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

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

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

or

acceleration due to gravity is the centripetal acceleration

\[ \frac{GM}{r^2} = \frac{v^2}{r} \quad \text{or} \quad \frac{GM}{r^2} = r\omega^2 \]
\[ \text{and} \quad v = \frac{2\pi r}{T} \quad \text{or} \quad \omega = \frac{2\pi}{T} \]

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

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

from west to east

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

\[ r^3 = 7.57 \times 10^{22} \]
\[ r = 4.2 \times 10^7 \text{ m} \]

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

\[ = 0.243 \]

\[ T = 12 \text{ hours} \]

or

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

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

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

\[ = 140 \]

\[ T = 12 \text{ hours} \]

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

\[ T = 5 \times 300 = 1500 \text{ K} \]

(ii) \( pV = nRT \)

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

or

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

\[ n = 0.016 \text{ mol} \]
(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) \(2k/m = \omega^2\)  
\[\omega = 2\pi f\]  
\[(2 \times 64 / 0.810) = (2\pi \times f)^2 \text{ leading to } f = 2.0 \text{ Hz}\] 

(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 \[\text{signal detected above/below a threshold creates new signal of 1s and 0s}\]  

(ii) noise is superposed on the (displacement of the) signal/cannot be distinguished  
or \[\text{analogue/signal is continuous (so cannot be regenerated)}\]  
or \[\text{analogue/signal is not discrete (so cannot be regenerated)}\]  
noise is amplified with the signal
(b)  
(i) gain/dB = 10 lg \( \frac{P_2}{P_1} \)

\[
32 = 10 \log \left( \frac{P_{\text{MIN}}}{0.38 \times 10^{-6}} \right)
\]

or

\[
-32 = 10 \log \left( \frac{0.38 \times 10^{-6}}{P_{\text{MIN}}} \right)
\]

\( P_{\text{MIN}} = 6.0 \times 10^{-4} \text{ W} \)  

(ii) attenuation = 10 lg \( \frac{(9.5 \times 10^{-3})}{(6.02 \times 10^{-4})} \)

= 12 dB  

attenuation per unit length (= 12/58) = 0.21 dB km\(^{-1} \)

5 (a) in an electric field, charges (in a conductor) would move

no movement of charge so zero field strength

or

charge moves until \( F = 0 \) / \( E = 0 \)

or

charges in metal do not move

no (resultant) force on charges so no (electric) field

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

at \( P \), \( E_B = \frac{(12 \times 10^{-12})}{[4\pi\varepsilon_0(10 \times 10^{-2})^2]} \) (= 10.79 N C\(^{-1} \))

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

\[
(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]
\]

fields due to charged spheres are (equal and) opposite in direction, so \( E = 0 \)

(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 V

(d) \( \frac{1}{2}mv^2 = qV \)

\( E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2 \)

\( qV = 47 \times 1.60 \times 10^{-19} \times 1.62 \)

\( v^2 = 1.37 \times 10^8 \)

\( v = 1.2 \times 10^4 \text{ m s}^{-1} \)
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

   \( V_- < V_+ \) or \( V_- \) decreases/low (must not contradict initial statement) M1

   \( V_{\text{OUT}} \) is positive/\(+5 \text{ (V)}\) and LED labelled as ‘pointing’ from \( V_{\text{OUT}} \) 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) \( mv^2/r = Bqv \) B1

   momentum or \( p \) or \( mv = Bqr \) B1 [2]
8 strong uniform magnetic field B1
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
(emitted) 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 M1
of change of (magnetic) flux (linkage) 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 $t = 0 \rightarrow 0.3 \text{ s}$, $0.6 \text{ s} \rightarrow 1.0 \text{ s}$, $1.6 \text{ s} \rightarrow 2.0 \text{ s}$ B1
$E = 4 \text{ mV}$ for $t = 0.3 \text{ s} \rightarrow 0.6 \text{ s}$ (either polarity) B1
$E = 2 \text{ mV}$ for $t = 1.0 \text{ s} \rightarrow 1.6 \text{ s}$ 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) \[ E = \frac{hc}{\lambda} \]
\[ = \frac{(6.63 \times 10^{-34} \times 3.00 \times 10^8)}{(436 \times 10^{-9})} \] C1
\[ = 4.56 \times 10^{-19} \text{ J} \] A1 [2]

(c) (i) \[ \Phi = \frac{hc}{\lambda_0} \]
\[ \lambda_0 = \frac{(6.63 \times 10^{-34} \times 3.00 \times 10^8)}{(1.4 \times 1.60 \times 10^{-19})} \] C1
\[ = 890 \text{ nm} \] 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

reference to (number of…) original nuclide/single isotope
or
reference to half of original value/initial activity

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

so \( \ln 2 = \lambda t_{\frac{1}{2}} \) (and \( \ln 2 = 0.693 \)), hence \( 0.693 = \lambda t_{\frac{1}{2}} \)

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

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

\( = 9.52 \times 10^7 \)

mass = \( (9.52 \times 10^7 \times 222 \times 10^{-3})/(6.02 \times 10^{23}) \)
or
mass = \( 9.52 \times 10^7 \times 222 \times 1.66 \times 10^{-27} \)

\( = 3.5 \times 10^{-17} \) kg