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MARK SCHEME

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

$GMm/r^2 = mv^2/r$ *or* $GMm/r^2 = mr\omega^2$
and $v = 2\pi r/T$ *or* $\omega = 2\pi/T$ M1

with algebra to $T^2 = 4\pi^2 r^3/GM$ A1 [3]

or

acceleration due to gravity is the centripetal acceleration (B1)

$GM/r^2 = v^2/r$ *or* $GM/r^2 = r\omega^2$
and $v = 2\pi r/T$ *or* $\omega = 2\pi/T$ (M1)

with algebra to $T^2 = 4\pi^2 r^3/GM$ (A1)

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

from west to east B1 [2]

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

$r^3 = 7.57 \times 10^{22}$

$r = 4.2 \times 10^7$ m A1 [2]

(c) $(T/24)^2 = \{(2.64 \times 10^7)/(4.23 \times 10^7)\}^3$ B1
$= 0.243$

$T = 12$ hours A1 [2]

or

$k\ (= T^2/r^3) = 24^2/(4.23 \times 10^7)^3$ (B1)
$= 7.61 \times 10^{-21}$

$T^2\ (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3$
$= 140$

$T = 12$ hours (A1)

2 (a) (i) $p \propto T$ *or* $pV/T =$ constant *or* $pV = nRT$ C1

$T\ (= 5 \times 300 =)$ 1500 K A1 [2]

(ii) $pV = nRT$

$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$
or
$5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$ C1

$n = 0.016$ mol A1 [2]

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(b) (i) 1. heating/thermal energy supplied — B1

2. work done on/to system — B1 [2]

(ii) 1. 240 J — A1

2. same value as given in **1.** (= 240 J) **and** zero given for **3.** — A1

3. zero — A1 [3]

3 (a) $2k/m = \omega^2$ — M1

$\omega = 2\pi f$ — M1

$(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to $f = 2.0$ Hz — A1 [3]

(b) $v_0 = \omega x_0$ *or* $v_0 = 2\pi f x_0$
or
$v = \omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ — C1

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

$= 0.20\,\text{m s}^{-1}$ — A1 [2]

(c) frequency: reduced/decreased — B1
maximum speed: reduced/decreased — B1 [2]

4 (a) (i) noise/distortion is removed (from the signal) — B1
the (original) signal is reformed/reproduced/recovered/restored — B1 [2]

or

signal detected above/below a threshold creates new signal — (B1)
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) — B1

noise is amplified with the signal — B1 [2]

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(b) (i) gain/dB = $10 \lg (P_2 / P_1)$

$32 = 10 \lg [P_{MIN} / (0.38 \times 10^{-6})]$
or
$-32 = 10 \lg (0.38 \times 10^{-6} / P_{MIN})$ C1

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

(ii) attenuation $= 10 \lg [(9.5 \times 10^{-3}) / (6.02 \times 10^{-4})]$ C1

$= 12$ dB

attenuation per unit length (= 12/58) = 0.21 dB km^{-1} A1 [2]

5 (a) in an electric field, charges (in a conductor) would move B1

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 (B1)
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

at P, $E_B = (12 \times 10^{-12}) / [4\pi\varepsilon_0 (10 \times 10^{-2})^2]$ (= 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 $= 8.99 \times 10^9 \{(3.0 \times 10^{-12}) / (5.0 \times 10^{-2}) + (12 \times 10^{-12}) / (10 \times 10^{-2})\}$ C1

$= 1.62$ V A1 [2]

(d) $\frac{1}{2} m v^2 = qV$

$E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$ C1

$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$ C1

$v^2 = 1.37 \times 10^8$

$v = 1.2 \times 10^4$ m s^{-1} A1 [3]

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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)** $2.00 / 3.00 = 1.50 / R$ C1

or

$V_+ = (3.00 \times 4.5) / (2.00 + 3.00) = 2.7$
$2.7 = 4.5 \times R / (R + 1.50)$ (C1)

resistance = $2.25\,\text{k}\Omega$ A1 [2]

(ii) **1.** correct symbol for LED M1
two LEDs connected with opposite polarities between V_{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_{OUT} is positive/+5 (V) and LED labelled as 'pointing' from V_{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]

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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 of change of (magnetic) flux (linkage) M1 A1 [2]

(b) flux linkage $= BAN$

$= \pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4}$ 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

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

$E = 2$ mV for $t = 1.0\,\text{s} \rightarrow 1.6\,\text{s}$ B1

with opposite polarity B1 [4]

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10 (a) electromagnetic radiation/photons incident on a surface B1

causes emission of electrons (from the surface) B1 [2]

(b) $E = hc / \lambda$

$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (436 \times 10^{-9})$ C1

$= 4.56 \times 10^{-19}$ J $(4.6 \times 10^{-19}$ J) A1 [2]

(c) (i) $\Phi = hc / \lambda_0$

$\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.4 \times 1.60 \times 10^{-19})$ C1

$= 890$ nm A1 [2]

(ii) $\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (4.5 \times 1.60 \times 10^{-19})$

$= 280$ nm A1 [1]

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

tungsten:
wavelength of photon greater than threshold wavelength (or v.v.)
or
$\lambda_0 = 280$ nm < 436 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]

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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 $t = t_{½}$, $A = ½A_0$ or $½A_0 = A_0 \exp(-\lambda t_{½})$ M1

so $\ln 2 = \lambda t_{½}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{½}$ A1 [2]

(b) $A = \lambda N$

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

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

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