ *QV*

0.083(7) or 0.084 C condone 0.083 C

**(2)**

(ii) power = 14 kW

**(1)**

(c) time constant = 5.5 s

sensible attempt to find the charge after 8.3 s – by calculation or reading from graph

about 78 mC and needs to be 85 mC/has not reached 85 mC so designer’s  
suggestion is not valid

**(3)**

**[Total 13]**

**M146.** (a) magnetic field direction: −*z* **(1)**

**1**

(b) direction changes meaning that velocity is not constant **(1)**

acceleration involves change in velocity (or acceleration is rate of change of velocity) **(1)**

[**alternatively**

magnetic force on electron acts perpendicular to its velocity **(1)  
**force changes direction of movement causing acceleration **(1)**]

**(2)**

(c) (i) *BQv* = **(1)**

gives *v* **(1)** (= 5.59 × 106 m s−1)

**(2)**

(ii) angular speed *ω*  = 7.5(5) × 107 **(1)**

*unit*: rad s−1 **(1)** (accept s−1)

**(2)**

(iii) frequency of electron’s orbit *f*  **(1)**

(= 1.20 × 107 s−1)

number of transits min−1 = 1.20 × 107 × 60 = 7.2 × 108 **(1)**

[**alternatively**

orbital period [**or** (= 8.32 × 10−8 s)

number of transits min−1 = = 7.2 x 108 **(1)**]

**(2)**

**[Total 9]**

**M147.** (a) (i) (vertically) downwards [**or** top to bottom, or down the page] **(1)**

**(1)**

(ii) force on sphere *F* (= *kx*) = 0.24 × 18 × 10−3 **(1)** (= 4.32 × 10−3 N)

**(1)**

(iii) **use of** *F = EQ* gives *E* = **(1)** (= 1.05 × 105 V m−1)

**use of** *E* = gives separation *d* = **(1)**

= 4.8 × 10−2 (m) **(1)** (4.76 × 10−2)

**(3)**

(b) (i) electric field becomes zero (or ceases to exist) **(1)**

flow of charge (or electrons) from one plate to the other [**or** plates discharge] **(1)**

(until) pd across plates becomes zero [**or** no pd across plates, **or** plates at same potential] **(1)**

**(Max 2)**

(ii) net downward force on sphere (when *E* becomes zero)  
[**or** gravitational force acts on sphere, **or** force is weight] **(1)**

this force extends spring **(1)**

force (or acceleration) is proportional to (change in) extension of spring **(1)**

acceleration is in opposite direction to displacement (or towards equilibrium) **(1)**

for shm, acceleration ∝ (−) displacement [**or** for shm, force ∝ (−) displacement] **(1)**

**(Max 3)**

**[Total 10]**

**M148.** (a) the square root of the mean of the squares of all the values of the voltage in one cycle **(1)**

**or**

the equivalent dc/steady/constant voltage that produces the same **heating effect**/**power (1)**

**(1)**

(b) (i) peak voltage = 230 × √2 **(1)**

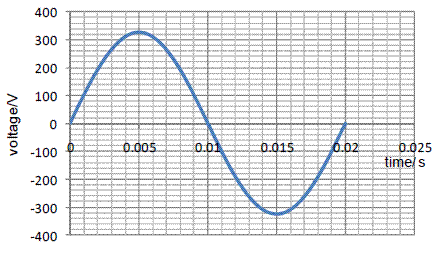
peak voltage = 325 V (or 324 V) **(1)**

**(2)**

(ii) average power = 230 × 0.26 = 60 W **(1)**

**(1)**

(c)



shape and symmetrical with consistent values of *x* at *y* = 0 and consistent  
*y*max (must be at least one cycle) **(1)**

appropriate scale y-axis **(1)**

correct peak values (to within one 2 mm square) **(1)**

correct period (accept 0.02s **or** 20 ms) **(1)**

**(4)**

**[Total 8]**

**M149.** (a) force of attraction between two point masses (or particles) **(1)**

proportional to product of masses **(1)**

inversely proportional to square of distance between them **(1)**

[**alternatively**

quoting an equation, *F* = with all terms defined **(1)**

reference to point masses (or particles) **or** *r* is distance between centres **(1)**

*F* identified as an attractive force **(1)**]

**(Max 2)**

(b) (i) mass of larger sphere *M*L (= π*r*3*ρ*) = π × (0.100)3 × 11.3 × 103 **(1)**

= 47(.3) (kg) **(1)**

[**alternatively**

use of *M* ∝ *r*3 gives **(1)** (= 64)

and *M*L = 64 × 0.74 = 47(.4) (kg) **(1)**]

**(2)**

(ii) gravitational force F **(1)**

= 1.5 × 10−7 (N) **(1)**

**(2)**

(c) for the spheres, mass ∝ volume (or ∝ *r*3, or *M* = π*r*3*ρ*) **(1)**

mass of either sphere would be 8 × greater (378 kg, 5.91 kg) **(1)**

this would make the force 64 × greater **(1)**

but separation would be doubled causing force to be 4 × smaller **(1)**

net effect would be to make the force (64/4) = 16 × greater **(1)** (ie 2.38 × 10−6 N)

**(Max 4)**

**[Total 10]**

**M150.** (a) (i) mass and energy have equivalent values

*E* = *mc*2 mentioned

MeV is energy unit (and kg that of mass)

**(Max2)**

(ii) clear attempt to substitute amu values into equation

5.135 × 10–3 (u) or 4.78 (MeV) seen

mass of 1 lithium nucleus = 9.98 × 10–27 (kg)

total number of nuclei in 1 kg = 1.00 × 1026

total energy given out = 4.78 × 1026 MeV

**(5)**

(iii) neutrons needed (for the lithium reaction) can come from the other (deuterium-tritium) reaction

**(1)**

(b) (i) potential energy equation (*E* = ) quoted or used

correct substitutions

1.5(3) × 10–13 (J)

**(3)**

(ii) ke = 3/2 kT

0.75/0.765 × 10–13 (J) **or** half of (b) (i) or 4 × 109 (K) used

3.7 × 109 (K) **or** total energy 1.6 × 10–13 (J)

**(3)**

(iii) each nucleus carries a positive charge

(electrostatically) repel each other

strong nuclear force

this has a range of nucleus diameters

high temperature needed for high kinetic energy

**(Max4)**

**[Total 18]**

**M151.** (a) ratio of charge to potential

4.2 μC per volt etc

**(2)**

(b) (i) method: time for voltage to half/tangent at origin/use of decay equation/1/e value

appropriate reading from graph (*T*½ = 440 or 450 μs)

substitution into correct equation

*R* correct for method (151/152/155 Ω)

**(4)**

(ii) **B** smaller than **A**

**B** discharges faster/**A** discharges slower

reference to decay equation/calculation for **B**

**(2)**

(c) *E* = ½ *CV*2 or ½ *QV* seen

both 4.0 (V) and 0.9 (V)/16.8 (μC) and 3.8 (μC) seen

31.9 (μJ)

**(3)**

**[Total 11]**

**M152.** (a) (i) (vertically) downwards **(1)**

**(1)**

(ii) force *F* is perpendicular to both *B* and *I* [**or** equivalent correct explanation using Fleming LHR] **(1)**

magnitude of *F* changes as size of current changes **(1)**

force acts in opposite direction when current reverses [**or** ac gives alternating force] **(1)**

continual reversal of ac means process is repeated **(1)**

**(Max 3)**

(b) appreciation that maximum force corresponds to peak current **(1)**

peak current = 2.4 × = 3.39 (A) **(1)**

*F*max (= *B I*pk *L*) = 0.22 × 3.39 × 55 × 10–3 **(1)** (= 4.10 × 10–2 N)

**(3)**

(c) wavelength (*λ*) of waves = = 0.80 (m) **(1)**

length of wire is *λ*/2 causing fundamental vibration **(1)**

[**or** *λ* of waves required for fundamental (= 2 × 0.40) = 0.80 m **(1)**

natural frequency of wire = 80 (Hz) **(1)**]

wire resonates (at frequency of ac supply) [**or** a statement that fundamental frequency (or a natural frequency) of the wire is the same as applied frequency] **(1)**

**(3)**

**[Total 10]**

**M153.** (a) ω = [or ω = ]

= 1.1 × 10–3 (1.08 × 10–3) **(1)** [= 6.2 (6.19) × 10–2]

rad s–1 [accept s–1] **(1)** [degree s–1]

**(3)**

(b) (i) **or (1)**

gives *r*3 = **(1)**

*****r* = 6.99 × 106 (m) **(1)**

**(3)**

(ii) *F* (= *mω*2*r*) = 1.1 × 104 × (1.08 × 10–3)2 × 6.99 × 106 **(1)**

= 9.0 × 104 (8.97 × 104) (N) **(1)**

[**or (1)**

= 9.0 × 104 (8.98 × 104) (N) **(1)**]

**(2)**

**[Total 8]**

**M154.** (a) (i) **(1)**

= 7.5 × 103 (V m–1) **(1)**

**(2)**

(ii) force *F* (= *EQ*) = 7500 × 0.17 × 10–6 **(1)** (= 1.28 × 10–3 N)

**(1)**

(b) (i) correct labelled arrows placed on diagram to show the three forces acting;

* electric force *F* (or 1.3 mN) horizontally to left **(1)**
* *W* (or *mg*) vertically down **and**
* tension *T* upwards along the thread **(1)**

**(2)**

(ii) *F* = *T* sin*θ* and *mg* = *T* cos*θ* give *F* = *mg* tan*θ* **(1)**(or by triangle or parallelogram methods)

tan*θ* (=0.272)**(1)**

gives *θ* = 15(.2) (°) **(1)**

**(3)**

**M155.** (a) *Q* (= *CV* = 330 × 9.0) = 2970 (μC) **(1)***E* (= ½*QV*) = ½ x 2.97 × 10–3 × 9.0 = 1.34 × 10–2J **(1)**[or *E* (= ½*CV*2) = ½ × 300 × 10–6 × 9.02 **(1)** = 1.34 × 10–2J **(1)**]

**(2)**

(b) time constant (= *RC*) = 470 × 103 × 330 × 10–6 = 155 s **(1)**

**(1)**

(c) Q (=Q0e-t/RC) = 2970 × e–60/155

= 2020 (μC)

(allow C.E. for time constant from (b))

V = = 6.11 V **(1)**

(allow C.E. for Q)

[or *V* = *V*0e–*t*/RC **(1)** = 9.0 e–60/155 **(1)**        = 6.11 V **(1)**]

**(3)**

**[Total 6]**

**M156.** (a) period = 24 hours or equals period of Earth’s rotation **(1)**remains in fixed position relative to surface of Earth **(1)**equatorial orbit **(1)**same angular speed as Earth or equatorial surface **(1)**

**(Max 2)**

(b) (i) = *mω*2*r* **(1)**

T =  **(1)**

**(1)**

(gives *r* = 42.3 × 103 km)

(ii) Δ*V* = *GM* **(1)**

= 6.67 × 10–11 × 6 × 1024 ×

= 5.31 × 107 (J kg–1) **(1)**

Δ*E*p = *m*Δ*V* (= 750 × 5.31 × 107) = 3.98 × 1010 J **(1)**

(allow C.E. for value of Δ*V*)

[**alternatives:**

calculation of (6.25 × 107) or (9.46 × 106) **(1)**

**or** calculation of (4.69 × 1010) or (7.10× 109) **(1)**

calculation of both potential energy values **(1)**subtraction of values or use of *mΔV* with correct answer **(1)**]

**(6)**

**[Total 8]**

**M157.** (a) units: *F* - newton (N), *B* - tesla (T) or weber metre–2 (Wb m–2), *I* - ampere (A), *l* - metre (m) **(1)**condition: *I* must be perpendicular to *B***(1)**

**(2)**

(b) (i) mass of bar, *m* = (25 × 10–3)2 × 8900 × *l* **(1)**(= 5.56*l*) weight of bar (= mg) = 54.6*l* **(1)***mg* = *BIl* or weight = magnetic force **(1)**54.6*l* = *B* × 65 × *l* gives *B* = 0.840 T **(1)**

(ii) arrow in correct direction (at right angles to *I*, in plane of bar) **(1)**

**(5)**

**[Total 7]**

**M158.** (a) *mg* = *T* cos 6 **(1)***F* = *T* sin 6 **(1)**hence *F* = *mg* tan 6 **(1)**[**or** correct use of triangle:**(1)** for sides correct, **(1)** for 6°, **(1)** for tan 6 = *F*/*mg***or** *F*Δ*x* = *mg* Δ*h* , tan *θ* = tan 6° =

**(3)**

(b) (i) (use of *E* = gives) *E* = = 7.0 × 104 V m–1 **(1)**

(ii) (use of *Q* = gives) *Q* = 3.1 × 10–9 C

(allow C.E. for value of E from (i))

**(3)**

**[Total 6]**

**M159.** (a) area of overlap of the plates

separation of/distance between the plates

permittivity/dielectric constant of free space/the  
material/dielectric between the plates (condone of the gap)

**(2)**

(b) (i) *Q = VC* (any form) or 0.047 µF × 12 (ignoring powers of 10)

5.6(4) × 10−7 C (0.56 µC)

(ii) time constant = 4.7 × 10−5 s or 0.01 = e−*t/RC*

0.01 = e–t/(0.000047) or 0.01 = e –t /47 or = = 4.605

2.2 (2.16) × 10−4 s or 0.22 ms

(iii) their (i) × 400 (230 (226) µA or 2.3 × 10−4 A if correct)

**(6)**

**[Total 8]**

**M160.** (a) force is proportional to the product of the two masses

force is inversely proportional to the square of their separation  
(condone radius between masses)  
**or**equation : masses defined, separation defined

**(2)**

(b) (i) appreciation that potential x distance from centre of sun = constant  
**or** calculation of *Vr* for two sets of values (1.33 × 1020)  
**or** uses distance ratio to calculate new *V* or *r*

calculation of all three + conclusion  
or uses distance ratios twice+ conclusion  
conclusion must be more than ‘numbers are same’  
(condone ‘signs’ and no use of powers of 10)

**(2)**

(ii) *V = GM/r* and *g = GM/r*2**or** *g = V/r* (no mark for *E* or *g= V/d* or *E* = *V/r )*

substitution of one set of data to obtain *GM* (1.33 × 1020)  
or 19 × 1010/7 × 108 seen

271 N kg−1 (m s−2) (J kg−1 m−1)

**(3)**

(iii) potential energy of the Earth = (−)*GMm/r***or** potential difference formula + *r*2 =∞  
**or** potential at position of Earth = −8.87 × 108 J kg−1(from *Vr =*1.33 × 1020)

correct substitution (allow ecf for *GM* from (ii))  
**or**  
potential energy = potential x mass of Earth

change in PE = 5.32 × 1033 J (cnao)  
*Fd* approach is PE so 0 marks

**(3)**

(iv) speed of Earth round Sun = 2π*r/T* **or** **or** 3.0 × 104 m s−1

**or** KE=

KE of Earth = ½ 6 × 1024 × their *v*2 (2.68 × 1033J)

energy needed = difference between (iii) and orbital KE (2.64 × 1033 J)

**or** KE in orbit = half total energy needed to escape (−1 for AE)

**(3)**

**[Total 13]**

**M161.** (a) (i) Lines of equipotential parallel to the plates

Field lines perpendicular to plates, evenly spaced and with arrows upwards

**Lack of clear labelling of at least one of the types of line loses 1 mark**Either field shown to be uniform

**(3)**

(ii) KE = 8.8 × 10–17 J

Use of ½ *mv*2

Speed = 1.4 × 107 m s–1 **ecf**

Momentum =1.27 × 10–23 kg m s–1 **ecf**

**(4)**

(b) Use of de Broglie wavelength = *h/mv*

5.2 × 10–11 m **ecf**

diffraction of electrons necessary

will work because wavelength is of same order as atomic separation   
(not just wavelength is too small)/argument  
consistent with their (a) (ii).

**(4)**

**[Total 11]**

**M162.** (a) (i) force per unit mass/force per kg

(ii) N kg−1 **not** ms–2 alone

**(2)**

(b) (i) *GM*/*R*2 seen

*GMQ*/(3*R)*2 seen

mass of Q = 9*M*

(ii) passes through (3*R*, *g*) and falls off in curve

two further points checked e.g., (6*R*,*g*/4) (12*R*, *g*/16)

overall line quality – single smooth line (both Ms for this)

**(6)**

**[Total 8]**

**M163.** (a) (i) 19 = (–) gives Δ*V* = 190 **(1)** J kg–1 **(1)**

(ii) *W* (= *m*Δ*V*) = 9.0 × 190 = 1710J [or *mgh* = 9.0 × 19 × 10 = 1710J] **(1)**

(iii) on mountain, required energy would be less because gravitational field strength is less **(1)**

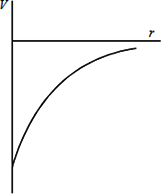
**(Max 3)**

(b) *g* ∝ (or F ∝ or correct use of *F* = ) **(1)**

∴ *g*′ = = 4.75(Nkg–1) **(1)**

**(2)**

**[Total 5]**

**M164.  
**

gradient decreases as *r* increases **(1)**   
*V* increases a s *r* increases **(1)**   
only negative values of *V* shown **(1)**

****

constant gradient **(1)**   
*V* increases as *r* increases **(1)**

**(Max 4)**

**M165.** (a) *m* = 4.0026 × 1.66 × 10–27 (kg) **(1)** (= 6.6 × 10–27 kg – electron masses are not significant)  
kinetic energy = 0.5 × 6.65 × 10–27 × (2.00 × 107)2 **(1)**

(= 1.33 × 10–12 J)

**(2)**

(b) loss in k.e. = gain in p.e. **(1)**

loss of ke. [or 1.33 × 10–12] = **(1)**

*R* = **(1)**

= 2.73 × 10–14 m **(1)**

**(4)**

(c) *any valid point including:*strong force complicates the process (\*)  
scattering caused by distribution of protons not whole nucleon distribution (\*)  
*α* particles are massive causing recoil of nucleus which complicates results (\*)  
(\*) any **one (1)**

**(1)**

**[Total 7]**

**M166.** (a) (i) *R*D = 1.3 × 21/3 = 1.64 fm **(1)** *RT* = 1.3 × 31/3 = 1.64 fm **(1)**

(ii) energy at ‘contact’ = **(1)**

**(1)**

= 6.56 × 10–14 J **(1)**

= 4.10 MeV **(1)**

**(Max 5)**

(b) energy of nucleus = 3/2 *kT* **(1)**

6.56 × 10–14 = 3/2 × 1.38 × 10–23 × *T* **(1)**

gives *T* = 3.2 × 109 K **(1)** (marks available for alternative sensible use of energy data)

reference to range of speeds (or energies) of nuclei (or atoms) **(1)**

**(Max 3)**

**[Total 8]**

**M167.** (a) attractive force between two particles (or point masses) **(1)**proportional to product of masses and inversely proportional to  
square of separation [or distance] **(1)**

**(2)**

(b) (for mass, *m*, at Earth’s surface) *mg* = **(1)**

rearrangement gives result **(1)**

**(2)**

(c) *Mmoon* **(1)**

= 7.35 × 1022 kg **(1)**

(= 0.0123) ∴ 1.23%

**(3)**

**[Total 7]**

**M168.**(a) (i) **(1)** = 2.5 x 105 Vm-1 **(1)**

(ii) *F* = *Eq* = 2.5 × 105 × 3.2 × 10–19 **(1)** = 8.0 × 10–14 N **(1)**

(iii) *qV = mv2* or *v =* **(1)** (= 3.1 × 105 m s–1)

**(5)**

(b) (i) field into paper **(1)**

(ii) force **⊥**r motion in B-field **(1)**   
∴ directed towards centre of a *circular* path **(1)**

(iii) so **(1)**

for B, *q* constant *r* ∝ *mυ*, momentum **(1)**

*r* = = 0.33 m **(1)**

**(6)**

(c) greater mass, so smaller speed at Q **(1)**

greater momentum justified e.g. *E* = (*E* const) **(1)**

∴ greater radius **(1)**

**(Max 2)**

**[Total 13]**

**M169.** (a) (i) electrons are negatively charged so beam is attracted to positive plate  
[**or** repelled by negative plate or electron experiences force towards positive plate] **(1)**

(ii) beam does not spread out **(1)**if speeds varied, faster electrons would be deflected less than slower electrons **(1)**

**(3)**

(b) (i) to give conduction electrons sufficient k.e. to leave metal [or to cause thermionic  
emission or electrons have insufficient ke. in a cold filament to leave filament] **(1)**

(ii) *mυ*2 = *eVA* [or *υ* = **(1)**

**(2)**

(c) (i) into the plane of the diagram **(1)**perpendicular to the diagram [or the electric field] **(1)**

(ii) *Beυ* = **(1)**

(iii) combine the two equations to give **(1)**

**(1)**

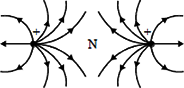
1.75 × 1011 Ckg–1 **(1)**

**(Max 5)**

**[Total 10]**

**M170.** (a) (i) force per unit positive charge **(1)(1)**[force on a unit charge **(1)** only]  
vector **(1)**

(ii)



overall correct symmetrical shape **(1)**outward directions of lines **(1)**spacing of lines on appropriate diagram **(1)**neutral point, N, shown midway between charges **(1)**

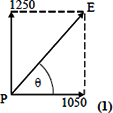
**(6)**

(b) (i) *EAP* **(1)**

= 1250 V m–1 **(1)**

(ii) *EPB* = = 1050Vm–1 **(1)**

(iii)



allow e.c.f. from wrong numbers in (i) and (ii)

*E* = **(1)** 1630Vm–1 **(1)**

*θ* = tan-1 = 50.0° to line PB and in correct direction **(1)**

**(Max 6)**

(c) (i) potential due to A is positive, potential due to B is negative **(1)**at X sum of potentials is zero **(1)**

(ii) + = 0 **(1)**

gives AX (= *x*) = 0.080m **(1)** (only from satisfactory use of potentials)

**(4)**

**[Total 16]**

**M171.** (a) (i) *including, for example:*positron is an antimatter particle; proton is a matter particle (\*)  
positron is a lepton; proton is a hadron (\*)  
positron has a smaller rest mass than a proton (\*)  
positron is not composed of other particles; proton is made up of quarks (\*)  
(\*) any two **[1] [1]**

(ii) proton path has greater radius of curvature than positron **(1)**

(iii) radius of curvature *r* = and *υ, B* and *e* are constants **(1)**

therefore *r* proportional to *m* **(1)**mass of proton is (much) greater than mass  
of positron (at same speed) **(1)**

**(5)**

(b) (i) Carbon-14 **(1)**

(ii) Carbon-10 **(1)**as this is furthest from stability **(1)**

**(3)**

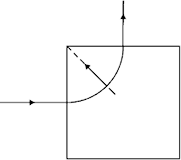
(c) rest mass of electron = 0.51 MeV therefore total energy available  
= (2.2 +2 × 0.51)= 3.22 (MeV) **(1)**

gamma photons produced have average energy = = 1.6 MeV**(1)**

**(2)**

**[Total 10]**

**M172.** (a)



(uniformly) curved path continuous with linear paths at entry and exit points **(1)**arrow marked F towards top left-hand corner **(1)**

**(2)**

(b) into (the plane of) the diagram **(1)** (do not accept “downwards”)

**(1)**

(c) *F*(= *BQυ*) = 0.50 × 1.60 × 10-19 × 5.0 × 106 **(1)**= 4.0 × 10-13 N **(1)**

**(2)**

(d) *B* must be in opposite direction **(1)**(much) smaller magnitude **(1)**

**(2)**

**[Total 7]**

**M173.** (a) (i) *Q* = 1.0 × 10–3 C **(1)**

(ii) *E* = 5.0 × 10–2 J **(1)**

**(2)**

(b) (i) V = 50 V **(1)**

(ii) (*E*1 = *QV* = 1.25 × 10–2 J) *E*2 = 2.5 × 10–2 J **(1)**

(iii) current flows (when capacitors connected together) **(1)**(energy lost due to) heat in wires **(1)**

**(4)**

**[Total 6]**

**M174.** (a) (i) (force) to the right **(1)**

(ii) electrons accelerate or speed increases **(1)**

**(2)**

(b) (i) sketch to show path curving upwards in the field (must not become vertical) **(1)**

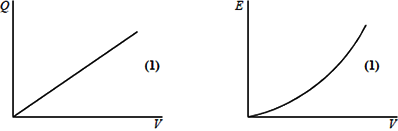
(ii) horizontal component of velocity is unchanged **(1)**   
vertical or upwards acceleration (or force) **(1)**   
parabolic path described (or named) **(1)**

**(Max 3)**

The Quality of Written Communication marks are awarded for the quality of answers to this question.

**[Total 5]**

**M175.** (a)



capacitance [or charge per volt or *Q*/*V*] **(1)**

**(3)**

(b) (i) *Q* = *CV* (= 0.68 × 6.0) = 4.1 C **(1)**

(ii) *E* = = 12 J **(1)**

**(2)**

**[Total 5]**

**M176.**(a)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| \_\_\_\_\_\_\_\_ | N kg–1 | electric field strength | N C–1 or V m–1 | **(1)** |
| gravitational constant | N m2 kg–2 | \_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_ | **(1)** |
| mass | kg | charge | C | **(1)** |
| distance (from mass to point) | m | distance (from charge to point) | m | **(1)** |

**(4)**

(b) (i) none **(1)**

both *FE* and *FG* ∝ (hence both reduced to [affected equally] **(1)**

(ii) charge on B must be doubled **(1)**

**(3)**

**[Total 7]**

**M177.** (a) (i)–31 MJ kg–1 **(1)**

(ii) increase in potential energy = *m*Δ*V* **(1)**= 1200 × (62 – 21) × 106 **(1)**= 4.9 × 1010 J **(1)**

**(4)**

(b) (i) *g* = – **(1)**

(ii) *g* is the gradient of the graph = **(1)**

= 2.44 N kg–1 **(1)**

(iii) *g* ∝ and *R* is doubled **(1)**

expect *g* to be = 2.45 N kg–1 **(1)**

[*alternative (iii)*

*g* ∝ and *R* is halved **(1)**

expect *g* to be 2.44 × 4 = 9.76 N kg–1 **(1)**]

**(5)**

**[Total 9]**

**M178.** (a) *V*0 = 8.0 V **(1)**

(b) *V*rms = 8/√2 = 5.7 (V) **(1)**(allow e.c.f. from (a))

(c) *T* = 3.0 ms **(1)**

(d) *f* = = 330 (333) Hz **(1)**

(allow e.c.f. from (c))

**[Total 4]**

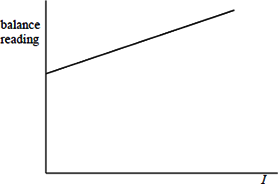
**M179.** (a) (i) interaction between current and B-field gives force on wire **(1)**equal and opposite force on magnet (down) **(1)**

(ii) force on wire must be up **(1)**∴ current right to left **(1)**by left hand rule **(1)**

(iii) (force = B*Il* = *mg* = change in mass × 9.8)  
B × 5.0 × 0.060 = 1.54 × 10–3 × 9.8 **(1)**B = 0.050 T [50.3 mT] **(1)**

**(Max 6)**

(b)



straight line **(1)**intercept, upward slope **(1)**

**(2)**

**[Total 8]**

**M180.** (a) (i) the emf (of the battery) **(1)**

(ii) the voltage across the battery when current flows  
[or terminal voltage or pd supplied to the circuit]

(iii) V = (3 × 0.5) = 1.5 (V) **(1)**current = (1.5/14) = 0.11 A **(1)** (0.107 A)

(iv) ( *=* *V* + *Ir* and emf = 3.5 × 0. 5 = 1.75 (V) gives)

1.75 = 1 .5 *+* 0.1 07*r* **(1)**

r = 2.3 Ω

[or use of  = *I* (*R* + *r*) with *I* = 0. 107 gives *r* = 2.4 Ω

and *I* = 0. 11 gives *r* = 1.9 Ω]

(allow C.E. for value of *I* from (iii))

**(6)**

(b) (i) peak value = 3.5√2 = 4.9 V **(1)**

(ii) oscilloscope screen to show vertical line of height 2.5 divisions above central axis **(1)**and below central axis **(1)**

**(3)**

**[Total 9]**

**M181.** (a) graph to show:   
straight line from origin **(1)**   
end point at 4.5 (V), 9.0 (μF) **(1)**

**(2)**

(b) (i) Δ*W* = *V* Δ*Q* explained **(1)**   
energy stored or total work done in charging = area under graph or   
charge × average voltage **(1)**

energy stored = work done (= ½*QV*) **(1)**

(ii) *Q* = 2.0 × 1.5 = 3.0 (μC) **(1)**   
*E* (=½ *QV*) = ½ × 3.0 × 10-6 × 1.5 = 2.25 × 10-6J **(1)**   
[or *E* = (½*CV*2 = ½ × 2.0 × 10-6 × 1.52 = 2.25 × 10-6 J]

**(5)**

**[Total 7]**

**M182.** (a) *Q = CV* **(1)**   
(= 4.7 × 10-6 × 6.0) = 28 × 10-6 C or 28 μC **(1)**

**(2)**

(b) *E* = ½*CV*2 **(1)**   
= ½ × 4.7 × 10-6 × 2.02 **(1)**   
= 9.4 × 10-6 J **(1)**   
[or *E* = ½*QV* **(1)**   
= ½ × 9.4 × 10-6 × 2.0 **(1)**   
= 9.4 × 10-6 J **(1)**]

**(3)**

(c) time constant is time taken for *V* to fall to **(1)**

∴*V* must fall to 2.2 V **(1)**   
time constant = 32 ms **(1)**   
[or draw tangent at *t* = 0 **(1)**   
intercept of tangent on *t* axis is time constant **(1)**   
accept value 30 - 35 ms **(1)**]   
[or *V = V*0 exp(-*t* / *RC*) or *Q = Q*0 exp(-*t* / *RC*) **(1)**

correct substitution **(1)**   
time constant = 32 ms **(1)**]

**(3)**

(d) time constant = *RC* **(1)**

*R* = = 6800 Ω **(1)**

(allow C.E. for value of time constant from (c))

**(2)**

**[Total 10]**

**M183.** (a) gravity or force acts towards centre **(1)**   
force acts at right angles to velocity or direction of motion   
[or velocity is tangential] **(1)**   
no movement in direction of force **(1)**   
no work done so no change of kinetic energy so no change in speed **(1)**

**(3)**

(b) (i) *B* = (562 + 172)½ = 59 μT **(1)**

(ii) tanθ = **(1)**

θ = 17° **(1)** (± 1°)

(iii) rod sweeps out or cuts (magnetic) flux [or rod cuts field] **(1)**

**(4)**

**[Total 7]**

**M184.** (a) (i) uud **(1)**

(ii)  **(1)**

**(2)**

(b) (i) = *Bev* [or *r* = ] **(1)**

*r* = *m* = 1.67 × 10-27 **(1)** **(1)**

= 0.98 m **(1)**

(ii) pion path more curved than proton path **(1)**

(iii) path more curved [or radius (of path) smaller] **(1)**   
for both paths **(1)**

**(7)**

**[Total 9]**

**M185.** (a) θ = 90° (or 270° or or ) **(1)**

**(1)**

(b) Φ = *BA* cosθ **(1)**   
= 2.5 × 10-3 × 35 × 10-3 × 20 × 10-3 × cos 30° = 1.5 × 10-6 Wb **(1)**

**(2)**

(c) Φmax = 2.5 × 10-3 × 35 × 10-3 × 20 × 10-3 (Wb) **(1)** (= 1.75 × 10-6)   
flux linkage = 650 × 1.75 × 10-6 = 1.1(4) × 10-3 (Wb turns) **(1)**

**(2)**

**[Total 5]**

**M186.** (a) (i) *E* (=) = **(1)**

= 3.15 × 1012Vm‑1 (or (NC‑1) **(1)**

(ii) *V* (=) = (–)**(1)**

= (–) 6.07 × 10‑26 **(1)** – sign and J kg‑1

**(5)**

(b) arrow pointing to the right **(1)**

**(1)**

**[Total 6]**

**M187.** (a) (i) mass per sec ( = density × vol per sec) = 1000 × 1.4 **(1)**   
= 1400 kg (s–1)

(ii) loss of *Ep* per sec = 1400 × 9.8 × 750 **(1)**

= 1.0 × 107 J (s–1) **(1)** (1.03 × 107 J s–1)

(allow C.E. for value of mass per sec from (i))

(iii) efficiency **(1)**

= 0.2 **(1)**(allow C.E. for value (ii))

**(6)**

(b) (i) (use of *P = IV* gives) *I*rms = **(1)**

= 80 A **(1)**

(ii) power output = (0.95 × power input) = 0.95 × 2.0 (MW) = 1.9 (MW) **(1)**

= 6.9 A **(1)**

[or *I* for 100% efficiency = 7.3 (A) **(1)**

*I* for 95% efficiency = 95% of 7.3 = 6.9 A]

**(4)**

**[Total 10]**

**M188.** (a) time elapsed = 8.5 ± 0.2 (ms) **(1)**   
distance travelled = 3 (m) **(1)** (allow C.E. if *d* = 1.5 (m))

speed of sound = = 350 m s–1 (353) **(1)**

**(3)**

(b) connect oscilloscope across ac source (or diagram or ac to Y plates) **(1)**   
adjust time base to give trace **(1)**   
adjust voltage sensitivity **(1)**   
sinusoidal trace shown **(1)**   
how to measure *T* from trace **(1)**

*f* **(1)**

**(Max 5)**

**[Total 8]**

**M189.** (a) (i) (use of *EP* = gives) *EP* = **(1)**

= 2.3 × 10–13 (J) **(1)**

(ii) *EK* at least distance apart = 0   
*EK* of (each) proton = 0.5 × 2.3 ×10–13 (J) **(1)**   
= (1.15 ×10–13(J)) = 0.72 MeV **(1)** (0.719 MeV)

**(5)**

(b) (i) uud **(1)**

(ii)  **(1)**

**(2)**

(c) (i) *Q* = –1(e) **(1)**   
*B* = 0 **(1)**

(ii)  **(1)**   
**(1)**

(iii) mass of extra particles produced from total initial kinetic energy **(1)**   
extra mass possible in (a) = 1.4 MeV / *c*2 **(1)**   
pions rest mass in (b) >> extra mass in (a) **(1)**

**(Max 5)**

**M190.** (a) *R = ρL/A*

*A =* 2.0 × 10–6 (m2) or π(0.8 × 10–3)2 seen in equation  
(condone π(1.6 × 10–3)2 or 8.04 × 10–6 seen)

*L =* 2900 m, 2940 m, 2960 or 3000 m

**(3)**

(b) resistance leads to loss of heat/energy/power **or** *I2*R loss or voltage drop (across cable)

lower current lowers loss of heat/energy/power **or** reduces voltage drop

ac can be transformed (to lower transmission current)

**(3)**

**[Total 6]**

**M191.** (a) *C =*

15.6 nF or 16 nF

**(2)**

(b) (i) 2.4 × 109 (V)

**(1)**

(ii) ½ *CV*2 (or ½*QV* if attempt to calculate *Q* made)

4.3–5.0 × 1010 J

**(2)**

(iii) 36–40 C

**(1)**

(c) recognition that 1% of charge or voltage remains

any appropriate form of decay equation (either exponential  
or logarithmic)

3.48 × 106 **Ω cao** (but do not allow if physics error)

**(3)**

**[Total 9]**

**M192.** (a) (i) shows arrows from + to –

(ii) surface of constant potential / no work done in moving charge on surface OWTTE

(iii) 3 correct lines between plates, straight, labelled, +12.5 kV on left

outwards curvature at edge of plates

(b) (i) **F** = ***Vq / d*** ***or 50000 × 5.5 × 10–9 / 4***

= 0.0690 [mN] [0.0688]

(ii) *a* = *F / m* = 0.069 × 10–3 / 0.12 × 10–3

= 0.575 / 0.573 m s–2

use of appropriate kinematic equation

*t* = √2 × 2 / 0.575 = (2.63) s

so length must be 0.8 × 2.63 = 2.11 m [gets mark ecf from third mark if number quoted]  
*allow alternative energy approach*

**[Total 10]**

**M93.** (a) product of flux and number of turns

Wb or equivalent

**(2)**

(b) changing primary magnetic field due to alternating voltage (applied to primary)

varying flux links with secondary

induced emf ∑ rate of change of flux linkage

NS NP so less voltage on secondary

**(4)**

(c) (i) equation or correct substitution

15.3 V

**(2)**

(ii)**not** just “heating” or “heat loss”

**(2)**

**[Total 10]**

**M194.** (a) (i) g.p.e. =  **must** **be** **equation** (*condone* *“V* *=”*)

**(1)**

(ii) equate with k.e. **must** **be** **seen**

cancelling **correct** ***m*** must be seen

**(2)**

(b) correct ratios taken

v = 15.8(4) km s–1

**(2)**

(c) mention of air resistance

k.e. of rocket → internal energy of rocket and atmosphere/  
work is done against air resistance

**(2)**

**[Total 7]**

**M195.** (a) (i) *E* = *eV*

2.9 (2.88) × 10–16 J

**(2)**

(ii) KE = 0.5 *mv*2

*v* = 2.5(2) × 107 m s–1

allow e.c.f. for (i) ie 1.5 × 1015 × √(their (i)

**(2)**

(b) (i) force acting per unit charge or *F* / *q* with symbols defined

**(1)**

(ii) *F = eE* or *F = eV / d* or *E = V / d*

2.4 × 10–15 N

downwards / towards *Q*

**(3)**

(iii) 3.2 (3.17) × 10–9 s   
e.c.f. for their (ii)

**(1)**

(iv) *a = F / m* or *v = Ft / m*

8.4 (8.36) × 106 m s–1

ecf their (ii) × their (iii)

**(2)**

(v) 4.0 cm (3.98 cm)

do not allow e.c.f.

**(1)**

**[Total 12]**

**M196.** (a) acceleration is (rate of) change of velocity

**or** velocity is a vector

**or** velocity has magnitude and direction

velocity is changing since direction is changing

(must be clear that it is the velocity that is changing direction)

allow 1 mark for ‘it would move in a straight line at constant speed if it were not accelerating’

**do not allow** because there is a force acting’

because direction is changing’

**(2)**

(b) (i) arrow toward centre of circle at **P**

**(1)**

(ii) *F* = *mv*2 / *r* **or** *mrω*2

**or** numerical equivalent (*r* must be 200 m)

5.4 × 10–16 N

**(2)**

(iii) graph showing correct curvature with *F* plotted correctly (e.c.f. for *F*)

(should be between 5 × 10–14 and 6 × 10–16 N

double *v*, quadruple *F*

(should be possible to do these tasks to ±½ a square)

**(2)**

(c) (i) circumference = 1256 m or 2*πr* × 420 000

(allow e.c.f. for incorrect *r* from (b)(ii))

distance travelled = 5.3 × 108 m

**(2)**

(ii) *s* = ½ *gt*2 **or** *ut* + ½*at*2

19.6m (20m)

**(2)**

(iii)    *mg* = 1.7 (1.67) × 10–26 N

**(1)**

**[Total 12]**

**M197.** (a) (i) 0.02 C of charge produce a p.d. of 1 V between the two terminals

**or** 0.02 C of charge per unit p.d.

**(2)**

(ii) straight line through the origin

correct gradient (possible check point 0.2 C at 10 V)

and graph line up to 20 V

**(2)**

(iii) area between graph line and charge axis

(allow area under graph)

**not** area of the graph

**not** area under graph / 2

from 0 to the required voltage or up to the required voltage

**or** energy = ½*QV* or ½*CV*2

read corresponding *Q* from the graph

(only allow second mark if graph is straight line through the origin)

**or** *C* determined from gradient of graph and *V* given

**(2)**

(iv) sketch showing two capacitors in parallel connected to a supply

**(1)**

(b) (i) energy stored = 0.5 *CV*2

4.0 J (condone 1 sf answer)

**(2)**

(ii) (useful) energy output = *mgh*

**or**

efficiency = useful energy out / energy input(in same time)

**or**

efficiency = useful power out / power input

energy output = 0.15 × 9.8 × 0.8 = 1.18 J

efficiency = 0.294 or 29.4% e.c.f. from (b)(i)

(allow 29% – 30%)

**(3)**

**[Total 11]**

**M198.** (a)

7000 (6960)

**(2)**

(b) (i) changing magnetic field

emf or changing magnetic field is in the core

e.m.f. induced (due to changing magnetic field) not back emf

current flows as core is made from a conducting material

**(4)**

(ii) laminated core

**(1)**

**[Total 7]**

**M199.** (a) direction changing, velocity vector

**(1)**

(b) Newton’s law equation

centripetal force equation

cancel mass of Triton

**(3)**

(c) *ω* *=* 2π*f* or *ω* *=* 2 π/*T*

*ω2r3* = constant or *ω2* *=*

**or** statement of Kepler III

= 5.2(2)

**(4)**

**[Total 8]**

**M200.** (a) (i) 2200 × 10–6 farads (C V–1 ) or 2200 *μ*C V–1   
**or** idea of capacitance measuring charge (or coulomb) per volt   
**or** C = *Q / V* with terms defined

the capacitor ‘stores’ 2200 *μ*C of charge for a potential difference of 1 volt

**(2)**

(ii) 15 V is the maximum safe voltage between the terminals of the capacitor.   
**or** the maximum voltage that should be used across the capacitor   
**or** the voltage at which the capacitor breaks down / insulator conducts

**(1)**

(b) (i) correct curvature starting at 6 V at time = 0   
points plotted correctly at 3 and 6 minutes with reasonable curve   
(2.2 V and 0.8 V)

**or** at 3 V at 2.1 minutes and 1.5 V at 4.2 minutes if ‘half life’ calculated and used

allow ±0.5 small square

**(2)**

(ii) time alarm rings read correctly from the graph at 2 V   
(about 200 s but use candidate's graph condone any shape graph)

**(1)**

(iii) time constant = *RC* or (*R* = ) **or** time to halve = 0.69*CR*

82 kΩ

**(2)**

(iv) cooking time ∝ *CR* ∝ *R*   
**or** quotes *V* = *V*0 e–t / *CR* **or** 2 = 6 e–300 / *CR*

resistance = 120 kΩ (124 kΩ)

**(2)**

(v) connect it in parallel (with the other capacitor)   
**or**   
replace capacitor with one of higher value (not just use a larger capacitor)

**(3)**

**[Total 11]**

**M201.** (a) (i) *F* = 2500 or 2600 N

*F* = mv2 / r

1500 m s–1 / 1480 m s–1   
**or** any further progress towards a solution such as   
attempting to use: *F = GMm / r2*   
**or** *½ mv2* = *mgh*   
**or** equations of motion   
**or** *r* = 6 ××105   
**or** *F* = *mv*2 / (*r* + *h*)

**or** evidence of time wasted, for example, repeated attempts   
at a solution   
no unit penalty or s.f. penalty

**(3)**

(ii) using the area under the graph between 0 and 6.0 × 105 m

**or** use of *VG* = *GM / r* or *PE* = *GMm / r*

between 20 and 22 squares

**or** 1 square = 108 J

**or** uses the trapezium rule or rectangle and triangle   
(allow if they fail with powers of ten)

**or** attempts to find the difference between the 2 values of PE

2.0 × 109 J to 2.2 × 109 J

**or** attempt to complete the calculation   
(may be confounded by lack of *r*)

**(3)**

(b) (work done by motors) relates to change in PE or (PE + KE)

2 × (PE + KE) condone 2 × (PE)

need to know energy value of fuel / fuel density / energy density of fuel /   
fuel economy / efficiency of engines

**(3)**

**[Total 9]**

**M202.** (a) (i) force per unit mass (allow equation with defined terms)

**(1)**

(ii) diagram of method that will work

(pendulum / light gates / solenoid and mechanical gate / strobe photography / video)

pair of measurements (eg length of pendulum and (periodic) time / distance and time of fall – could be shown on diagram)

instruments to measure named quantities (may be on diagram)

correct procedure (eg calculate period for range of lengths, measure the time of fall for range of heights)

good practice – series of values and averages / use of gradient of graph

appropriate formula and how *g* calculated

**(6)**

(b) (i) evidence of *gr*2 being used

values of 0.25, 0.11, 0.06(25)

no s.f. penalty here unless values given as fractions

**(2)**

(ii) points correctly plotted on grid (e.c.f.)

smooth curve of high quality at least to 10 × 107 m, no intercept on *r* axis

**(2)**

(iii) attempt to use area under curve

evidence of × 800 kg

(4.3 – 5.3) × 109 J

**or**

use of equation for potential Δ*EG* = *m*(*g*1*r*1 – *g*2*r*2)

evidence of × 800 kg

(4.7 – 4.9) × 109 J

max 2 if assumed values of *G* and *M* used

allow calculation of *GM* from graph followed by substitution into Δ*EG* = *MG*(*m* / *r*1 – *m* / *r*2) for 3 marks

**(3)**

**[Total 14]**

**M203.** (a) (i) vertical field line(s)

directed downwards

**(2)**

(ii) *mv*2/r and *Bev* seen

equated and correctly rearranged

**(2)**

(iii) *v* = or equivalent

T =

**(2)**

(iv) no *v* in the equation for *T* *(m,* *B* and *e* all independent of *v*)

**(1)**

(b) (i) proton spirals outwards/suitable diagram

as v ↑ *r* ↑

**(2)**

(ii) *f* *=1*/*T*

**(1)**

(c) (i) conversion of keV to J (1.92 × 10–17)

use of ½ *mv2* 1.50 × 105 ms–1

**(3)**

(ii) λ =

*p* *=* *mv* or substituted values

2.6 × 10–12 m

**(3)**

(iii) *y*-rays or X-rays or answer consistent with candidate’s λ

**(1)**

**[Total 17]**

**M204.** (a 1

**(1)**

(b) (i) *Ek* = *Ep* when the protons touch   
**or** *Ek* = *q*2 / 4*πε*0*r*   
**or** separation when they touch = 3.0 × 10–15 m   
**or** *V* = *q* / 4π*ε*0*r*

*Ek* = (1.6 × 10–19)2 / 4π (8.9 × 10–12) (3.0 × 10–15)   
**or**   
*Ek* = (1.6 × 10–19)2 / 4π (8.9 × 10–12) (1.5 × 10–15)

7.6(1) × 10–14 J (cao)

**(3)**

(ii) incident proton will stop and the stationary proton will move off at velocity / speed  
of the incident proton   
**or**   
All KE / momentum is transferred to the stationary particle   
**NB** not they will not touch

**(1)**

(iii) protons travel in the opposite directions or velocity is reversed

with initial speeds

total momentum before = 0 so momentum after must be 0   
or   
**provided they have said that speeds are the same**   
total KE is same before and after the collision   
**or**   
the collision is elastic

**(3)**

(iv) mention of strong nuclear force   
**or**   
the repulsive force is overcome

the strong nuclear force is greater than the electrostatic repulsion   
**or**   
the strong nuclear force is effective when the protons touch

**(2)**

(c) *E* = *mc*2

mass increase = {(2 × 2.2) – (2 × 1.7)} × 10–27 kg = 1.0 × 10–27 kg   
**or**   
calculates initial energy equivalence of 2 protons   
**or**   
final energy equivalence of 2 delta + particles

8.6 or 9 × 10–11 J (i.e. allow 1sf) c.a.o.   
(NB Adding on the answer to (b) (i) is correct but it has no influence on the answer to 2 sf  
so its absence is condoned)

**(3)**

**[Total 13]**

**M205.** (a) (i) *E* at 2*R* = 20 to 21 (NC–1) i.e. no up

(i.e. have used inverse square law possibly misreading the *E* axis)

correct curvature with line through given point   
must not increase near tail   
(ignore below 6400 km)

no intercept on distance axis and through correctly   
calculated point

(ii) determine the area under the graph

between **A** and **B** or between the points   
ignore any reference to *V* = *Ed*)

**(4)**

(b) (i) *E* = *q*/4π*ε*0*r*2 (*Q* = 84 × 4π 8.9 × 10–12 (6400 000)2

(3.8–3.9) × 105 C

(ii) surface area of the Earth = 5.15 × 1014 (m2)

**or:**   
charge per square metre = total charge/ surface area of   
Earth   
(may be seen as a numerical substitution with wrong area)

738 – 760 pC (m–2) ecf for *Q* from (b)(i)

**NB**

(i) answer is the same when unit is left in km since r2 cancels so condone   
(ii) Use of *E* = *q* / 4π*ε*0*r* followed by area = 4π*r* gives correct value but no marks

**(4)**

**[Total 8]**

**M206.** (a) 1 coulomb of charge is stored for a p.d. of 1 V between the plates  
(or equivalent statement) Condone I coulomb per volt

**(1)**

(b) (i) Correct substitution in C = (ignore powers of 10)

Plate area = 4.65 × 10–3 m2 or C = with correct data

Radius = (their area /3.14)1/2; 0.038(4 or 5) m if correct

**(3)**

(ii) E = ½ CV2 **or** correct numerical substitution **or** E = ½ QV & Q = VC

4.1(4) × 10–10 J

**(2)**

(c) Time constant = *RC* **or** Time to halve = *0.69* *RC* **or** V = V0 e– t/*RC*

Time to fall to 1/e (0. 19 ms) **or** time to halve (0. 13 ms)  
**or** *V0* *=* 6 V and correct coordinates of point on line  
(0.6 ms max)

8.1 - 8.6 MΩ

**(3)**

**[Total 9]**

**M207.** (a) the radius/diameter of the planet **not** ‘size’

the mass (or density) of the planet

**(2)**

(b) (i) volume of the granite = 4/3π *r*3**or**radius of the granite = 0.2 km (may be seen in an  
incorrect equation)

2003 or 4/3π 0.23 or 3.35 × 107 m3

Mass = density × volume used with any density and their volume  
(Volume may be in formula form)  
If they use correct volume then either 1.24 × 1011 or 7.37 × 1010 gets the mark)

(3700-2200) × 3.35 × 107 **or** 1500 × 3.35 × 107 kg  
**or** (1.24 × 1011 –7.37 × 1010) **or** 5.025 × 1010 **or** 5.03 × 1010 seen  
Condone rounding off early leading to 4.6 × 1010 kg

**(4)**

**NB**1)the fourth mark is not for 5.0 × 1010 – all working must be shown  
2)those who do not show conversion of radius from km to m in the  
calculation but otherwise correct will get 3

(ii) Gravitation field strength *g* = *GM*/*r*2**or**uses distance of 0.4 km for *r*

Substitution for extra field strength  
= 6.7 × 10–11 × 5.0 × 1010/(0.4×103)2Condone *r* = 0.4 for this mark

Correct substitution for the extra field strength with **correct** powers of 10

2.1 × 10–5 N kg–1 (condone m s–2)  
**or**1.9 × 10–5 if 4.6 × 1010 carried forward from (i)

**(4)**

(iii) Correct general shape always below original curve

**(1)**

**Alternative scheme for different approach to (ii)**

(ii) Gravitation field strength = *GM*/*r*2**or** uses distance of 0.4 km for *r*

Correct substitution for field strength for granite (or soil)  
6.7 × 10–11 × 1.24 × 1011/(0.4×103)2 or 6.7 × 10–11 × 7.37 ×1010/(0.4×103)2

Condone r = 0.4 for this mark

Correct substitution for field strength for soil (or granite)

2.1 × 10–5 N kg–1 (condone m s–2)

**(4)**

**[Total 11]**

**M208.** (a) (i) 1 N per A per m  
**or** 1 Wb m–2**or** quotes: *B* = *F*/*IL* with terms defined  
**or** induced *EMF* = Δ*BAN*/*t* with terms defined  
**or** a slightly flawed attempt at the definition in  
statement form

It is the flux density (perpendicular to a wire) that  
produces a force of 1N per m on the wire when  
the current is 1A  
**or***B* = *F*/*IL* **and** 1 T is flux density when *F* = 1N; *I* = 1A  
and *L* = 1 m  
**or** induced *EMF* = Δ*BAN* /*t* and 1 T is the flux change  
when emf = 1V for *A*=1 *N* =1 and *t* =1 or similar

**(2)**

(ii) force on charge due to *E* field , *F*E= *Eq* **or** *Vq*/*d***and**force due to *B* field, FB = *Bqv***or** *Eq*=*Bqv*

= *Bqv*; cancels *q* **and states explicitly** *v* =   
**or** *v* =

**(2)**

(iii) *v* = 20000/0.14 (seen) **or** 143 × 103 m s–1

**(1)**

(b) (i) *Bqv* =*mv*2/*r* or *r* = *mv*/*Bq* ( allow *e* instead of *q*)  
mass of ion = 1.7 × 10–27 × 58 (may be in equation)  
**or** (9.86 × 10–26 kg seen)

**or**radius = 0.14 m (may be in equation)

Substitutes and arrives at 0.62 to 0.63 T

**(3)**

(ii) Calculates new radius (0.145 m) or diameter (0.288 m)  
using *r* ∝ *m* or otherwise **allowing ecf**

0.010 m (condone 0.01 m) or 0.0096 – 0.0097 m  
(Allow 0.0079 m or 0.008 m due to use of different  
sfs for *B* and *v* )

**(2)**

**[Total 10]**