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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 potential energy = (–)GMm / r	**C1**
	$\Delta E_P = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 2.4 \times 10^3 \times [(6.4 \times 10^6)^{-1} - (1.2 \times 10^7)^{-1}]$	**C1**
	or	
	$\Delta\phi = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times [(6.4 \times 10^6)^{-1} - (1.2 \times 10^7)^{-1}]$	**(C1)**
	$\Delta E_P = m\Delta\phi$	**(C1)**
	$\Delta E_P = 7.0 \times 10^{10}$ J	**A1**
1(b)(ii)	$GMm / r^2 = mv^2 / r$	**C1**
	$v^2 = GM / r$ $= (6.67 \times 10^{-11} \times 6.0 \times 10^{24}) / (1.2 \times 10^7)$	**C1**
	$v = 5800$ m s^{-1}	**A1**
1(c)	any one point from: • smaller gain in energy required if orbit is west to east • smaller change in velocity if orbit is west to east • smaller gain in energy if orbit is in same direction as Earth's rotation • smaller change in velocity if orbit is in same direction as Earth's rotation • satellite already moving west to east at launch • Earth's rotation is from west to east	**B1**

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Question	Answer	Marks
2(a)	sum of potential energy and kinetic energy (of particles)	**B1**
	(total) energy of random motion of particles	**B1**
2(b)(i)	$pV = nRT$	**C1**
	$2.60 \times 10^5 \times 2.30 \times 10^{-3} = n \times 8.31 \times 180$ $n = 0.400$ mol	**A1**
2(b)(ii)	$(2.30 \times 10^{-3}) / 180 = (3.80 \times 10^{-3}) / T$ **or** $2.60 \times 10^5 \times 3.80 \times 10^{-3} = 0.400 \times 8.31 \times T$	**C1**
	$T = 297$ K	**A1**
2(c)(i)	$\Delta W = p\Delta V$ $= 2.60 \times 10^5 \times (2.30 – 3.80) \times 10^{-3}$	**C1**
	= (–)390 J	**A1**
	negative because work is done by gas **or** negative because work is done against atmospheric pressure **or** negative because volume of gas increases	**B1**
2(c)(ii)	$\Delta U = (980 – 390)$ $= 590$ J	**A1**

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Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration is in opposite direction to displacement **or** acceleration is (directed) towards a fixed point	**B1**
3(b)(i)	zero	**B1**
3(b)(ii)	E_T is maximum potential energy = *mgh* $E_T = 94 \times 10^{-3} \times 9.81 \times 0.90 \times 10^{-2}$	**C1**
	$= 8.3 \times 10^{-3}$ J	**A1**
3(b)(iii)	$E_{MAX} = ½\, mv_0^2$ **and** $v_0 = \omega x_0$ **or** $E_{MAX} = ½m(\omega x_0)^2$	**C1**
	$8.3 \times 10^{-3} = ½ \times 94 \times 10^{-3} \times \omega^2 \times (12.7 \times 10^{-2})^2$ …leading to ω = 3.3 rad s^{-1}	**A1**
3(c)	$T = 2\pi / \omega$	**C1**
	$2\pi / 3.3 = 2\pi \times (L / 9.81)^{½}$	**C1**
	L = 0.90 m	**A1**

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Question	Answer	Marks
4(a)	any two points from: • signal can be regenerated/noise can be removed • signal can be encrypted • signal can be checked for errors • multiplexing is possible • circuits are more reliable/cheaper • data can be transmitted at a greater rate	**B2**
4(b)(i)	right-hand zero underlined (0110)	**B1**
4(b)(ii)	analogue signals given as: 3.0, 4.8, 1.0	**B1**
	0011 at 0.30 ms **and** 0001 at 0.50 ms	**B1**
	0100 at 0.40 ms	**B1**
4(c)	series of steps, all of width 0.1 ms	**B1**
	steps levels, in order, at output voltage 0, 5, 6, 3 and 4 mV 2 marks: all levels correct 1 mark: one level incorrect and all others correct **or** one level omitted and last step shown at 1 mV	**B2**

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Question	Answer	Marks
5(a)(i)	region (of space)	**B1**
	where a particle experiences a force	**B1**
5(a)(ii)	similarity – any one point from: • both have an inverse square variation • both decrease with distance • both are radial	**B1**
	difference – any one point from: • gravitational field always towards (the mass) • electric field can be towards or away from (the charge)	**B1**
5(b)(i)	$E = Q / 4\pi\varepsilon_0 x^2$	**C1**
	$Q = 4\pi \times 8.85 \times 10^{-12} \times 84 \times 0.15^2$ $= 2.1 \times 10^{-10}$ C	**A1**
5(b)(ii)	$E = 84 \times (0.15 / 0.45)^2$ **or** $E = (2.1 \times 10^{-10}) / (4\pi \times 8.85 \times 10^{-12} \times 0.45^2)$	**C1**
	$E = 9.3$ V m^{-1}	**A1**
5(c)	line at $E = 0$ from $x = 0$ to $x = 0.15$ m	**B1**
	smooth curve with decreasing negative gradient throughout, from $x = 0.15$ m to $x = 0.45$ m, passing through (0.15, 84)	**B1**
	line passing through (0.45, 9.3)	**B1**

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Question	Answer	Marks
6(a)(i)	charge per unit potential (difference)	**M1**
	charge on one plate and potential difference between the plates	**A1**
6(a)(ii)	any three points from: • smoothing • timing/(time) delaying • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	**B3**
6(b)(i)	parallel combination of two in series and a single capacitor	**B1**
6(b)(ii)	one capacitor in series with two in parallel	**B1**

Question	Answer	Marks
7(a)	X-ray photon produced when electron is decelerated	**B1**
	larger acceleration results in larger photon energy	**B1**
	continuous range of accelerations so continuous spectrum of wavelengths/frequencies	**B1**
7(b)	electron in (inner shell of) target atom is excited (on collision)	**B1**
	electron de-excites causing emission of a photon	**B1**
	discrete energy levels so discrete photon wavelengths	**B1**

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Question	Answer	Marks
8(a)(i)	gain is the same for all frequencies	**B1**
8(a)(ii)	no (time) delay in change in output when input is changed	**B1**
8(b)(i)	(at saturation,) V_{OUT} = 5.0 V	**C1**
	gain = 5.0 / 0.40 = 12.5 or 13	**A1**
8(b)(ii)	12.5 = 1 + (R / 800)	**C1**
	R = 9200 Ω	**A1**

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Question	Answer	Marks
9(a)(i)	(induced) e.m.f. (directly) proportional to rate	**M1**
	of change of magnetic flux (linkage)	**A1**
9(a)(ii)	e.m.f. = 0 apart from thin pulses at t_1 and t_2	**B1**
	rectangular pulses centred on t_1 and t_2, of widths 2 small squares and 1 small square respectively	**B1**
	e.m.fs. at t_1 and t_2 have opposite polarities	**B1**
	magnitude of e.m.f. at t_2 double the magnitude of e.m.f. at t_1	**B1**
9(b)	V_H shown as zero before (t_1 – 2 squares) and after (t_2 + 2 squares) and rises to a constant non-zero value between t_1 and t_2	**M1**
	change at t_1 shown as 2 small squares wide and change at t_2 shown as 1 small square wide	**A1**

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Question	Answer	Marks
10(a)	concentric circles centred on the wire	**B1**
	separation of lines increasing with distance from wire	**B1**
	arrows show anti-clockwise direction	**B1**
10(b)(i)	current in (each) wire creates a magnetic field (at the other wire)	**B1**
	current (in wire) at 90° to field causes force	**B1**
10(b)(ii)	force on each wire towards other wire/attractive	**B1**
10(c)	Newton's third law pair of forces so yes (forces are equal) **or** force proportional to product of both currents so yes (forces are equal)	**B1**

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Question	Answer	Marks
11(a)	any two points from: • (maximum) kinetic energy of electrons is independent of intensity • maximum kinetic energy of electrons depends on frequency • no time delay (between illumination and emission)	**B2**
11(b)(i)	(for $E_{MAX} = 0$,) $1 / \lambda_0 = 1.93 \times 10^6$ (m^{-1})	**C1**
	$f_0 = 3.00 \times 10^8 \times 1.93 \times 10^6$ $= 5.8 \times 10^{14}$ Hz	**A1**
11(b)(ii)	$hc / \lambda = \Phi + E_{MAX}$	**C1**
	hc = gradient	**C1**
	gradient = e.g. $[(0.40 – 0.20) \times 1.60 \times 10^{–19}] / [(2.25 – 2.09) \times 10^6]$ (*working needed*) $(= 2.0 \times 10^{–25})$	**M1**
	$h = (2.0 \times 10^{–25}) / (3.00 \times 10^8) = 6.7 \times 10^{–34}$ J s (*both working and answer needed*)	**A1**
11(c)	straight line with same gradient as the original	**B1**
	straight line with x-axis intercept greater than $1.93 \times 10^6\ m^{–1}$	**B1**

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Question	Answer	Marks
12(a)(i)	energy required to separate nucleons (of nucleus)	**M1**
	to infinity	**A1**
12(a)(ii)	a (single) large nucleus <u>divides</u> to form (smaller) nuclei	**B1**
	any one point from: • initiated by neutron bombardment • resulting nuclei are of similar size • binding energy per nucleon increases • total binding energy increases • neutrons released • combined mass of smaller nuclei is less than mass of large nucleus	**B1**
12(b)	binding energy per nucleon is a maximum at around $A = 56$	**B1**
	products of splitting a ^{56}Fe nucleus must have a lower total binding energy	**B1**
	(reaction would require) a net input of energy	**B1**

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