MOMENTUM

IB Physics HL

Atomic physics - Set 1 - Markscheme

E.1-E.3 | First assessment 2025 | Higher Level

Independent examination-style practice material

10 original problems

Task 01 - Black-body radiation at two temperatures

Paper 2 style | IB code E.1 | Total [6]

Part	Marking guidance	Marks
(a)	lambda_max values are 967 nm and 483 nm.	**2**
(b)	Power ratio = (6000/3000)^4 = 16.	**2**
(c)	Wien's law shifts the maximum; Stefan-Boltzmann law makes total emitted power proportional to T^4.	**2**

Task 02 - Photon energy and momentum

Paper 2 style | IB code E.1 | Total [6]

Part	Marking guidance	Marks
(a)	f = c/lambda = 6.67e14 Hz and E = hf = 4.42e-19 J.	**3**
(b)	E = 2.76 eV and p = h/lambda = 1.47e-27 kg m s^{-1}.	**3**

Task 03 - Photoelectric threshold and stopping potential

Paper 2 style | IB code E.2 | Total [7]

Part	Marking guidance	Marks
(a)	phi = hc/lambda0 = 2.00 eV.	**2**
(b)	Photon energy is 3.10 eV, so K_max = 1.10 eV and V_s = 1.10 V.	**3**
(c)	Photoelectric current increases, but maximum kinetic energy and stopping potential are unchanged.	**2**

Task 04 - Planck's constant from a graph

Paper 2 style | IB code E.2 | Total [6]

Part	Marking guidance	Marks
(a)	From eV_s = hf-phi, h = e Delta V/Delta f = 6.65e-34 J s.	**3**
(b)	phi = hf-eV = 1.99e-19 J = 1.24 eV and f0 = phi/h = 3.00e14 Hz.	**3**

Task 05 - Compton scattering

Paper 2 style | IB code E.2 | Total [6]

Part	Marking guidance	Marks
(a)	Delta lambda = lambda_C(1-cos90) = 2.426 pm, so lambda' = 0.07343 nm.	**2**
(b)	K = hc(1/lambda-1/lambda') = about 0.578 keV.	**3**
(c)	The photon transfers energy and momentum to the electron.	**1**

Task 06 - Electron diffraction from a crystal

Paper 2 style | IB code E.2 | Total [6]

Part	Marking guidance	Marks
(a)	2d sin theta = lambda gives theta = 14.5 degrees.	**2**
(b)	lambda is proportional to 1/sqrt(V), so new lambda = 0.0500 nm and theta = 7.18 degrees.	**3**
(c)	Electrons have wave behaviour.	**1**

Task 07 - A hydrogen transition

Paper 2 style | IB code E.3 | Total [6]

Part	Marking guidance	Marks
(a)	Delta E = 13.6(1/4-1/16) = 2.55 eV.	**2**
(b)	f = 6.17e14 Hz and lambda = 486 nm.	**3**
(c)	Balmer series.	**1**

Task 08 - Ionizing hydrogen from an excited state

Paper 2 style | IB code E.3 | Total [6]

Part	Marking guidance	Marks
(a)	E3 = -13.6/9 = -1.51 eV; ionization energy is 1.51 eV.	**2**
(b)	r3 = n^2 a0 = 0.476 nm.	**2**
(c)	lambda_max = hc/E = 821 nm.	**2**

Task 09 - The short-wavelength limit of an X-ray tube

Paper 2 style | IB code E.3 | Total [6]

Part	Marking guidance	Marks
(a)	Maximum energy is eV = 35.0 keV.	**1**
(b)	lambda_min = hc/(eV) = 0.0354 nm.	**2**
(c)	The continuum is bremsstrahlung from electron deceleration; peaks arise from transitions into inner-shell vacancies.	**3**

Task 10 - Atomic recoil after photon emission

Paper 2 style | IB code E.1, E.3 | Total [7]

Part	Marking guidance	Marks
(a)	p = E/c = 5.45e-27 kg m s^{-1}.	**2**
(b)	Momentum conservation gives v = p/M = 3.26 m s^{-1}.	**2**
(c)	K = p^2/(2M) = 8.89e-27 J = 5.55e-8 eV, negligible compared with the photon energy.	**3**