8(a)	packet / quantum of <u>energy</u>
	of electromagnetic radiation
8(b)(i)	$E = c^2\Delta m$
	$\Delta m = (4.274 \times 10^6 \times 1.60 \times 10^{-19}) / (1.66 \times 10^{-27} \times (3.00 \times 10^8)^2)$ (= 0.00458 u)
	m = 233.915174 + 4.000407 + 0.00458 = 237.92016 u
8(b)(ii)	$E = hc / \lambda$ **or** $E = hf$ **and** $c = f\lambda$
	$(4.274 - 4.200) \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$
	$\lambda = 1.7 \times 10^{-11}$ m
8(b)(iii)	(true) energy of gamma photon is smaller so (true) wavelength is larger
8(c)	(anti)neutrinos are emitted during beta decay
	particles emitted during beta decay carry varying amounts of energy, so energy of gamma photon is also variable (between decays)

8(a)	*Any three points from*: • electrons moving between levels emit a single photon • energy of photon = difference between energy levels • energy of photon depends on frequency • discrete frequencies (in spectrum) so differences between electron energies must be discrete • discrete differences between electron energies means energy levels must be discrete
8(b)(i)	energy = $-(13.6 \times 1.60 \times 10^{-19})$ $= -2.18 \times 10^{-18}$ J
8(b)(ii)	$\Delta E = hf$
	$= (6.63 \times 10^{-34} \times 2.47 \times 10^{15}) / (1.60 \times 10^{-19}) = 10.2$ eV
8(b)(iii)	n = 2 energy level = – 3.4 eV
	n = 3 energy difference = 12.1 eV
	n = 4 energy difference = 12.8 eV
	n = 3 energy level = – 1.5 eV **and** n = 4 energy level = – 0.8 eV

9(a)	emission of electrons (from a metal surface)
	when electromagnetic radiation is incident (on surface)
9(b)(i)	threshold frequency = $2F$
9(b)(ii)	Planck constant = Φ / F
9(c)	two diagonal straight lines with positive gradient in the positive E_K region only, starting at non-zero values of f
	line labelled X passing through (F, 0) **and** line labelled Y passing through ($2F$,0) and extending to $3F$ or $+2\Phi$
	two diagonal straight lines with equal gradients
	X line extrapolates back to (0, $-\Phi$) **and** Y line extrapolates back to (0, -2Φ)

9(a)(i)	electromagnetic wave can behave like a particle
	moving particle can behave like a wave
9(a)(ii)	$\lambda = h / p$
	h is the Planck constant
9(b)(i)	*Any two points from:* • pattern similar to diffraction of light • diffraction (pattern) is characteristic of wave behaviour • rings show constructive and destructive interference
9(b)(ii)	(de Broglie) wavelength decreases
	rings become closer together