1 (a) (i) \[ F_G = G M m / R^2 = \left(6.67 \times 10^{-11} \times 5.98 \times 10^{24}\right) / (6380 \times 10^3)^2 \]
\[ = 9.80 \text{ N} \]
A1 [2]

(ii) \[ F_C = m R \omega^2 \]
\[ \omega = 2\pi / T \]
\[ F_C = (4\pi^2 \times 6380 \times 10^3) / (8.62 \times 10^4)^2 \]
\[ = 0.0339 \text{ N} \]
A1 [3]

(iii) \[ F_G - F_C = 9.77 \text{ N} \]
A1 [1]

(b) 9.77 m\(s^{-2}\) because acceleration is resultant force per unit mass
B1 [1]

[Total: 7]

2 (a) \[ pV / T = \text{constant} \]
\[ T = \left(6.5 \times 10^6 \times 30 \times 300\right) / (1.1 \times 10^5 \times 540) \]
\[ = 985 \text{ K} \]
C1

(b) (i) \[ \Delta U = q + w \]
symbols explained (q = heating, w = work)
M1
consistent set of directions of energy change
A1 [2]

(ii) \[ q \text{ is zero} \]
\[ \Delta U = w \text{ and so } U \text{ increases} \]
\[ U \text{ increases so } E_K \text{ of atoms increases and } T \text{ increases} \]
A1 [3]

[Total: 7]

3 (a) (i) \[ \omega = 2\pi f \]
B1 [1]

(ii) \textit{either (−)ve because } a \text{ and } x \text{ are in opposite directions or } a \text{ is always directed towards mean position}
B1 [1]

(b) (i) forces in springs are \( k(e + x) \) and \( k(e - x) \)
resultant = \( k(e + x) - k(e - x) \)
\[ = 2kx \]
C1
M1
A0 [2]

(ii) \[ F = ma \]
\[ a = -2kx / m \]
\[ (−) \text{ sign explained} \]
B1 [2]

(iii) \[ \omega^2 = 2k / m \]
\[ (2\pi f)^2 = (2 \times 120) / 0.90 \]
\[ f = 2.6 \text{ Hz} \]
C1
A1 [3]

[Total: 9]
4 (a) amplitude of carrier wave varies
in synchrony with displacement of information signal

(b) graph: three vertical lines
symmetrical with smaller sidebands
at frequencies 70, 75 and 80 kHz

(c) bandwidth = 10 kHz

[Total: 6]

5 (a) unwanted energy / power that is random

(b) number of dB = 10 \log(P_{OUT} / P_{IN})
63 = 10 \log(P_{OUT} / (2.5 \times 10^{-6}))
\quad P_{OUT} = 5.0 \text{ W}

(c) attenuation = 10 \log(5.0 / (3.5 \times 10^{-8})) = 81.5 \text{ dB}
length = 81.5 / 12 = 6.8 \text{ km}

[Total: 6]

6 (a) field strength equals the potential gradient
field strength and potential gradient are in opposite directions

(b) at x = 10 cm, force is maximum
because the gradient is largest
repulsion / force to right because sphere and proton have like charges
as x increases, force decreases
becomes zero at x = 35 cm
as x increases from x = 35 cm to x = 41 cm, force increases in opposite direction

[Total: 8]

7 (a) + −

(b) (i) 1. 4.5 V
2. use of potential divider formula \( (9 \times 800) / (800 + 2200) \)
\quad 2.4 V
3. − 9.0 V

(ii) LED G (allow e.c.f. from (i))

(c) as temperature rises, potential at B increases
at 60°C, green goes out and red comes on (allow ecf from (b)(iii))

[Total: 8]
8 (a) (i) 50 mT (allow 50 ± 1 mT for full credit)  

(ii) flux linkage = \( BAN \)  
\[ = 50 \times 10^{-3} \times 0.4 \times 10^{-4} \times 150 \]  
\[ = 3.0 \times 10^{-4} \text{ Wb} \]  

(b) e.m.f. (induced) is proportional to the rate of change of (magnetic) flux (linkage)  
(allow "rate of cutting")  

\[ A1 \]  

(c) (i) new flux linkage = \[ 8.0 \times 10^{-3} \times 0.4 \times 10^{-4} \times 150 \]  
\[ = 4.8 \times 10^{-4} \text{ Wb} \]  
change = \[ 2.52 \times 10^{-4} \text{ Wb} \]  

(ii) e.m.f. = \( \frac{(2.52 \times 10^{-4})}{0.30} \)  
\[ = 8.4 \times 10^{-4} \text{ V} \]  

(d) flux linkage decreases as distance increases  
so speed must increase to keep rate constant  

[Total: 11]

9 (a) into the plane of the paper / downwards  

(b) (i) centripetal force = \( \frac{mv^2}{r} \)  
\[ \frac{mv^2}{r} = Bqv \]  
hence \( q/m = \frac{v}{rB} \) (some algebra essential)  

(ii) \[ q/m = \frac{(8.2 \times 10^6)}{(23 \times 10^{-2} \times 0.74)} \]  
\[ = 4.82 \times 10^7 \text{ C kg}^{-1} \]  

[Total: 5]

10 (a) single diode  
\[ \text{either in series with } R \text{ or in series with a.c. supply} \]  

(b) (i) 1. 5.4 V (allow ±0.1 V)  
2. \( V = IR \)  
\[ I = 5.4 / (1.5 \times 10^3) \]  
\[ = 3.6 \times 10^{-3} \text{ A} \]  
3. time = 0.027 s  

(ii) 1. \[ Q = It \]  
\[ = 3.6 \times 10^{-3} \times 0.027 \]  
\[ = 9.72 \times 10^{-5} \text{ C} \]  
2. \( C = \frac{\Delta Q}{\Delta V} \) (allow Q/V)  
\[ = \frac{(9.72 \times 10^{-5})}{1.2} \]  
\[ = 8.1 \times 10^{-5} \text{ F} \]  

[Total: 5]
(c) line: reasonable shape with less ripple  

11 at 0 K, VB is filled, CB is empty  
as temperature rises, electrons gain energy to enter CB  
positive holes are formed in VB  
lattice vibrations increase  
effect due to increase in charge carriers outweighs effect due to increase in  
lattice vibrations  
so current larger and resistance smaller  

12 (a) (i) clear distinction of boundaries between regions  
(ii) significant difference in degree of blackening between regions  

(b) (i) $\frac{1}{2} = e^{-\mu}$  
$\mu = 0.693 \text{mm}^{-1}$  

(ii) X-ray photons are more penetrating  
$\mu$ is smaller  

13 (a) (i) probability of decay (of a nucleus) per unit time  
(ii) greater energy of \( \alpha \)-particle  
(parent) nucleus less stable  
nucleus more likely to decay  
hence radium–224  

(b) (i) $\lambda = \ln 2 / 3.6$  
$= 0.193$  
unit: day\(^{-1}\)  
*(allow full credit for \(2.23 \times 10^{-6} \text{s}^{-1}\))*  

(ii) $N = \{(2.24 \times 10^{-3}) / 224\} \times 6.02 \times 10^{23}$  
$= 6.02 \times 10^{18}$  
activity $= \lambda N$  
$= 2.23 \times 10^{-6} \times 6.02 \times 10^{18}$  
$= 1.3 \times 10^{13} \text{Bq}$  

[Total: 10]  
[Total: 6]  
[Total: 6]  
[Total: 11]
Categorisation of marks

The marking scheme categorises marks on the **MACB** scheme.

**B** marks: These are awarded as independent marks, which do not depend on other marks. For a B-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

**M** marks: These are method marks upon which A-marks (accuracy marks) later depend. For an M-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular M-mark, then none of the dependent A-marks can be scored.

**C** marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a C-mark and the candidate does not write down the actual equation but does correct working which shows he/she knew the equation, then the C-mark is awarded.

**A** marks: These are accuracy or answer marks which either depend on an M-mark, or allow a C-mark to be scored.

**Conventions within the marking scheme**

**BRACKETS**
Where brackets are shown in the marking scheme, the candidate is not required to give the bracketed information in order to earn the available marks.

**UNDERLINING**
In the marking scheme, underlining indicates information that is essential for marks to be awarded.