

Question	Answer	Marks
1(a)	work done per unit mass	**B1**
	work done moving mass from infinity (to the point)	**B1**
1(b)(i)	gravitational force provides centripetal force	**C1**
	$mv^2 / r = GMm / r^2$ and $v = 2\pi r / T$ OR $mr\omega^2 = GMm / r^2$ and $\omega = 2\pi / T$ OR $r^3 = GMT^2 / 4\pi^2$	**C1**
	$r^3 = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (13.7 \times 24 \times 3600)^2 / 4\pi^2$ so $r = 2.4 \times 10^8$ m	**A1**
1(b)(ii)	$(E_P = -)\ GMm / r$ work done = $GMm / r_1 - GMm / r_2$	**C1**
	$= 6.67 \times 10^{-11} \times 360 \times 6.0 \times 10^{24}\ (1/6.4 \times 10^6 - 1 / 2.4 \times 10^8)$	**C1**
	= $\mathbf{2.2 \times 10^{10}}$ J	**A1**
1(b)(iii)	$g = GM / r^2$	**C1**
	ratio $= r_{TESS}^2 / r_{earth}^2$ $= (2.4 \times 10^8 / 6.4 \times 10^6)^2$ = **1400**	**A1**

Question	Answer	Marks
2(a)	n = 110 / 0.032 or 110000 / 32 or 3440	**C1**
	$pV = nRT$	**C1**
	$T = (1.0 \times 10^5 \times 85) / (8.31 \times (110 / 0.032)) = 300$ K	**A1**
2(b)	$E = mc\Delta\theta$ $= 110 \times 0.66 \times 50$	**C1**
	= **3600** J	**A1**
2(c)	Any 3 from: • molecule collides with wall • momentum of molecule changes during collision (with wall) • force on molecule so force on wall • many forces act over surface area of container exerting a pressure	**B3**
2(d)	$KE \propto T$ $v \propto \sqrt{T}$	**C1**
	ratio $= \sqrt{(350 / 300)}$ = **1.1**	**A1**

Question	Answer	Marks
3(a)(i)	**0.050** m	**A1**
3(a)(ii)	$\omega = v_o / x_o$	**C1**
	$T = 2\pi / \omega$ $0.42 = (2\pi \times 0.050) / T$	**C1**
	$T =$ **0.75** s	**A1**
3(a)(iii)	one point labelled P where ellipse crosses displacement axis marked	**A1**
3(b)(i)	(induced) e.m.f. proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
3(b)(ii)	(there is) current in the circuit	**B1**
	either	
	current causes thermal energy (dissipated) in resistor	**B1**
	thermal energy comes from energy of magnet	**B1**
	or	
	current causes magnetic field around coil	**(B1)**
	two fields cause an opposing force on magnet	**(B1)**

Question	Answer	Marks
4(a)(i)	Any 2 from: • allows the reflected signal to be distinguished from the emitted signal • detection occurs in the time between emitted pulses • (reflection of ultrasound) detected by same probe / transducer / crystal • cannot emit and detect at same time (hence pulses)	**B2**
4(a)(ii)	piezo-electric crystal	**B1**
	ultrasound makes crystal vibrate / resonate	**B1**
	vibration produces (alternating) e.m.f. / p.d. across crystal	**B1**
4(b)(i)	$= (1.6 \times 10^6 - 4.3 \times 10^2)^2 / (1.6 \times 10^6 + 4.3 \times 10^2)^2$ = **0.999**	**B1**
4(b)(ii)	without the gel most of the ultrasound is reflected	**B1**
	Z values more similar / α reduces so less (ultrasound) is reflected / more (ultrasound) is transmitted	**B1**

Question	Answer	Marks
5(a)	Any 2 from: • noise can be filtered out / noise can be removed / signal can be regenerated • can carry more information per unit time / greater rate of transmission of data • can have extra bits of data to check for errors • can be encrypted	**B2**
5(b)(i)	$v \propto \lambda$	**C1**
	ratio $= v_{air} / v_{fibre}$ $= 3.00 \times 10^8 / 2.07 \times 10^8$ = **1.45**	**A1**
5(b)(ii)	attenuation = 10 log (P_2/P_1)	**C1**
	$0.40 \times L$ = 10 log (1.5 / 0.06) $0.40 \times L$ = 13.979	**C1**
	L = **35** km	**A1**

Question	Answer	Marks
6(a)	**2.0** cm	**B1**
6(b)	At 16 (cm) from A the electric fields are equal or $E_A = E_B$	**B1**
	$E = Q / 4\pi\varepsilon_o r^2$ $Q_A / (4\pi\varepsilon_o r_A^2) = Q_B / (4\pi\varepsilon_o r_B^2)$ $3.6 \times 10^{-9} / 0.16^2 = Q_B / 0.08^2$	**C1**
	Q_B = $\mathbf{9.0 \times 10^{-10}}$ C	**A1**
6(c)(i)	$V = Q / 4\pi\varepsilon_o r_A$ $V = 3.6 \times 10^{-9} / (4 \times \pi \times 8.85 \times 10^{-12} \times 0.020)$	**C1**
	V = **1600** V	**A1**
6(c)(ii)	$C = Q / V$ $= 3.6 \times 10^{-9} / 1600$	**C1**
	= $\mathbf{2.3 \times 10^{-12}}$ F	**A1**

Question	Answer	Marks
7(a)	axes labelled with resistance and temperature	**M0**
	concave curve not touching temperature axis	**A1**
	line with negative gradient throughout	**A1**
7(b)	resistance of thermistor decreases	**B1**
	total circuit resistance decreases so voltmeter reading increases *or* current increases so voltmeter reading increases *or* greater proportion of resistance in fixed resistor so voltmeter reading increases *or* p.d. across thermistor decreases so voltmeter reading increases	**B1**
7(c)	(0.020 strain means) $\Delta R / R = 0.090$	**C1**
	$\Delta R = 0.090 \times 120 = 10.8\,\Omega$	**C1**
	resistance = 120 + 10.8 = **130** Ω	**A1**

Question	Answer	Marks
8(a)	a region where a magnet / magnetic material / moving charge / current carrying conductor experiences a force	**B1**
8(b)	$B = F / Il$ e.g. = $9 \times 10^{-3} / (5.0 \times 0.045)$	**C1**
	= **0.040** T	**A1**
8(c)(i)	force is (always) perpendicular to the velocity / direction of motion	**B1**
	magnetic force provides the centripetal force *or* force perpendicular to motion causes circular motion	**B1**
	magnitude of force (due to the magnetic field) is constant *or* no work done by force *or* the force does not change the speed	**B1**
8(c)(ii)	Applying the list rule, any 2 from: accelerating p.d. radius of path / radius of semicircle magnetic flux density	**B2**

Question	Answer	Marks
9(a)(i)	9.0 / √2 = **6.4** V	**A1**
9(a)(ii)	ω = 20 ω = 2π / T T = 2π / 20	**C1**
	T = **0.31** s	**A1**
9(b)	the r.m.s. voltages are different, so no	**B1**
9(c)(i)	$P = V_{r.m.s.} \times I_{r.m.s.}$	**C1**
	= 120 × 0.64 = 76.8 W	**C1**
	efficiency = (76.8 / 80) × 100 = **0.96** or **96** %	**A1**
9(c)(ii)	Any one from: • heat losses due to resistance of windings / coils • heat losses in magnetising and demagnetising core / hysteresis losses in core • heat losses due to eddy currents in (iron) core • loss of flux linkage	**B1**

Question	Answer	Marks
10(a)	energy of a photon required to remove an electron	**B1**
	either: energy to remove electron from a surface *or*: minimum energy to remove electron *or*: energy to remove electron with zero kinetic energy	**B1**
10(b)(i)	Correct read off from graph of *f* as 5.45×10^{14} Hz when $E_{MAX} = 0$ $5.45 \times 10^{14} \times 6.63 \times 10^{-34}$	**C1**
	= $\mathbf{3.6 \times 10^{-19}}$ J	**A1**
10(b)(ii)	$3.6 \times 10^{-19} / 1.6 \times 10^{-19} = 2.3$ eV so potassium	**A1**
10(c)(i)	each photon has same energy so no change	**B1**
10(c)(ii)	more photons (per unit time) so (rate of emission) increases	**B1**

Question	Answer	Marks
11(a)	$eV = hf$ $f = 1.60 \times 10^{-19} \times 100\,000 / 6.63 \times 10^{-34}$	**C1**
	$=$ **2.41×10^{19}** Hz	**A1**
11(b)	(aluminium filter) absorbs (most) low energy X-rays	**B1**
	Any 2 from • X-ray beam contains many wavelengths • so low energy X-rays are not absorbed in the body • low energy X-rays can can cause harm but do not contribute to the image	**B2**
11(c)(i)	$I / I_0 = e^{-\mu x}$ $e^{-0.23 \times 0.80} = 0.83$	**C1**
	17% absorbed	**A1**
11(c)(ii)	bone is seen as lighter / muscle is seen as darker	**B1**
	either bone has a higher μ value so absorbs more *or* muscle has a lower μ value so transmits more	**B1**

Question	Answer	Marks
12(a)	(minimum) energy required to separate the nucleons	**M1**
	to infinity	**A1**
12(b)(i)	**37** **2**	**B1**
12(b)(ii)	fission	**B1**
12(b)(iii)	binding energy per nucleon smaller for U than for Cs	**B1**
12(c)	Current ratio 2 Y to 1 Zr, so initially 3 Y $2 = 3\,e^{-\lambda t}$ $\lambda = 0.693 / 2.7$	**C1**
	$\ln(2/3) = -(\ln 2/2.7)t$	**C1**
	t = **1.6** days	**A1**
	or	
	$(½)^n = 2/3$	**(C1)**
	n = 0.585	**(C1)**
	time = 0.585 × 2.7 = **1.6** days	**(A1)**

