IB · SL · Physics

2 hours · 12 questions

Structured Questions

Doppler Effect

The Doppler Effect / The Doppler Effect of Light / Galactic Redshift

Easy (4 questions)	/50
Medium (4 questions)	/42
Hard (4 questions)	/33
Total Marks	**/125**

Scan here to return to the course
or visit savemyexams.com

© 2024 Save My Exams, Ltd.

Easy Questions

1 (a) A stationary observer is standing on a train platform. A steam train sounds its horn as it travels towards and then passes the observer without stopping at the platform.

Describe, from the point of view of the observer, what happens to the pitch and frequency of the sound of the horn when the train is travelling towards them.

....

....

(2 marks)

(b) Describe, from the point of view of the observer, what happens to the pitch and frequency of the sound of the horn when the train is travelling away from the observer.

....

....

(2 marks)

(c) A different steam train, also sounding its horn, now approaches the stationary observer on the platform and stops beside him with the horn still sounding.

State and explain whether the frequency of the sound heard by the train driver is the same as that of the stationary observer when the train is stationary next to the observer.

....

....

(2 marks)

(d) The train now pulls away from the platform, still sounding its horn. As it pulls away the observer starts walking in the opposite direction to the moving train.

Explain whether the train driver and the observer still hear the same pitch of sound.

....

(2 marks)

2 (a) State what is meant by redshift.

....

....

(2 marks)

(b) Explain how cosmologists are able to determine that light from a distant star has undergone redshift.

....

....

(2 marks)

(c) After the discovery of Doppler redshift, astronomers began to realise that almost all the galaxies in the universe are receding.

Explain the theory that this led to and the observations made to determine this theory.

....

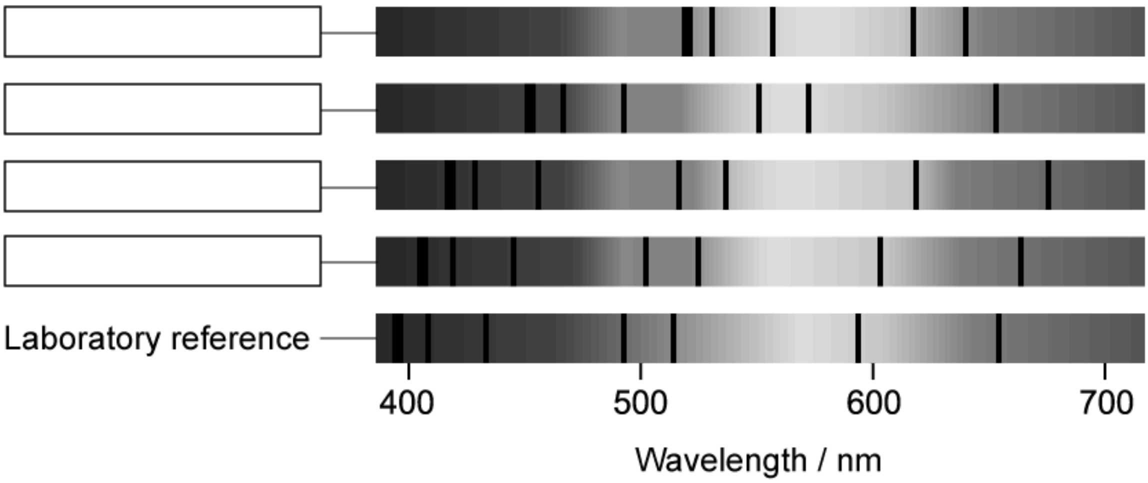
....

....

(3 marks)

(d) The emission spectra from different objects in space are shown above the laboratory reference.

© 2024 Save My Exams, Ltd.



Identify which emission spectra corresponds to each of the objects:

- A nearby star
- A very distant galaxy
- A distant galaxy
- A nearby galaxy

....

....

....

....

(4 marks)

3 (a) Define the Doppler effect.

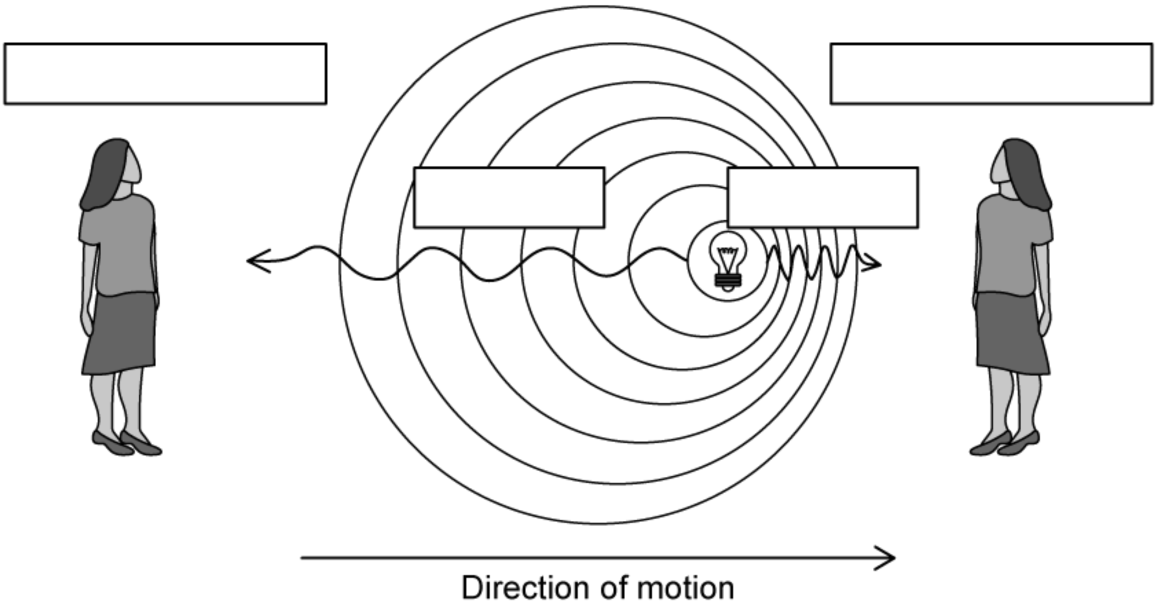
....

....

....

(3 marks)

(b) The diagram shows two people observing the same light source, which is in motion. The light is moving to the right.



Complete the boxes on the diagram with words or phrases from the list below.

higher frequency	lower frequency	phase difference	wavelength
blue shift	relative motion	star	red shift

....

....

....

....

(4 marks)

(c) The following text is about the Doppler effect.

Complete the following sentences by circling the correct words:

When a source starts to move **away from / towards** the observer, the wavelength of the wave broadens.

For sound waves, sound therefore appears at a **higher / lower** frequency to the observer.

For light waves, the light shifts towards the **blue / red** end of the electromagnetic spectrum due to its **lower / higher** frequency.

When a source starts to move **away from / towards** the observer, the wavelength of the wave shortens.

For sound waves, sound therefore appears at a **higher / lower** frequency to the observer.

For light waves, the light shifts towards the **blue / red** end of the electromagnetic spectrum due to its **lower / higher** frequency.

This is because **blue / red** light has a longer wavelength than **blue / red** light.

(7 marks)

© 2024 Save My Exams, Ltd. Get more and ace your exams at savemyexams.com

(d) State two uses of the Doppler effect.

....

....

(2 marks)

© 2024 Save My Exams, Ltd. | Get more and ace your exams at savemyexams.com

4 (a) Define redshift.

....

....

(2 marks)

(b) For non-relativistic galaxies, Doppler redshift can be calculated using:

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f} = \frac{v}{c}$$

(i) State what is meant by a non-relativistic galaxy.

[1]

(ii) Define the symbols λ, f, v and c in the equation above.

[4]

....

....

....

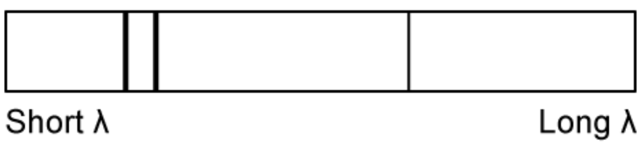
....

....

(5 marks)

(c) The shift in wavelength can be identified using spectral lines in an absorption spectrum.

The following absorption spectrum is generated using light from a source in a laboratory:



Sketch the spectrum obtained using light from a galaxy moving away from the Earth.

....

© 2024 Save My Exams, Ltd.

(3 marks)

(d) An absorption line in the spectrum of light from a source in a lab in part (c) has a frequency of 5.783×10^{14} Hz. The same line in the spectrum of light from a distant galaxy has a frequency of 5.791×10^{14} Hz.

Calculate the speed of the distant galaxy in relation to the Earth.

(5 marks)

Medium Questions

1 (a) Every year, an alien species holds a race between two teams. One of the teams has green lights on its spaceships and the other has purple light. During the race the two ships approach a space station.

From the point of view of the space station commander on the space station, the two colours appear to be identical as the ships approach the station.

Explain how the commander knows which spaceship is travelling faster.

....

....

(2 marks)

(b) The wavelength of light from the purple ship is 420 nm but is observed to be 405 nm at the space station.

Determine the speed of the purple ship.

....

....

....

....

(4 marks)

(c) The purple ship accelerates to four times its speed in (b) and then remains at this speed as it approaches the space station.

Determine the new wavelength of observed visible light coming from this spaceship as it approaches the space station.

....

....

(3 marks)

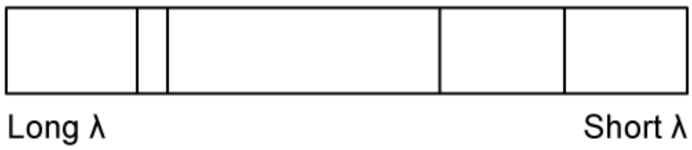
(d) The space station also can detect light from other galaxies. In a laboratory, the frequency of electromagnetic radiation from a distant galaxy has been redshifted by 5.108×10^9 Hz. In the laboratory, the same light has a frequency of 5.103×10^9 Hz.

Calculate the speed of recession of the galaxy.

(2 marks)

© 2024 Save My Exams, Ltd.
Get more and ace your exams at savemyexams.com

2 (a) An emission spectrum of light was obtained from a light source in a laboratory.



The same wavelengths of light were observed on an emission spectrum from a distant galaxy but were found to be redshifted.

Describe how you would expect the emission spectrum of the distant galaxy to look compared to the spectrum from the laboratory.

....

....

(2 marks)

(b) An astronomer observes that light from a galaxy has been shifted towards the blue end of an emission spectrum.

State and explain what can be deduced about the motion of the galaxy from this observation.

....

....

(2 marks)

(c) Hydrogen is an element of particular interest to cosmologists, as it can emit visible light waves.

A lot of useful information can be obtained by measuring the wavelength of the emitted light from the hydrogen in distant galaxies and comparing them to a laboratory sample.

	Wavelength in nm
Laboratory sample	541.21
Galaxy 1	542.40
Galaxy 2	540.85

© 2024 Save My Exams, Ltd. | Get more and ace your exams at savemyexams.com

Galaxies 1 and 2 are both moving relative to Earth.

Compare the motions of galaxies 1 and 2 relative to Earth.

....

....

....

(3 marks)

(d) Calculate the speed of galaxy 1 relative to Earth.

....

....

....

(3 marks)

3 (a) Astronomers can determine whether a star is moving away from or towards the Earth.

State and explain what is meant by 'Doppler effect' in this context.

....

....

(2 marks)

(b) In a laboratory, hydrogen is found to emit light of wavelength 621.89 nm. The spectrum of a star observed on Earth is found to have the same line in the spectrum shifted to 623.22 nm.

Show that the star is moving away from the Earth at a speed of 6.42×10^5 m s^{-1}.

....

....

....

(3 marks)

(c) A second spectral line from the same star is observed at 621.49 nm in the laboratory.

Determine the frequency of the spectral line from the star as observed on Earth.

....

....

....

(3 marks)

(d) Explain the effect on the colour of light from the star if it were travelling towards the Earth.

....

....

© 2024 Save My Exams, Ltd. | Get more and ace your exams at savemyexams.com

(2 marks)

4 (a) The Doppler effect can be used to determine whether a star is moving away from or towards the Earth.

Outline what is meant by 'Doppler effect' in this context.

....

....

(2 marks)

(b) In a laboratory, the spectrum of atomic hydrogen has a wavelength of 656.61 nm. The spectrum of a star observed on Earth is found to have the same line in the spectrum shifted to 656.54 nm.

(i) Calculate the speed of the star relative to the Earth.

[2]

(ii) Explain whether the star is moving towards or away from the Earth.

[2]

....

....

....

....

(4 marks)

(c) A second spectral line is observed at 567.34 nm in the laboratory.

Determine the frequency of the spectral line from the star, as observed on Earth.

....

....

....

(3 marks)

(d) Explain the effect on the colour of light from the star if it were travelling towards the Earth.

(2 marks)

Hard Questions

1 (a) A police officer is standing on the side of the road pointing a radar gun at an approaching car. The gun emits microwaves which are reflected off the car and then received again by a detector on the gun. The gun measures the change in frequency between the emitted and received microwaves. This is calculated by the equation:

$$\Delta f = \frac{2fv}{c}$$

Where:

- *f* is the frequency of the emitted microwaves
- *v* is the speed of the approaching car
- *c* is the speed of the microwaves through the air

The following data are available:

- Frequency of emitted microwaves = 50 GHz
- Frequency of detected microwaves = 50.0000056 GHz
- Speed limit on the road = 30 mph

Explain why the frequency of the microwaves emitted and detected by the gun are different.

....

....

....

(3 marks)

(b) Explain why there is a factor of two in the equation.

....

....

....

(3 marks)

(c) Determine whether the car is breaking the speed limit.

1 mile = 1.6 km

....

....

....

(3 marks)

2 (a) An astronomer analyses the light from a distant galaxy.

One of the observed spectral lines of hydrogen has a wavelength of 849 nm. The same spectral line has a wavelength of 767 nm when measured in the laboratory.

Determine the ratio of observed and measured wavelength and explain what this provides evidence for.

....

....

(2 marks)

(b) Cosmologists commonly quote the recessional velocity *v* of astronomical objects in relation to the speed of light *c*. This ratio is known as redshift *z*:

$$z = \frac{v}{c}$$

The Andromeda galaxy is the closest galaxy to our own Milky Way. Andromeda has a redshift value of z = −0.001.

State the significance of the minus sign and discuss its implication for the Milky Way and Andromeda in the distant future.

....

....

(2 marks)

(c) The table shows some information about two galaxies.

Galaxy	Red-shift	Recessional velocity / km s^{-1}	Distance / km
NGC 253	8.0×10^{-4}		1.1×10^{20}
NGC 1326		1200	

Hubbles Law is

$$v = H_0 d$$

© 2024 Save My Exams, Ltd.

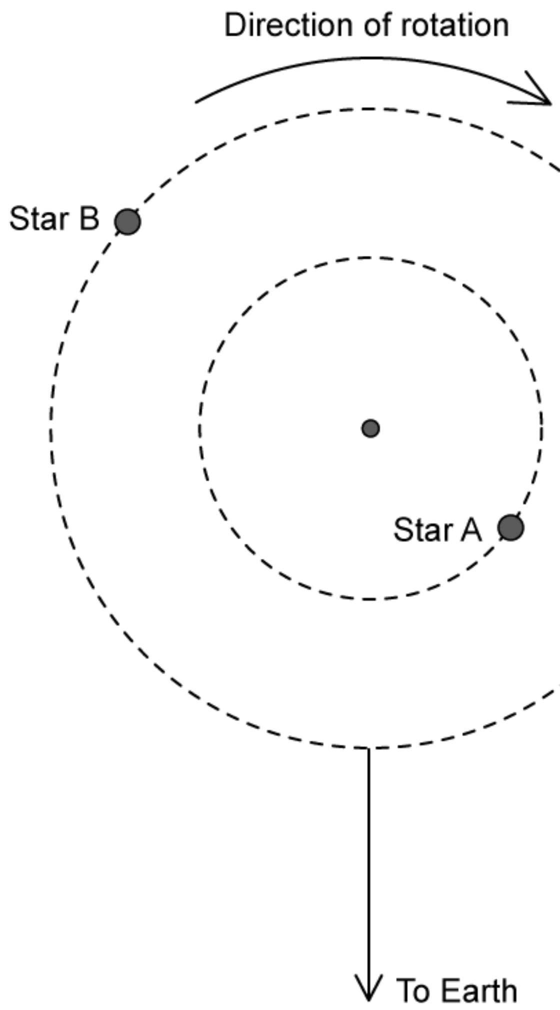
Where:

- v is the recessional velocity of the galaxy
- H_0 is the Hubble constant
- d is the distance between the galaxy and the Earth

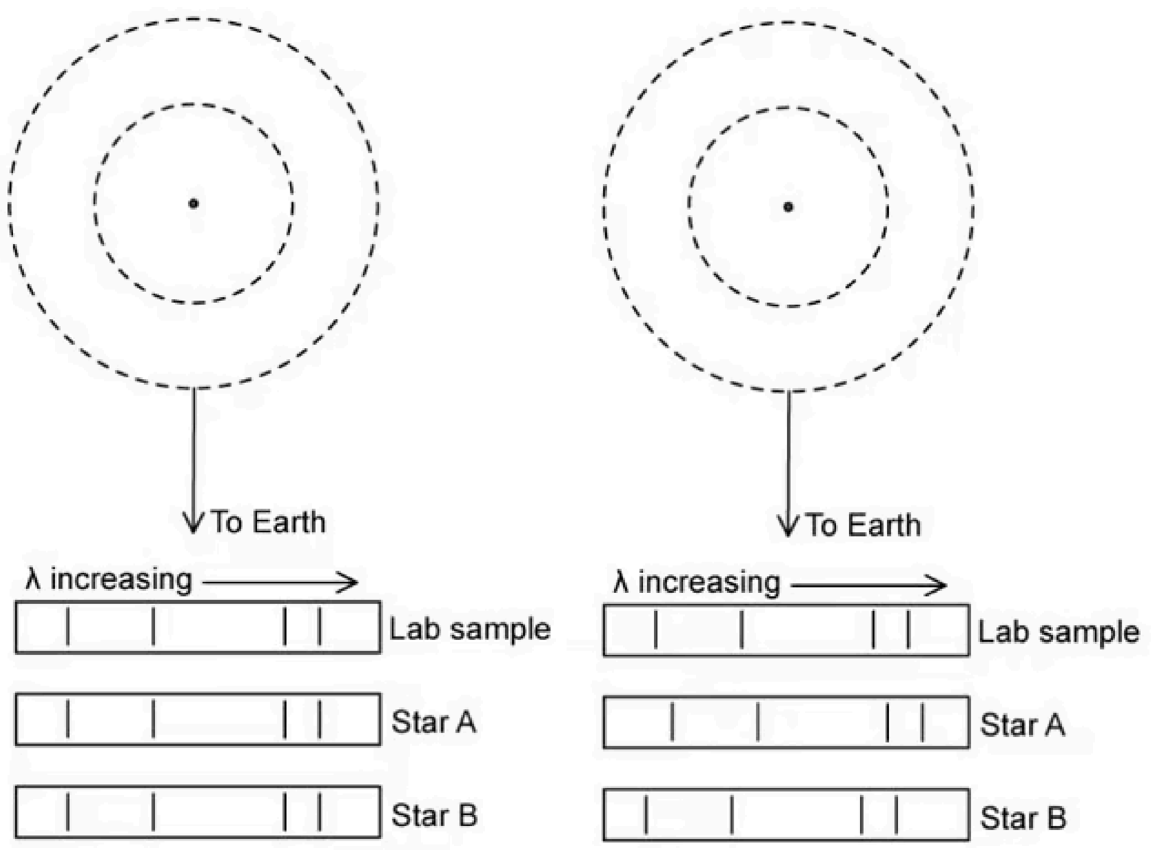
Determine the missing information in the table.

(3 marks)

3 (a) Two stars, A and B, in a binary system, move in a clockwise direction around a common centre of mass.



Mark the positions of stars A and B corresponding to their spectra as observed on Earth.



(4 marks)

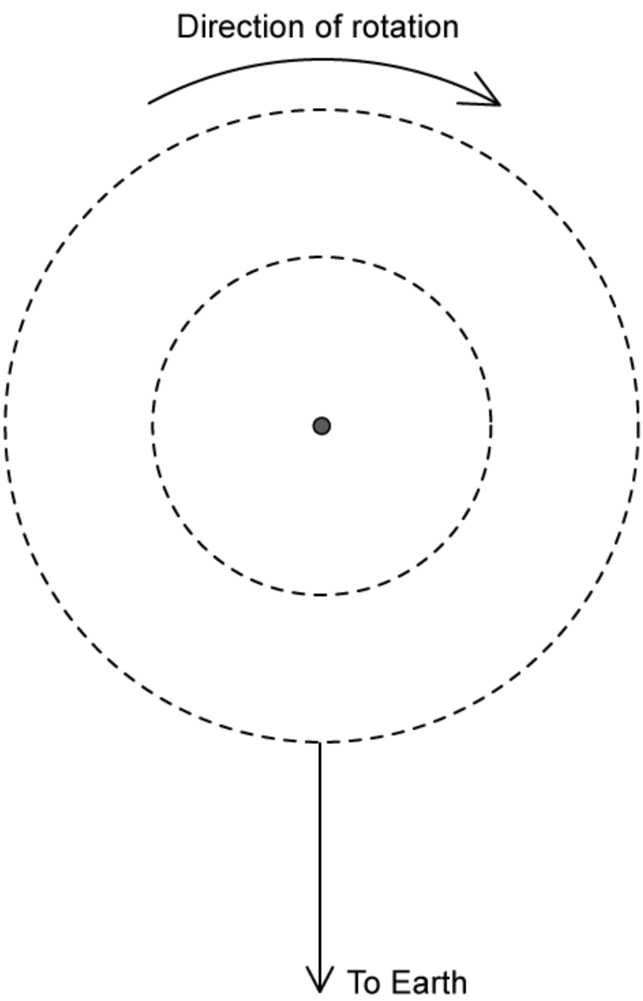
(b) When measured in the laboratory, one of the spectral lines of hydrogen has a wavelength of 4.942×10^{-7} m. The same hydrogen line in the spectrum of one of the stars fluctuates from its laboratory wavelength by $\pm 0.310 \times 10^{-7}$ m and the line in the spectrum of the other star fluctuates by $\pm 0.994 \times 10^{-7}$ m. Both stars have the same time period.

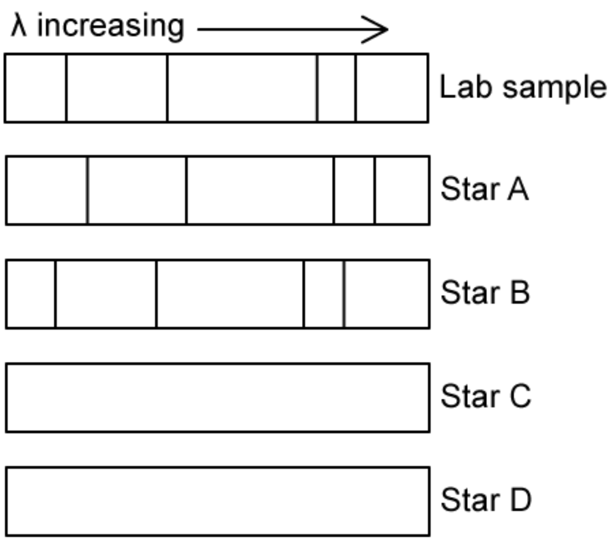
Calculate the orbital velocity of each star in the binary system and determine which of the stars, A or B, is faster.

(4 marks)

(c) In a different binary star system, also rotating clockwise, star C has an orbital velocity of 8.92×10^7 m s^{-1} and star D an orbital velocity of 1.2×10^7 m s^{-1}. Both stars have the same time period.

© 2024 Save My Exams, Ltd.





Identify the possible positions of stars C and D and an absorption spectrum as star C moves towards Earth and star D away from Earth.

© 2024 Save My Exams, Ltd.

(6 marks)

4 (a) Two stars, A and B, in a binary system move in an anti-clockwise direction. Both stars emit light with wavelength, $\lambda = 5.89 \times 10^{-7}$ m, which reaches an observer on Earth. In the laboratory, the light is shown to fluctuate between wavelengths of 5.86×10^{-7} m and 6.02×10^{-7} m.

Assume they orbit in a circle around their common centre of mass.

Draw a diagram which indicates the position of the stars relative to the Earth when:

(i) There is no redshift.

[1]

(ii) The wavelength is recorded as 5.86×10^{-7} m from both stars.

[2]

....

....

(2 marks)

(b) The radius of orbit of star B is 4.98×10^{11} m.

Calculate the time taken for one orbit of star A about the common centre of mass.

....

(1 mark)