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

	(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* $v = \omega(x_0^2 - x^2)^{1/2}$ <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 maximum speed: reduced/decreased	B1 B1	[2]
4	**(a)** **(i)**		noise/distortion is removed (from the signal) the (original) signal is reformed/reproduced/recovered/restored	B1 B1	[2]
			or		
			signal detected above/below a threshold creates new signal of 1s and 0s	(B1) (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]

(b) (i)	gain/dB = 10 lg (P_2 / P_1)		
	32 = 10 lg [P_{MIN} / (0.38 × 10^{-6})] *or* –32 = 10 lg (0.38 × 10^{-6} / P_{MIN})	C1	
	P_{MIN} = 6.0 × 10^{-4} W	A1	[2]
(ii)	attenuation = 10 lg [(9.5 × 10^{-3}) / (6.02 × 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 no (resultant) force on charges so no (electric) field	(B1) (B1)	
(b)	at P, E_A = (3.0 × 10^{-12}) / [4πε_0(5.0 × 10^{-2})^2] (= 10.79 N C^{-1})	M1	
	at P, E_B = (12 × 10^{-12}) / [4πε_0(10 × 10^{-2})^2] (= 10.79 N C^{-1})	M1	
	or		
	(3.0 × 10^{-12}) / [4πε_0(5.0 × 10^{-2})^2] – (12 × 10^{-12}) / [4πε_0(10 × 10^{-2})^2] = 0 *or* (3.0 × 10^{-12}) / [4πε_0(5.0 × 10^{-2})^2] = (12 × 10^{-12}) / [4πε_0(10 × 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 × 10^9 {(3.0 × 10^{-12}) / (5.0 × 10^{-2}) + (12 × 10^{-12}) / (10 × 10^{-2})}	C1	
	= 1.62 V	A1	[2]
(d)	½mv^2 = qV		
	E_K = ½ × 107 × 1.66 × 10^{-27} × v^2	C1	
	qV = 47 × 1.60 × 10^{-19} × 1.62	C1	
	v^2 = 1.37 × 10^8		
	v = 1.2 × 10^4 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)**	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 kΩ	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 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 *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 <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]
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	
		$= 4.0$ 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 (4.6×10^{-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)	$A = A_0 \exp(-\lambda t)$ <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]