

Exercise walk-through

5.9

Doppler shifts and cosmology (169–171)

Pearson Edexcel · International A-Level · Physics

CP15: attenuation is a thickness law

Action	Why it matters
Fix geometry and count time	Source contribution must be comparable across thicknesses.
Measure and subtract background	Background does not follow the absorber transmission law.
Repeat; plot log corrected rate versus lead thickness	Test exponential attenuation. Avoid near-background readings with large relative uncertainty.

Use the evidence

Three half-value thicknesses transmit $1/8$. Follow supervised source handling and shielding.

Separate free, forced and damped oscillations

Term	Physical meaning
Free oscillation	After release, motion occurs at a natural frequency.
Forced oscillation	A periodic external force drives the motion.
Damping	Oscillation energy transfers to other stores.
Resonance	Large response near a natural frequency under comparable driving.

Use the evidence

One oscillator can be forced and damped at the same time.

Use the documents in their learning order

Reference: learn the complete knowledge, methods and assumptions.



Skill sheet: supported practice → reduced support → exam-style demands.



Authentic set: transfer to original wording; correct with reasons.



Return to the reference for a diagnosed gap; reattempt before using reserved assessment questions.

Exercise 2.1

2.1 A spectral line has rest wavelength 600 nm and observed wavelength 606 nm. Calculate redshift and recession speed using $c_0 = 3.00 \times 10^8 \text{ m s}^{-1}$. State the sign of the observed frequency change. [4]

rest 600 nm

observed 606 nm

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rest 600 nm

observed 606 nm

2.1 Compare the same line with its rest wavelength.

$$z = \frac{\lambda_o - \lambda_r}{\lambda_r} = \frac{(606 - 600) \text{ nm}}{600 \text{ nm}} = 0.010$$

Redshift.

$$v \approx z c_0 = 0.010(3.00 \times 10^8 \text{ m s}^{-1}) = 3.00 \times 10^6 \text{ m s}^{-1}$$

Speed. Observed frequency decreases.

Exercise 2.2

2.2 Convert $H_0 = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$ to s^{-1} , using $1 \text{ Mpc} = 3.1 \times 10^{22} \text{ m}$. Find the reciprocal timescale in seconds and years, using $1 \text{ year} = 3.15 \times 10^7 \text{ s}$. [4]

$$H_0 = 65 \text{ km/s/Mpc}$$

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$$H_0 = 65 \text{ km/s/Mpc}$$

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2.2 Convert km to m and Mpc to m.

$$H_0 = \frac{65 \times 10^3 \text{ m s}^{-1}}{3.1 \times 10^{22} \text{ m}} = 2.10 \times 10^{-18} \text{ s}^{-1}$$

Rate.

$$t_H = \frac{1}{H_0} = \frac{1}{2.0968 \times 10^{-18} \text{ s}^{-1}} = 4.77 \times 10^{17} \text{ s}$$

Seconds.

$$t_{H,\text{years}} = \frac{t_H}{3.15 \times 10^7 \text{ s/year}} = \frac{4.7692 \times 10^{17} \text{ s}}{3.15 \times 10^7 \text{ s/year}} = 1.51 \times 10^{10} \text{ years}$$

Years.

Exercise 2.3

2.3 Explain how relative motion produces a Doppler shift. Distinguish a measured wavelength increase from identification of a different atomic line. [3]



observer

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2.3 Motion changes spacing/arrival interval of successive wavefronts along the line of sight. Recession stretches wavelength and reduces frequency; approach does the reverse. Identify the same atomic transition before comparing observed and rest wavelengths; different lines already have different rest wavelengths.

Exercise 3.1

3.1 Opposite equatorial limbs of a rotating star show wavelengths 499.98 nm and 500.02 nm for the same line. Assume equal opposite line-of-sight velocities and the equator viewed edge-on. Star radius is 5.0×10^8 m. Find limb speed and rotation period using c from 2.1. Explain why using the full line separation overestimates speed. [6]

$$R = 5.0 \times 10^8 \text{ m}$$



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3.1 Rest wavelength is the midpoint 500.00 nm under the given symmetry. Each limb shift is half the full separation.

$$\Delta\lambda = \frac{\lambda_+ - \lambda_-}{2} = \frac{(500.02 - 499.98) \text{ nm}}{2} = 0.020 \text{ nm}$$

$$v \approx \frac{\Delta\lambda}{\lambda_0} c_0 = \frac{0.020 \text{ nm}}{500.00 \text{ nm}} (3.00 \times 10^8 \text{ m s}^{-1}) = 1.20 \times 10^4 \text{ m s}^{-1}$$

Speed. Use circumference per period.

$$T = \frac{2\pi R}{v} = \frac{2\pi(5.0 \times 10^8 \text{ m})}{1.20 \times 10^4 \text{ m s}^{-1}} = 2.62 \times 10^5 \text{ s}$$

Period. Full separation includes one red and one blue shift, so it doubles either limb's speed.

Exercise 3.2

3.2 A galaxy has redshift 0.020. Estimate its distance using c from 2.1 and $H_0 = 2.2 \times 10^{-18} \text{ s}^{-1}$. Explain two limitations of treating Hubble's law and $1/H_0$ as exact distance and age formulas in every situation. [5]

$z = 0.020$
 $H_0 = 2.2 \times 10^{-18} \text{ s}^{-1}$



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3.2 Use the small-redshift approximation.

$$v \approx zc_0 = 0.020(3.00 \times 10^8 \text{ m s}^{-1}) = 6.00 \times 10^6 \text{ m s}^{-1}$$

$$d = \frac{v}{H_0} = \frac{6.00 \times 10^6 \text{ m s}^{-1}}{2.2 \times 10^{-18} \text{ s}^{-1}} = 2.73 \times 10^{24} \text{ m}$$

Distance method/value. Nearby peculiar motion can dominate recession, and high redshift needs a fuller cosmological relation. Reciprocal present expansion rate is an age scale; actual age depends on expansion history rather than assuming constant-rate extrapolation.

Exercise 3.3

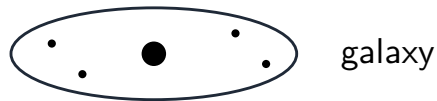
3.3 Explain how observed stellar/galactic motions can provide evidence for matter not seen in luminous objects. Explain why uncertainty about cosmic mass/energy content prevents a simple certain prediction of the universe's fate from present expansion alone. Distinguish dark matter from dark energy. [6]



galaxy

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3.3 Infer gravitational mass needed for observed orbital/rotation speeds. Motions can require more mass than luminous material accounts for, supporting a non-luminous gravitating component called dark matter. Dark energy describes the component/effect associated with accelerated cosmic expansion, not unseen gravitating mass alone. Future expansion depends on cosmic matter/energy content and how it evolves; current expansion plus uncertain content does not by itself establish certain recollapse or one exact future history.