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MARK SCHEME

Maximum Mark: 100

**Published**

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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 $T^2 = 4\pi^2r^3/GM$ | 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 $T^2 = 4\pi^2r^3/GM$ | (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 | |
| $r^3 = 7.57 \times 10^{22}$ | | |
| $r = 4.2 \times 10^7$ m | A1 | [2] |
| **(c)** $(T/24)^2 = \{(2.64 \times 10^7)/(4.23 \times 10^7)\}^3 = 0.243$ | B1 | |
| $T$ = 12 hours | A1 | [2] |
| *or* | | |
| $k\ (= T^2/r^3) = 24^2/(4.23 \times 10^7)^3 = 7.61 \times 10^{-21}$ | (B1) | |
| $T^2\ (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3 = 140$ | | |
| $T$ = 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* $v_0 = 2\pi f x_0$<br>*or*<br>$v = \omega(x_0^2 - x^2)^{1/2}$ <u>and</u> $x = 0$ | 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<br>maximum speed: reduced/decreased | B1<br>B1 | [2] |
| **4** | **(a)** | **(i)** | noise/distortion is removed (from the signal)<br>the (original) signal is reformed/reproduced/recovered/restored | B1<br>B1 | [2] |
| | | | *or* | | |
| | | | signal detected above/below a threshold creates new signal<br>of 1s and 0s | (B1)<br>(B1) | |
| | | **(ii)** | noise is superposed on the (displacement of the) signal/cannot be distinguished<br>*or*<br>analogue/signal is continuous (so cannot be regenerated)<br>*or*<br>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 = $10\lg(P_2/P_1)$ | | |
| | $32 = 10\lg[P_{MIN}/(0.38 \times 10^{-6})]$<br>*or*<br>$-32 = 10\lg(0.38 \times 10^{-6}/P_{MIN})$ | 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<br>*or*<br>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* | | |
| | $(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0$<br>*or*<br>$(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]$ | (M2) | |
| | fields due to charged spheres are (equal and) <u>opposite in direction</u>, 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)** | $\frac{1}{2}mv^2 = qV$ | | |
| | $E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$ | C1 | |
| | $qV = 47 \times 1.60 \times 10^{-19} \times 1.62$ | C1 | |
| | $v^2 = 1.37 \times 10^8$ | | |
| | $v = 1.2 \times 10^4$ m s$^{-1}$ | A1 | [3] |

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| **6** | **(a)** | reference to input (voltage) and output (voltage)<br>there is no time delay between change in input and change in output | B1<br>B1 | <br>[2] |
| | | *or* | | |
| | | reference to rate at which output voltage changes<br>infinite rate of change (of output voltage) | (B1)<br>(B1) | |
| | **(b) (i)** | $2.00/3.00 = 1.50/R$ | C1 | |
| | | *or* | | |
| | | $V_+ = (3.00 \times 4.5)/(2.00 + 3.00) = 2.7$<br>$2.7 = 4.5 \times R/(R + 1.50)$ | <br>(C1) | |
| | | resistance = 2.25 kΩ | A1 | [2] |
| | **(ii) 1.** | correct symbol for LED<br>two LEDs connected with opposite polarities between $V_{OUT}$ and earth | M1<br>A1 | <br>[2] |
| | **2.** | below 24 °C, $R_T > 1.5$ kΩ 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) <u>and</u> 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<br>*or*<br>speed is constant/kinetic energy is constant | <br><br>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 <u>uniform</u> 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] |

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| **9** | **(a)** | (induced) e.m.f. proportional to rate<br>of change of (magnetic) flux (linkage) | M1<br>A1 | [2] |
| | **(b)** | flux linkage $= BAN$<br>$= \pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4}$ Wb | B1 | [1] |
| | **(c)** | e.m.f. $= \Delta N\Phi / \Delta t$ | | |
| | | $= (6.0 \times 10^{-4} \times 2) / 0.30$ | C1 | |
| | | $= 4.0$ mV | A1 | [2] |
| | **(d)** | sketch: $E = 0$ for $t = 0 \rightarrow 0.3$ s, $0.6$ s $\rightarrow 1.0$ s, $1.6$ s $\rightarrow 2.0$ s | B1 | |
| | | $E = 4$ mV for $t = 0.3$ s $\rightarrow 0.6$ s (either polarity) | B1 | |
| | | $E = 2$ mV for $t = 1.0$ s $\rightarrow 1.6$ 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:<br>wavelength of photon less than threshold wavelength (or v.v.)<br>*or*<br>$\lambda_0 = 890$ nm $> 436$ nm<br>so yes | A1 | |
| | tungsten:<br>wavelength of photon greater than threshold wavelength (or v.v.)<br>*or*<br>$\lambda_0 = 280$ nm $< 436$ nm<br>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)** $A = A_0 \exp(-\lambda t)$ <u>and</u> 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]