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1 (a) gravitational force provides/is the centripetal force B1

\[
\frac{GMm}{r^2} = \frac{mv^2}{r} \quad \text{or} \quad \frac{GMm}{r^2} = mr\omega^2
\]

and \( v = \frac{2\pi}{T} \quad \text{or} \quad \omega = \frac{2\pi}{T} \) M1

with algebra to \( T^2 = \frac{4\pi^2r^3}{GM} \) A1 [3]

or

acceleration due to gravity is the centripetal acceleration (B1)

\[
\frac{GMm}{r^2} = \frac{v^2}{r} \quad \text{or} \quad \frac{GMm}{r^2} = r\omega^2
\]

and \( v = \frac{2\pi}{T} \quad \text{or} \quad \omega = \frac{2\pi}{T} \) (M1)

with algebra to \( T^2 = \frac{4\pi^2r^3}{GM} \) (A1)

(b) (i) equatorial orbit/orbits (directly) above the equator B1

from west to east B1 [2]

(ii) \( (24 \times 3600)^2 = 4\pi^2r^3/(6.67 \times 10^{-11} \times 6.0 \times 10^{24}) \) C1

\[
r^3 = 7.57 \times 10^{22}
\]

\[
r = 4.2 \times 10^7 \text{ m} \quad \text{A1} \quad [2]
\]

(c) \( (T/24)^2 = (((2.64 \times 10^7)/(4.23 \times 10^7))^3 \) B1

\[
= 0.243
\]

\( T = 12 \text{ hours} \) A1 [2]

or

\[
k (= \frac{T^2}{r^3}) = \frac{24^2}{(4.23 \times 10^7)^3}
\]

\[
= 7.61 \times 10^{-21} \quad \text{B1}
\]

\[
T^2 (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3
\]

\[
= 140
\]

\( T = 12 \text{ hours} \) (A1)

2 (a) (i) \( p \propto T \quad \text{or} \quad \frac{pV}{T} = \text{constant} \quad \text{or} \quad pV = nRT \) C1

\( T (= 5 \times 300 =) \ 1500 \text{ K} \) A1 [2]

(ii) \( pV = nRT \)

\[
1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300
\]

or

\[
5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500 \quad \text{C1}
\]

\[n = 0.016 \text{ mol} \quad \text{A1} \quad [2]\]
(b) (i) 1. heating/thermal energy supplied  

2. work done on/to system  

(ii) 1. 240 J  

2. same value as given in 1. (= 240 J) and zero given for 3.  

3. zero  

3 (a) \[ 2k/m = \omega^2 \]  

\[ \omega = 2\pi f \]  

\[ (2 \times 64 / 0.810) = (2\pi \times f)^2 \] leading to \( f = 2.0 \) Hz  

(b) \[ v_0 = \omega x_0 \text{ or } v_0 = 2\pi fx_0 \]  

or \[ v = \omega(x_0^2 - x^2)^{1/2} \text{ and } x = 0 \]  

\[ v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2} \]  

\[ = 0.20 \text{ m s}^{-1} \]  

(c) frequency: reduced/decreased  

maximum speed: reduced/decreased  

4 (a) (i) noise/distortion is removed (from the signal)  

the (original) signal is reformed/reproduced/recovered/restored  

or  

signal detected above/below a threshold creates new signal of 1s and 0s  

(B1)  

(ii) noise is superposed on the (displacement of the) signal/cannot be distinguished  

or  

analogue/signal is continuous (so cannot be regenerated)  

or  

analogue/signal is not discrete (so cannot be regenerated)  

noise is amplified with the signal  

(B1)  

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(b) (i) gain\(\text{dB} = 10 \log (P_2/P_1)\)
\[32 = 10 \log (P_{\text{MIN}}/(0.38 \times 10^{-6})]\]
or
\[-32 = 10 \log (0.38 \times 10^{-6}/P_{\text{MIN}})\] C1

\[P_{\text{MIN}} = 6.0 \times 10^{-4} \text{ W}\] A1 [2]

(ii) attenuation \(= 10 \log [(9.5 \times 10^{-3})/(6.02 \times 10^{-4})]\)
\[= 12 \text{ dB}\]
attenuation per unit length \((= 12/58) = 0.21 \text{ dB km}^{-1}\] A1 [2]

5 (a) in an electric field, charges (in a conductor) would move
no movement of charge so zero field strength
or
charge moves until \(F = 0 / E = 0\) B1 [2]

or
charges in metal do not move
no (resultant) force on charges so no (electric) field (B1)

(b) at \(P\), \(E_A = (3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2]\) (= 10.79 N C\(^{-1}\)) M1

\[E_B = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]\) (= 10.79 N C\(^{-1}\)) M1

or
\[(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0\]
or
\[(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]\] (M2)
fields due to charged spheres are (equal and) opposite in direction, so \(E = 0\) A1 [3]

(c) potential \(= 8.99 \times 10^9 \{(3.0 \times 10^{-12})/(5.0 \times 10^{-2}) + (12 \times 10^{-12})/(10 \times 10^{-2})\}\)
\[= 1.62 \text{ V}\] A1 [2]

(d) \(\frac{1}{2}mv^2 = qV\)
\[E_k = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2\] C1
\[qV = 47 \times 1.60 \times 10^{-19} \times 1.62\] C1
\[v^2 = 1.37 \times 10^8\]
\[v = 1.2 \times 10^4 \text{ m s}^{-1}\] A1 [3]
6  (a) reference to input (voltage) and output (voltage) B1
there is no time delay between change in input and change in output B1 [2]

    or

reference to rate at which output voltage changes (B1)
infinite rate of change (of output voltage) (B1)

(b) (i) \( \frac{2.00}{3.00} = \frac{1.50}{R} \) C1

    or

\[ V_+ = \frac{(3.00 \times 4.5)}{(2.00 + 3.00)} = 2.7 \]
\[ 2.7 = 4.5 \times \frac{R}{(R + 1.50)} \] (C1)

resistance = 2.25 k\( \Omega \) A1 [2]

(ii) 1. correct symbol for LED M1
two LEDs connected with opposite polarities between \( V_{\text{OUT}} \) and earth A1 [2]

2. below 24 °C, \( R_T > 1.5 \text{k}\( \Omega \) or resistance of thermistor increases/high B1
\[ V_- < V_+ \text{ or } V_- \text{ decreases/low (must not contradict initial statement)} \] M1
\[ V_{\text{OUT}} \text{ is positive/+5 (V) and LED labelled as ‘pointing’ from } V_{\text{OUT}} \text{ to earth} \] A1 [3]

7 (a) region (of space) where a force is experienced by a particle B1 [1]

(b) (i) gravitational B1

(ii) gravitational and electric B1

(iii) gravitational, electric and magnetic B1 [3]

(c) (i) force (always) normal to direction of motion M1

(magnitude of) force constant or
speed is constant/kinetic energy is constant M1
magnetic force provides/is the centripetal force A1 [3]

(ii) \( \frac{mv^2}{r} = Bqv \) B1
momentum or \( p \) or \( mv = Bqr \) B1 [2]
8 strong uniform magnetic field
nuclei precess/rotate about field (direction) (1)
radio-frequency pulse (applied) B1
R.F. or pulse is at Larmor frequency/frequency of precession (1)
causes resonance/excitation (of nuclei)/nuclei absorb energy B1
on relaxation/de-excitation, nuclei emit r.f./pulse B1
(emanated) r.f./pulse detected and processed (1)
non-uniform magnetic field B1
allows position of nuclei to be located B1
allows for location of detection to be changed/different slices to be studied (1)
any two of the points marked (1) B2 [8]

9 (a) (induced) e.m.f. proportional to rate
of change of (magnetic) flux (linkage) M1
A1 [2]

(b) flux linkage  = BAN
= \pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4} \text{ Wb} B1 [1]

(c) e.m.f. = \Delta N\phi/\Delta t
= (6.0 \times 10^{-4} \times 2)/0.30 C1
= 4.0 \text{ mV} A1 [2]

(d) sketch: 
E = 0 for t = 0 \to 0.3 \text{ s}, 0.6 \text{ s} \to 1.0 \text{ s}, 1.6 \text{ s} \to 2.0 \text{ s} B1

E = 4 \text{ mV for } t = 0.3 \text{ s} \to 0.6 \text{ s} (either polarity) B1

E = 2 \text{ mV for } t = 1.0 \text{ s} \to 1.6 \text{ s} B1

with opposite polarity B1 [4]
10 (a) electromagnetic radiation/photons incident on a surface
causes emission of electrons (from the surface) B1 [2]

(b) \( E = \frac{hc}{\lambda} \)
\[
= \frac{(6.63 \times 10^{-34} \times 3.00 \times 10^8)}{(436 \times 10^{-9})}
= 4.56 \times 10^{-19} \text{ J} (4.6 \times 10^{-19} \text{ J}) A1 [2]

(c) (i) \( \Phi = \frac{hc}{\lambda_0} \)
\[
\lambda_0 = \frac{(6.63 \times 10^{-34} \times 3.00 \times 10^8)}{(1.4 \times 1.60 \times 10^{-19})}
= 890 \text{ nm} A1 [2]

(ii) \( \lambda_0 = \frac{(6.63 \times 10^{-34} \times 3.00 \times 10^8)}{(4.5 \times 1.60 \times 10^{-19})}
= 280 \text{ nm} A1 [1]

(d) caesium:
- wavelength of photon less than threshold wavelength (or v.v.)
or
\( \lambda_0 = 890 \text{ nm} > 436 \text{ nm} \)
so yes A1

tungsten:
- wavelength of photon greater than threshold wavelength (or v.v.)
or
\( \lambda_0 = 280 \text{ nm} < 436 \text{ nm} \)
so no A1 [2]

11 in metal, conduction band overlaps valence band/no forbidden band/no band gap B1
as temperature rises, no increase in number of free electrons/charge carriers B1
as temperature rises, lattice vibrations increase M1
(lattice) vibrations restrict movement of electrons/charge carriers M1
(current decreases) so resistance increases A1 [5]
12 (a) (i) time for number of atoms/nuclei or activity to be reduced to one half M1

- reference to (number of...) original nuclide/single isotope
  or
  - reference to half of original value/initial activity A1 [2]

(ii) \( A = A_0 \exp(-\lambda t) \) and either \( t = t_{1/2} \), \( A = \frac{1}{2}A_0 \) or \( \frac{1}{2}A_0 = A_0 \exp(-\lambda t_{1/2}) \) M1

  so \( \ln 2 = \lambda t_{1/2} \) (and \( \ln 2 = 0.693 \)), hence \( 0.693 = \lambda t_{1/2} \) A1 [2]

(b) \( A = \lambda N \)

\[ N = \frac{200}{(2.1 \times 10^{-6})} \] C1

\[ = 9.52 \times 10^7 \] C1

mass = \( (9.52 \times 10^7 \times 222 \times 10^{-3})/(6.02 \times 10^{23}) \)

or

mass = \( 9.52 \times 10^7 \times 222 \times 1.66 \times 10^{-27} \) C1

\[ = 3.5 \times 10^{-17} \text{ kg} \] A1 [4]