CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 25: Astrophysics

Past Papers 2021 – 2025

Note: No question in 2021 from Astrophysics

MARK SCHEME 21 Questions

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Question 1 — Mark Scheme

Question	Answer	Marks
12(a)	total power of radiation emitted (by the star)	B1
12(b)	$F = \frac{L}{4\pi d^2}$ $= \frac{3.83\times10^{26}}{4\times\pi\times1.51\times10^{112}}$	C1
	$= 1340\ W\ m^{-2}$	A1

Question	Answer	Marks
12(c)	$m = \frac{E}{c^2}$ $= \frac{3.83\times10^{26}}{3.00\times10^{82}}$ $= 4.26\times10^{9}\ kg$	A1
12(d)	$L = 4\pi\sigma r^2 T^4$ $3.83\times10^{26} = 4\times\pi\times5.67\times10^{-8}\times6.96\times10^{82}\times T^4$ leading to $T = 5770\ K$	B1
12(e)	$\lambda_{(max)} \propto \frac{1}{T}$ $\frac{5.00\times10^{-7}}{\lambda} = \frac{9940}{5770}$	C1
	$\lambda = 2.90\times\ 10^{-7} m$	A1

Question 2 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme May/June 2022
PUBLISHED

Question	Answer	Marks
10(a)	wavelength of maximum intensity is inversely proportional to (thermodynamic) temperature	**B1**
10(b)(i)	λ_{MAX} = 0.50 μm for A **and** 0.65 μm for B	**C1**
	T = 5800 × (0.50 / 0.65) = 4500 K	**A1**
10(b)(ii)	(star B has) greater peak / average wavelength	**B1**
	(star B looks) redder	**B1**
10(c)(i)	apparent wavelength is greater **or** wavelength is greater than known value	**B1**
	(due to) movement of star away (from observer)	**B1**
10(c)(ii)	by examining the (lines in the) spectrum (of light from the star)	**B1**
	and comparing with known spectrum	**B1**

Question 3 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme May/June 2022
PUBLISHED

Question	Answer	Marks
9(a)(i)	speed is (directly) proportional to distance	**M1**
	where speed is speed of recession of galaxy (from observer) and distance is distance of galaxy away from observer	**A1**
9(a)(ii)	wavelengths (of spectral lines) are greater (than their known values)	**B1**
	redshift shows stars (in distant galaxies) moving away from Earth	**B1**
9(b)	(all) parts of Universe moving away from each other	**B1**
	more distant objects are moving away faster	**B1**
	matter must have been close together / very dense in the past	**B1**

Question 4 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme October/November 2022
PUBLISHED

Question	Answer	Marks
9(a)	total power of radiation emitted (by the star)	**B1**
9(b)(i)	$F = L / (4\pi d^2)$	**C1**
	$= 9.86 \times 10^{27} / [4\pi \times (8.14 \times 10^{16})^2]$ $= 1.18 \times 10^{-7}$ W m^{-2}	**A1**
9(b)(ii)	$L = 4\pi\sigma r^2 T^4$ $9.86 \times 10^{27} = 4 \times \pi \times 5.67 \times 10^{-8} \times r^2 \times 9830^4$	**C1**
	radius = 1.22×10^9 m	**A1**
9(c)	wavelength of peak intensity determined (from spectrum of star)	**B1**
	wavelength of peak intensity from object of known temperature determined	**B1**
	Wien's displacement law used **or** wavelength of peak intensity inversely proportional to temperature	**B1**

Question 5 — Mark Scheme

Question	Answer	Marks
9(a)(i)	• energy of photon has a corresponding frequency • change in electron energy level emits a single photon • photon energy = difference in energy levels • discrete frequencies must have come from discrete energy gaps • discrete energy changes imply discrete energy levels *Any three points, 1 mark each*	**B3**
9(a)(ii)	transition (to – 3.400 eV) from X corresponds to 658 nm line	**C1**
	$E_1 - E_2 = hc / \lambda$	**C1**
	$E_1 - (-3.400) = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (658 \times 10^{-9} \times 1.60 \times 10^{-19})$ and so $E_1 = -1.51$ eV (*full substitution and answer needed*)	**A1**
9(b)(i)	redshift	**B1**
9(b)(ii)	moving away (from observer)	**B1**
9(b)(iii)	$\Delta\lambda / \lambda = v / c$ e.g. for 658 nm line: $\Delta\lambda$ = 686 – 658 (= 28 nm) (*other lines may be used*)	**C1**
	$28 / 658 = v / (3.00 \times 10^{8})$ (*other lines may be used*)	**C1**
	$v = 1.3 \times 10^{7}$ m s^{-1}	**A1**
9(c)	$v = H_0 d$	**C1**
	$H_0 = (1.3 \times 10^{7}) / (5.7 \times 10^{24})$ $= 2.3 \times 10^{-18}$ s^{-1}	**A1**

Question 6 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** February/March 2023

Question	Answer	Marks
10(a)	brighter star could be closer (to Earth)	**B1**
	brighter star could have a greater luminosity (in the visible wavelengths)	**B1**
10(b)	object with known luminosity	**B1**
10(c)(i)	$\frac{660.9-656.3}{656.3} \approx \frac{v}{3.0\times10^{8}}$ leading to $2.1\times 10^{6}\,\text{m s}^{-1}$	**B1**
10(c)(ii)	$v = H_o d$	**C1**
	$d = 2.1 \times 10^{6} / 2.3 \times 10^{-18}$ $= 9.1 \times 1023\,\text{m}$	**A1**
10(c)(iii)	wavelength has increased / light is redshifted	**B1**
	star within galaxy is moving away / receding (from Earth)	**B1**
	Universe is expanding	**B1**

Question 7 — Mark Scheme

Question	Answer	Marks
10(a)	speed is (directly) proportional to distance	M1
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	A1
10(b)	$F = L / (4\pi d^2)$	C1
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$ $= 9.3 \times 10^{-19}$ W m^{-2}	A1
10(c)(i)	galaxy is moving away (from the Earth)	B1
	wavelength (of light from the galaxy) increased by the Doppler effect / due to redshift	B1
10(c)(ii)	$\Delta\lambda / \lambda = v / c$ $v = [(492 - 486) \times 3.00 \times 10^8] / 486$ $(v = 3.7 \times 10^6$ m s$^{-1})$	C1
	$H_0 = v / d$	C1
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$ $= 2.1 \times 10^{-18}$ s^{-1}	A1

Question 8 — Mark Scheme



Question	Answer	Marks
3(a)(i)	N: number of molecules (of the gas)	B1
	m: mass of one molecule (of the gas)	B1
	$\langle c^2 \rangle$: mean square speed (of molecules)	B1
3(a)(ii)	$pV = NkT$	M1
	$NkT = \frac{1}{3}Nm\langle c^2 \rangle$ **and** $E_K = \frac{1}{2}m\langle c^2 \rangle$ leading to $E_K = (3/2)\,kT$	A1
3(b)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times 9300^2 = (3/2) \times 1.38 \times 10^{-23} \times T$	C1
	$T = 6980$ K	A1
3(c)(i)	$L = F \times 4\pi d^2$	C1
	$L = 2.52 \times 10^{-8} \times 4\pi \times (4.16 \times 10^{16})^2$ $= 5.48 \times 10^{26}$ W	A1
3(c)(ii)	$L = 4\pi\sigma r^2 T^4$ $5.48 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 6980^4$	C1
	$r = 5.69 \times 10^8$ m	A1
3(d)	(very high pressure so) molecules are (very) close together (*not just 'nearer'*)	B1
	forces between molecules are not negligible **or** volume of molecules not negligible compared with gas volume	B1

Question 9 — Mark Scheme

Question	Answer	Marks
10(a)	temperature inversely proportional to wavelength	M1
	temperature is thermodynamic temperature of surface, and wavelength is the wavelength at which maximum emission rate occurs	A1
10(b)(i)	(astronomical) object of known luminosity	B1
10(b)(ii)	star / galaxy is moving away from the student	B1
10(b)(iii)	one tick placed in correct column in each row: wavelength: too high	B1
	surface temperature: too low	B1
	distance: unchanged	B1
	radius: too high	B1

Question 10 — Mark Scheme

Question	Answer	Marks
10(a)(ii)	$F = L / 4\pi d^2$ $= (3.85 \times 10^{26}) / (4\pi \times (1.50 \times 10^{11})^2)$	C1
	$= 1.36 \times 10^3$ W m^{-2}	A1
10(a)(iii)	line of same shape showing peak intensity at greater wavelength	B1
	line of same shape showing lower peak intensity	B1
10(b)(i)	5 lines in same pattern shifted to longer wavelengths	B1
10(b)(ii)	$\Delta\lambda / \lambda = v / c$ $\Delta\lambda = (21400 / 300000) \times 656$ $= 46.8$ nm	C1
	wavelength = 656 + 46.8 = 703 nm	A1
10(b)(iii)	(peak) wavelength too high so temperature too low	B1

Question 11 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** May/June 2024

Question	Answer	Marks
10(a)(i)	total power	B1
	power radiated (by the star)	B1
10(a)(ii)	standard candle has known luminosity	B1
	radiant flux intensity measured by observer	B1
	(distance calculated using) $F = L / 4\pi d^2$	B1
10(b)(i)	luminosity $= 4\pi\sigma r^2 T^4$ $= 4\pi \times 5.67 \times 10^{-8} \times (6.96 \times 10^8)^2 \times 5780^4$	C1
	$= 3.85 \times 10^{26}$ W	A1
10(b)(ii)	$\lambda_{MAX} T$ = constant	C1
	temperature $= (5780 \times 501) / 624$ $= 4640$ K	A1

Question 12 — Mark Scheme

Question	Answer	Marks
10(a)	• redshift is the increase in observed wavelength / decrease in observed frequency (caused by Doppler effect) • radiation from distant galaxies is observed to be redshifted • redshift provides evidence that galaxies are moving apart • galaxies moving apart means Universe must be expanding *Any three points, 1 mark each*	**B3**
10(b)(i)	$F = L / 4\pi d^2$	**C1**
	$d = \sqrt{(1.90 \times 10^{36} / [4\pi \times 8.42 \times 10^{-16}])}$ $= 1.34 \times 10^{25}$ m	**A1**
10(b)(ii)	$\Delta\lambda / \lambda = v / c$ $(726 - 658) / 658 = v / (3.00 \times 10^8)$	**C1**
	$v = 3.1 \times 10^7$ m s^{-1}	**A1**
10(c)(i)	line with positive gradient passing through the origin	**B1**
	straight line with positive gradient	**B1**
10(c)(ii)	Hubble constant	**B1**

Question 13 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** February/March 2025

Question	Answer	Marks
10(a)(i)	total power of radiation emitted (by the star)	B1
10(a)(ii)	standard candle has known luminosity	B1
	measure the radiant flux intensity	B1
	use $F = L / (4\pi d^2)$ to calculate d	B1
10(b)(i)	$v = 2\pi R / T$	C1
	$v = 3.00 \times 10^8 \times (656.2877 - 656.2831) / 656.2831$	C1
	$R = [3.00 \times 10^8 \times (656.2877 - 656.2831) / 656.2831] \times (2.07 \times 10^6) / 2\pi = 6.93 \times 10^8$m	A1
10(b)(ii)	Z is moving towards Earth	M1
	so observed wavelength is less than the emitted wavelength	A1
10(b)(iii)	$L = 4\pi\sigma r^2 T^4$ $3.8 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times (6.93 \times 10^8)^2 \times T^4$	C1
	$T = 5800$K	A1

Question 14 — Mark Scheme

Question	Answer	Marks
10(a)	speed is (directly) proportional to distance	**M1**
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	**A1**
10(b)(i)	galaxy is receding from the Earth	**B1**
	observed wavelength is redshifted from emitted wavelength	**B1**
10(b)(ii)	$\Delta\lambda / \lambda = v / c$ $(4.91 - 4.62) / 4.62 = v / (3.00 \times 10^8)$	**C1**
	$v = 1.9 \times 10^7$ m s^{-1}	**A1**
10(b)(iii)	wavelength (of maximum intensity) is inversely proportional to temperature	**B1**
	observed wavelength too high, so determined temperature too low	**B1**
10(c)	$v = H_0 d$	**C1**
	$d = (1.9 \times 10^7) / (2.3 \times 10^{-18})$ $= 8.3 \times 10^{24}$ m	**A1**

Question 15 — Mark Scheme

Question	Answer	Marks
11(a)(i)	(nuclear) fusion	**B1**
11(a)(ii)	Δm = [0.030377 – (3 × 0.002388)] u (= 0.023213 u)	**B1**
	$E = \Delta m\, c^2$	**C1**
	= 0.023213 × 1.66 × 10^{-27} × (3.00 × 10^{8})^2 = 3.47 × 10^{-12} J	**A1**
11(b)(i)	mass of 1 mol of helium-4 = 4 g **or** mass of 1 helium atom = 4 u	**C1**
	N rate = (6.02 × 10^{23} × 7.34 × 10^{11}) / (4 × 10^{-3}) **or** N rate = (7.34 × 10^{11}) / (4 × 1.66 × 10^{-27})	**C1**
	luminosity = 1.10 × 10^{38} × 3.47 × 10^{-12} = 3.83 × 10^{26} W	**A1**
11(b)(ii)	$L = 4\pi\sigma r^2 T^4$ 3.83 × 10^{26} = 4π × 5.67 × 10^{-8} × (6.96 × 10^{8})^2 × T^4	**C1**
	T = 5770 K	**A1**

Question 16 — Mark Scheme

Question	Answer	Marks
9(a)	temperature inversely proportional to wavelength	**M1**
	temperature is thermodynamic temperature of surface of star **and** wavelength is the wavelength at which maximum emission rate from star occurs	**A1**
9(b)	*Any three points from:* • (surface) temperature of star X = 7000 K **or** star X has a higher temperature than the Sun • star X has a higher luminosity than the Sun • luminosity of star X = 2.7×10^{27} W • radius of star X = 1.3×10^{9} m	**B3**
9(c)	light (from star X) is redshifted	**B1**
	wavelength of peak emission rate would be greater (using observed data)	**B1**

Question 17 — Mark Scheme

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Question	Answer	Marks
9(a)	difference between mass of nucleus and mass of (constituent) nucleons	M1
	when nucleons are separated to infinity	A1
9(b)	$\Delta m = (2 \times 2.013553) - (4.001505)$ (u) $(= 0.025601$ u)	C1
	$E = c^2\Delta m$	C1
	energy from one He-4 nucleus= $0.025601 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ $(= 3.82 \times 10^{-12}$ J)	C1
	energy to form 1.00 mol= $3.82 \times 10^{-12} \times 6.02 \times 10^{23}$ $= 2.30 \times 10^{12}$ J	A1
9(c)(i)	$L = 1.09 \times 10^{11} \times (3.00 \times 10^8)^2$	C1
	$= 9.81 \times 10^{27}$ W	A1
9(c)(ii)	$L = 4\pi\sigma r^2 T^4$ $9.81 \times 10^{27} = 4\pi \times 5.67 \times 10^{-8} \times (1.19 \times 10^9)^2 \times T^4$	C1
	$T = 9930$ K	A1
9(d)	standard candles have known luminosity	B1
	radiant flux intensity (from star) measured (on the Earth)	B1
	distance found from $F = L / (4\pi d^2)$	B1

Question 18 — Mark Scheme

Question	Answer	Marks
10(a)	recession of galaxy (from observer) causes emitted light to have	**B1**
	increase in observed wavelength / decrease in observed frequency	**B1**
10(b)	(distant) galaxies show redshift so galaxies are moving apart	**B1**
	galaxies moving apart means universe must be expanding	**B1**
10(c)	the speed of recession is proportional to the distance of the galaxies from each other **or** more distant galaxies are receding faster	**B1**
	Any two points from: • more distant galaxies represent further back in time • a long time ago, all matter in the universe must have been very close together • a long time ago, all matter in the universe must have been moving apart very fast	**B2**

Question 19 — Mark Scheme

Given:

$$\lambda_0 = 486\ \text{nm}$$
$$\lambda = 502\ \text{nm}$$
$$F = 3.6\times10^{-15}\ \text{W m}^{-2}$$
$$H_0 = 2.2\times10^{-18}\ \text{s}^{-1}$$

(a)

(i) Show galaxy is receding [1]

Observed wavelength > emitted wavelength

$$502 > 486$$

Wavelength increased → **redshift** → galaxy moving away.

✔️ Galaxy is receding.

(ii) Speed of recession [2]

Use Doppler formula:

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$
$$\Delta\lambda = 502 - 486 = 16 \text{ nm}$$
$$\frac{16}{486} = \frac{v}{3.00\times10^8}$$
$$v = \frac{16}{486}\times3.00\times10^8$$
$$v = 9.88\times10^6 \text{ m s}^{-1}$$

(b) Distance using Hubble's Law [2]

$$v = H_0 d$$
$$d = \frac{v}{H_0}$$
$$d = \frac{9.88\times10^6}{2.2\times10^{-18}}$$
$$d = 4.49\times10^{24} \text{ m}$$

(c) Luminosity [2]

$$F = \frac{L}{4\pi d^2}$$
$$L = 4\pi d^2 F$$
$$L = 4\pi(4.49\times10^{24})^2(3.6\times10^{-15})$$
$$d^2 = 2.02\times10^{49}$$

$$L = 4\pi(2.02\times10^{49})(3.6\times10^{-15})$$
$$L = 9.15\times10^{35}\ \text{W}$$

(d)

(i) Surface temperature [2]

Wien's Law:

$$\lambda_{max}T = 2.9\times10^{-3}$$
$$T = \frac{2.9\times10^{-3}}{410\times10^{-9}}$$
$$T = 7070\ \text{K}$$

(ii) Radius [3]

Stefan–Boltzmann:

$$L = 4\pi R^2\sigma T^4$$
$$R^2 = \frac{L}{4\pi\sigma T^4}$$
$$T^4 = (7070)^4 = 2.50\times10^{15}$$
$$\sigma T^4 = 5.67\times10^{-8}\times2.50\times10^{15} = 1.42\times10^{8}$$
$$4\pi\sigma T^4 = 1.78\times10^{9}$$

$$R^2 = \frac{9.15\times10^{35}}{1.78\times10^{9}}$$
$$R^2 = 5.14\times10^{26}$$
$$R = 7.17\times10^{13}\ \text{m}$$

Question 20 — Mark Scheme

Given:

$$\lambda_1 = 656.298\ \text{nm}$$
$$\lambda_2 = 656.342\ \text{nm}$$
$$T = 1.9\times10^{6}\ \text{s}$$

(a) Why different? [2]

One edge moving towards observer → blueshift
Other edge moving away → redshift

Due to Doppler effect from rotation

(b) Equatorial speed [3]

$$\Delta\lambda = 656.342 - 656.298 = 0.044\ \text{nm}$$

Half shift corresponds to one side:

$$0.022\ \text{nm}$$
$$\frac{0.022}{656.3} = \frac{v}{3.00\times10^{8}}$$
$$v = 1.01\times10^{4}\ \text{m s}^{-1}$$

(c) Radius [3]

$$v = \frac{2\pi R}{T}$$

$$R = \frac{vT}{2\pi}$$

$$R = \frac{(1.01\times10^{4})(1.9\times10^{6})}{2\pi}$$

$$R = 3.05\times10^{9}\ \mathbf{m}$$

(d) Redshift meaning [2]

Redshift means galaxy moving away
Therefore Universe is expanding

Question 21 — Mark Scheme

Given:

$$\Delta m = 0.028u$$
$$1u = 1.66\times10^{-27}kg$$
$$\Delta m = 4.65\times10^{-29}kg$$

(a) Luminosity [3]

$$E = mc^2$$
$$E = (4.65\times10^{-29})(3.00\times10^{8})^2$$
$$E = 4.19\times10^{-12}J$$

Total reactions per second:

$$9.0\times10^{37}$$
$$L = (9.0\times10^{37})(4.19\times10^{-12})$$
$$L = 3.77\times10^{26}W$$

(b) Distance [2]

$$F = \frac{L}{4\pi d^2}$$
$$d^2 = \frac{L}{4\pi F}$$

$$d^2 = \frac{3.77\times10^{26}}{4\pi(4.5\times10^{-10})}$$
$$d = 8.17\times10^{17} m$$

(c) Temperature bias [3]

Observed wavelength is increased (redshift).
If redshift ignored → wavelength assumed larger than actual.

From Wien:

$$T \propto \frac{1}{\lambda}$$

Larger wavelength → smaller calculated temperature

✔️ Temperature will be **too low**
