PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 10: SPACE

DOPPLER EFFECT, REDSHIFT AND HUBBLE'S LAW

SCORE	PERCENTAGE
/183	%

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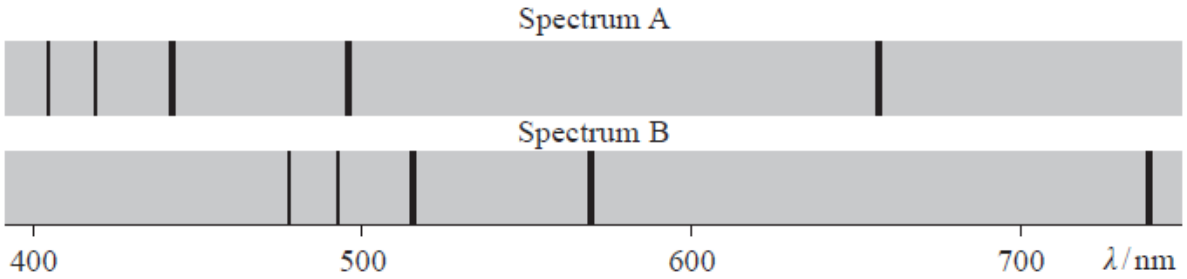
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Q1.

The diagram shows the spectra produced by two stars. Spectrum A is produced from the light from the Sun and spectrum B is produced from the light from a distant star.



The dark lines are produced when light from the core of the star is absorbed by hydrogen atoms in the outer regions of the star. Light is then re-radiated, but in all directions, giving rise to the dark lines in the spectrum.

Explain why the long wavelength lines are shifted by a greater amount than the short wavelength lines.

(2)

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(Total for question = 2 marks)

Q2.

Helium was first discovered because of dark lines observed in the continuous spectrum of light from the Sun. The lines were caused by a few specific frequencies of light in the spectrum being present at very much lower intensity than the rest.

Scientists deduced that this was due to an unknown element in the Sun's atmosphere.

(a) Explain how helium in the Sun's atmosphere caused this set of dark lines.

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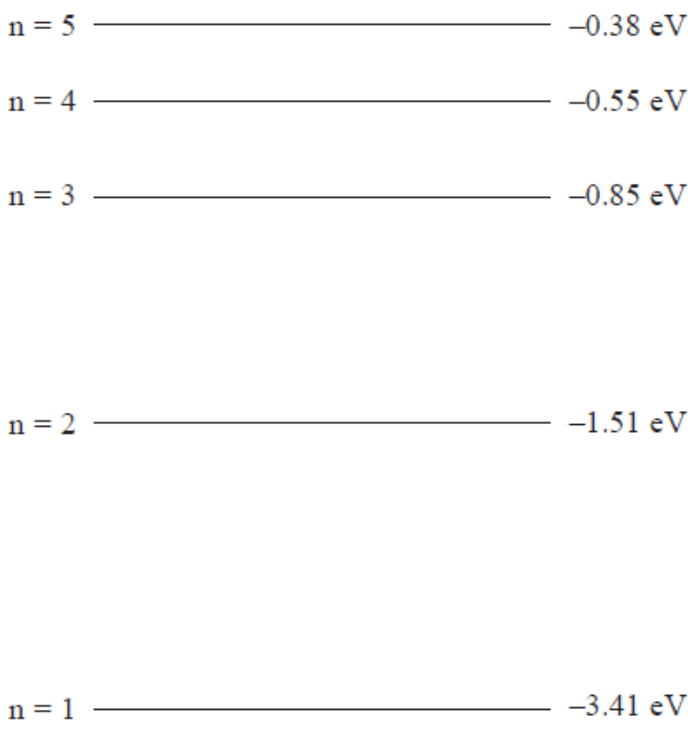
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(b) The diagram shows some of the energy levels for an atom of another element.



(i) Determine which energy levels are associated with photons of frequency 4.6×10^{14} Hz.

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(ii) Suggest why the energy levels all have a negative value.

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(c) Lines such as those described in (a) can be used to determine the motion of stars relative to the Earth.

Suggest how these lines may be used to determine the motion of stars.

(3)

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(Total for question = 14 marks)

Q3. Analysing the light from a star allows elements present in its outer atmosphere to be identified because each element produces a distinctive set of spectral lines.

*(a) Describe how a spectral line is produced by a hot gas, explaining why a particular element can only give rise to particular frequencies.

(6)

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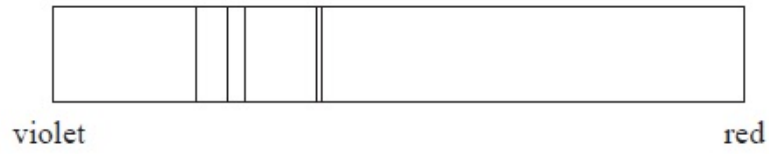
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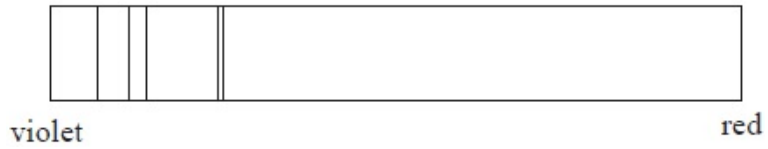
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(b) The diagram shows the spectral lines produced by a particular element when observed in a laboratory.



The diagram below shows the spectral lines obtained by analysing the light from a star. This shows the same pattern of lines, but in a different part of the spectrum.



Name this effect and explain what may be deduced about the motion of this star relative to the Earth.

(3)

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(c) Suggest what the phenomena in parts (a) and (b) imply about the nature of light.

(1)

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(Total for Question = 10 marks)

Q4.

When a large potential difference is applied to a discharge tube, the gas in the discharge tube emits coloured light. When this light is passed through a diffraction grating, an emission spectrum which is made up of a series of lines of different wavelengths may be seen.

The photographs show the spectra produced from a tube containing hydrogen and a tube containing helium.

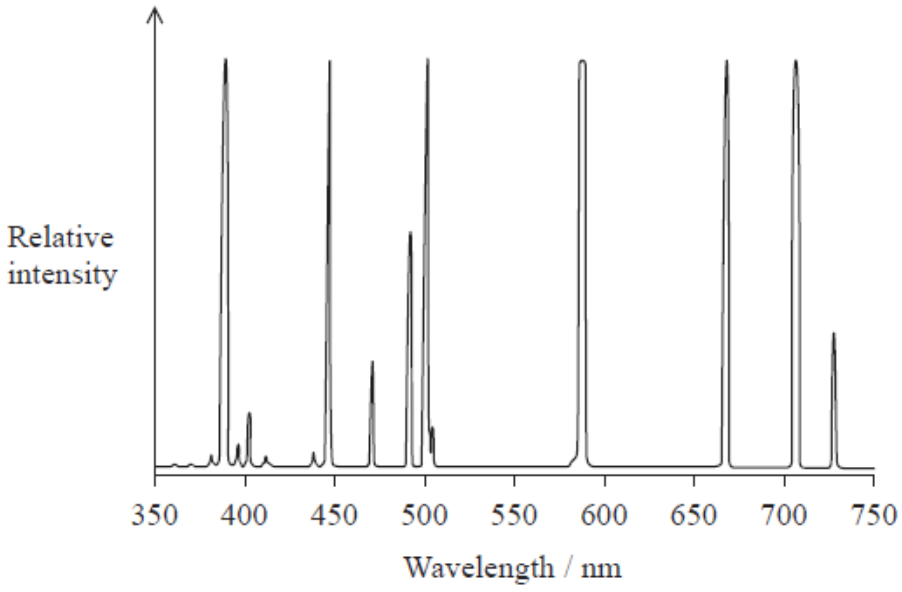
Hydrogen:



Helium:



The graph shows the relative intensities of different wavelengths of light in the spectrum of a sample of helium.



The graph shows that the lines are not at a single wavelength. This effect is known as thermal Doppler broadening and occurs because of the random motion of the helium atoms.

(i) Explain why the thermal motion of the helium atoms causes the broadening of the spectral lines.

(2)

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(ii) The width of a line may be used to determine the speed of the atoms in the gas and hence the temperature of the gas.

The spectral line with wavelength 587 nm for a particular tube containing helium has a width of 6×10^{-3} nm.

(1) Show that this corresponds to a speed, for a helium atom, of about 1500 m s^{-1}.

(2)

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(2) Assuming that this is the root mean square speed for the helium (He 4) atoms in the tube, calculate the temperature of the gas in the tube.

(3)

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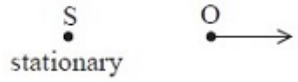
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Temperature = ...

Q5. The diagrams show the motions of a source of sound, S, and an observer, O.

Which line of the table correctly shows the effect this relative motion has on the frequency of the sound heard by the observer.

	Motions of S and O	Frequency
☒ **A**		increased
☒ **B**		decreased
☒ **C**		decreased
☒ **D**		increased

(Total for Question = 1 mark)

Q6.

Ultrasound is used to investigate the blood in an artery in a human body by detecting a Doppler shift. This Doppler shift is used to measure the

☒ **A** diameter of the artery.

☒ **B** size of the particles in the blood.

☒ **C** temperature of the blood.

☒ **D** velocity of the blood.

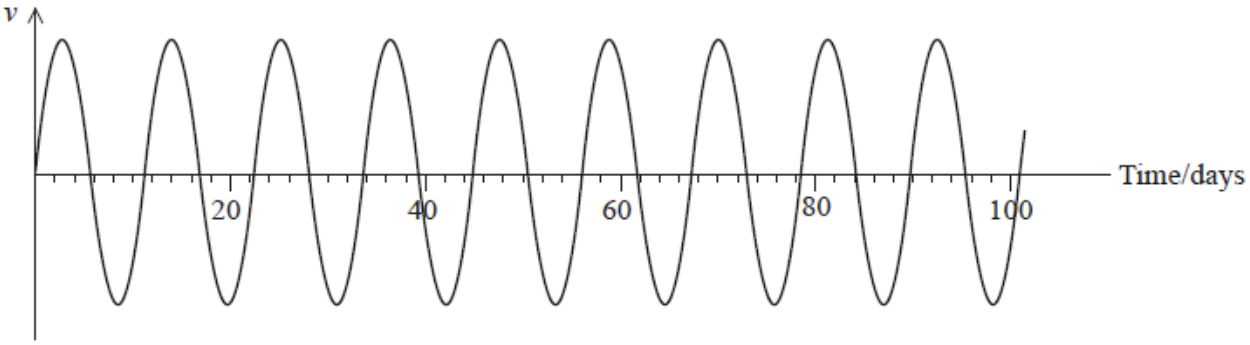
(Total for question = 1 marks)

Q7.

In 2016 astronomers announced the discovery of an Earth-like planet orbiting Proxima Centauri, the closest star to the Sun.

The planet was detected because of the small movement of the star as the planet orbited. The movement was detected using the Doppler shift in the frequency of light travelling to the Earth.

The graph shows how the component of the star's velocity *v* towards the Earth varied over time.



Explain how the Doppler shift was used to obtain the data shown on the graph.

(4)

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(Total for question = 4 marks)

Q8.

When light from the galaxy in Andromeda is analysed, it is found that the wavelengths are shorter than expected.
This tells us that the galaxy is

☒ **A** moving towards us.

☒ **B** moving away from us.

☒ **C** a very distant galaxy.

☒ **D** rotating on an axis.

(Total for question = 1 mark)

Q9.

Almost a century ago Edwin Hubble was investigating the light spectra emitted from a large number of galaxies. He used redshift values obtained from these spectra to determine the velocity of the galaxies relative to the Earth. He also measured the distances to each galaxy using Cepheid variable stars, which are a type of standard candle. From these measurements Hubble was able to formulate a law linking the velocity of distant galaxies to their distance from the Earth.

(a) (i) Explain what is meant by redshift.

(2)

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*(ii) Explain how redshift can be used to determine the velocity of a galaxy relative to the Earth.

(3)

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(b) State what is meant by a standard candle.

(1)

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(c) Explain how Hubble's law can be used to find a value for the age of the universe.

(2)

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(d) Hubble's law is seen as one piece of evidence supporting the Big Bang theory of the origin of the universe. In this theory the universe has been expanding ever since it was created 14 billion years ago.

(i) Describe how you would expect the average density of matter in the universe to affect its ultimate fate.

(3)

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(ii) It is difficult for scientists to estimate the average density of the universe reliably. Explain why.

(2)

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(Total for question = 13 marks)

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The diagram shows a source of sound waves and an observer.

source observer

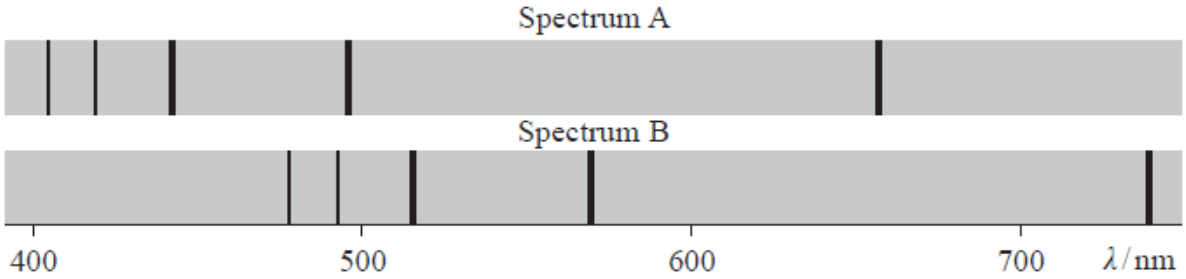
Which row of the table shows a situation which would result in a decrease in the frequency of sound observed?

		Source	Observer
☒	**A**	moves to the right at $20\,m\,s^{-1}$	moves to the left at $20\,m\,s^{-1}$
☒	**B**	moves to the right at $20\,m\,s^{-1}$	moves to the right at $20\,m\,s^{-1}$
☒	**C**	moves to the right at $20\,m\,s^{-1}$	stationary
☒	**D**	stationary	moves to the right at $20\,m\,s^{-1}$

(Total for question = 1 mark)

Q1.

The diagram shows the spectra produced by two stars. Spectrum A is produced from the light from the Sun and spectrum B is produced from the light from a distant star.



The dark lines are produced when light from the core of the star is absorbed by hydrogen atoms in the outer regions of the star. Light is then re-radiated, but in all directions, giving rise to the dark lines in the spectrum.

Explain why the long wavelength lines are shifted by a greater amount than the short wavelength lines.

(2)

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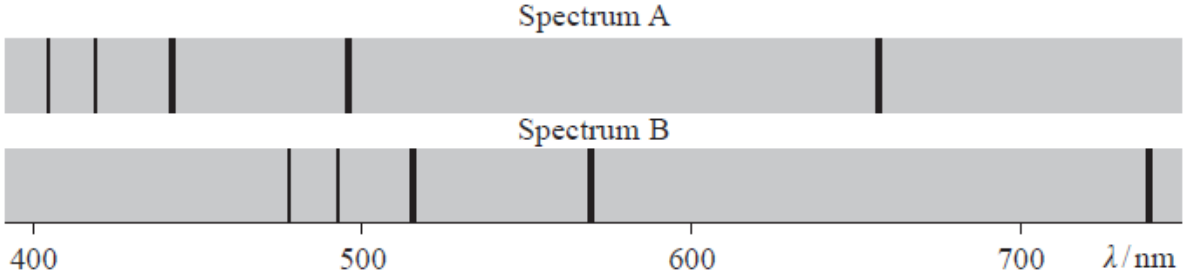
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(Total for question = 2 marks)

Q2.

The diagram shows the spectra produced by two stars. Spectrum A is produced from the light from the Sun and spectrum B is produced from the light from a distant star.



The dark lines are produced when light from the core of the star is absorbed by hydrogen atoms

in the outer regions of the star. Light is then re-radiated, but in all directions, giving rise to the dark lines in the spectrum.

One of the lines in the hydrogen spectrum occurs at a wavelength of 656 nm in the laboratory.

Explain what conclusion can be made from the shift in wavelength of this line in spectrum B. Your answer should include a calculation.

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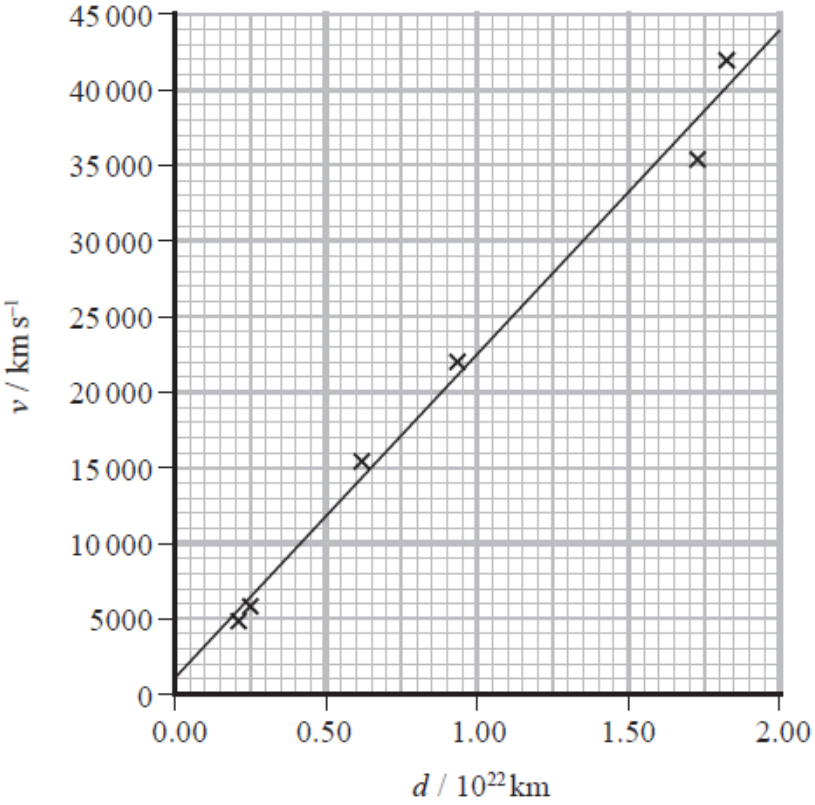
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(Total for question = 4 marks)

Q3.

In 1990, the Hubble Space Telescope (HST) was launched into a low Earth orbit above the Earth's atmosphere.

High resolution images from HST allow astronomers to make detailed measurements of very distant galaxies. The graph shows how the recessional velocities of distant galaxies depend on their distance from Earth.



Determine an age for the universe.

(3)

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Age for the universe = ...

(Total for question = 3 marks)

Q4.

Barnard's star is a red dwarf star in the vicinity of the Sun. The wavelength of a line in the spectrum of light emitted from Barnard's star is measured to be 656.0 nm. The same light produced by a source in a laboratory has a wavelength of 656.2 nm.

Calculate the velocity of Barnard's star relative to the Earth.

(3)

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Velocity = ...

(Total for question = 3 marks)

Q5.

When a large potential difference is applied to a discharge tube, the gas in the discharge tube emits coloured light. When this light is passed through a diffraction grating, an emission spectrum which is made up of a series of lines of different wavelengths may be seen.

The photographs show the spectra produced from a tube containing hydrogen and a tube containing helium.

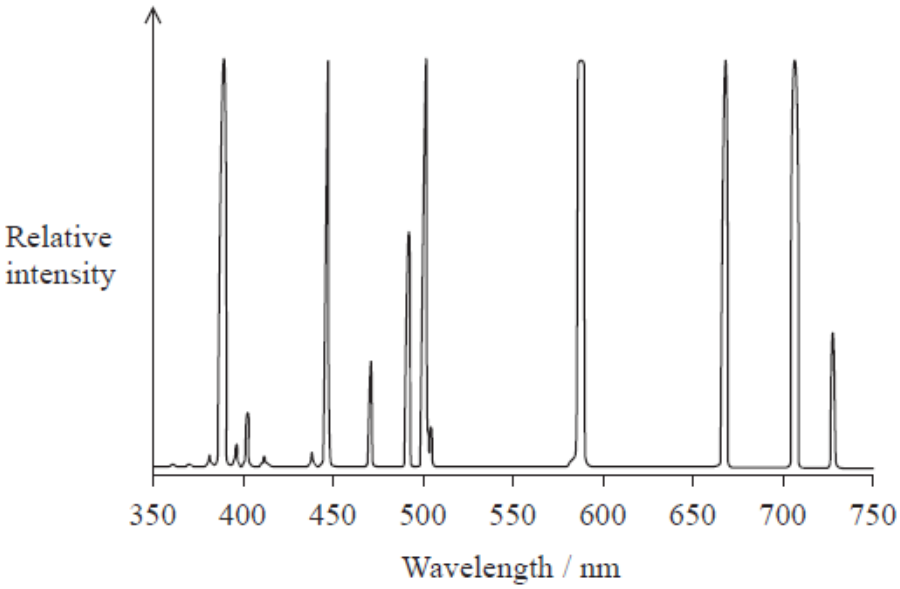
Hydrogen:



Helium:



The graph shows the relative intensities of different wavelengths of light in the spectrum of a sample of helium.



The graph shows that the lines are not at a single wavelength. This effect is known as thermal Doppler broadening and occurs because of the random motion of the helium atoms.

(i) Explain why the thermal motion of the helium atoms causes the broadening of the spectral lines.

(2)

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(ii) The width of a line may be used to determine the speed of the atoms in the gas and hence the temperature of the gas.

The spectral line with wavelength 587 nm for a particular tube containing helium has a width of 6×10^{-3} nm.

(1) Show that this corresponds to a speed, for a helium atom, of about 1500 m s^{-1}.

(2)

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(2) Assuming that this is the root mean square speed for the helium (He 4) atoms in the tube, calculate the temperature of the gas in the tube.

(3)

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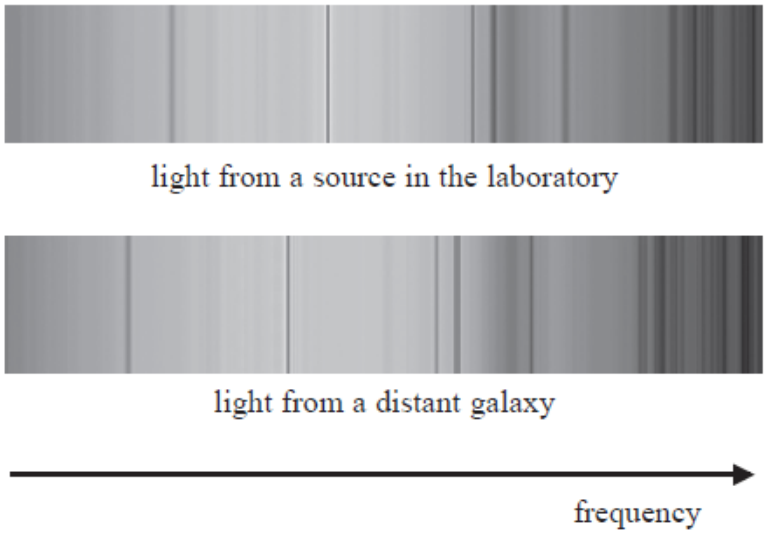
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Temperature = ...

Q6.

The spectra below show dark absorption lines against a continuous visible spectrum.



A particular line in the spectrum of light from a source in the laboratory has a frequency of 4.570×10^{14} Hz.
The same line in the spectrum of light from a distant galaxy has a frequency of 4.547×10^{14} Hz.

With the aid of a calculation state what should be concluded about the distant galaxy.

(3)

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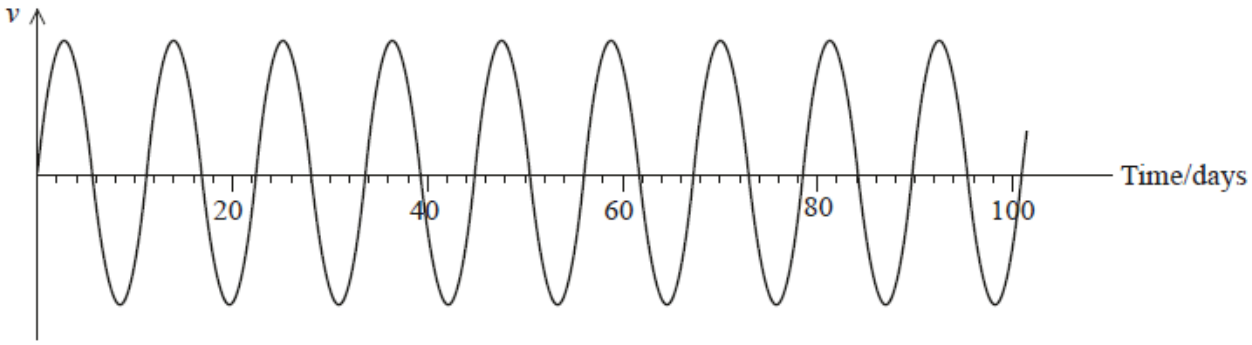
(Total for question = 3 marks)

Q7.

In 2016 astronomers announced the discovery of an Earth-like planet orbiting Proxima Centauri, the closest star to the Sun.

The planet was detected because of the small movement of the star as the planet orbited. The movement was detected using the Doppler shift in the frequency of light travelling to the Earth.

The graph shows how the component of the star's velocity *v* towards the Earth varied over time.



Explain how the Doppler shift was used to obtain the data shown on the graph.

(4)

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(Total for question = 4 marks)

Q8.

About 100 years ago the first measurements of spectra from galaxies beyond the Milky Way were made. Wavelengths of spectral lines were observed to be shifted and Hubble discovered a rough correlation between the shift in the spectral line and the distance to the galaxy.

The graphs below show plots for data collected in 1929 (Figure 1) and 1931 (Figure 2).

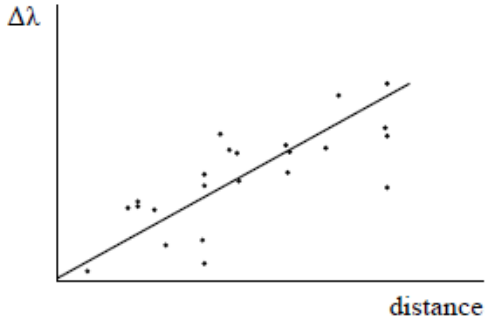


Figure 1

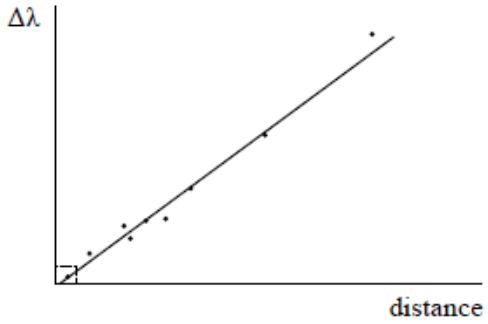


Figure 2

The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).

Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.

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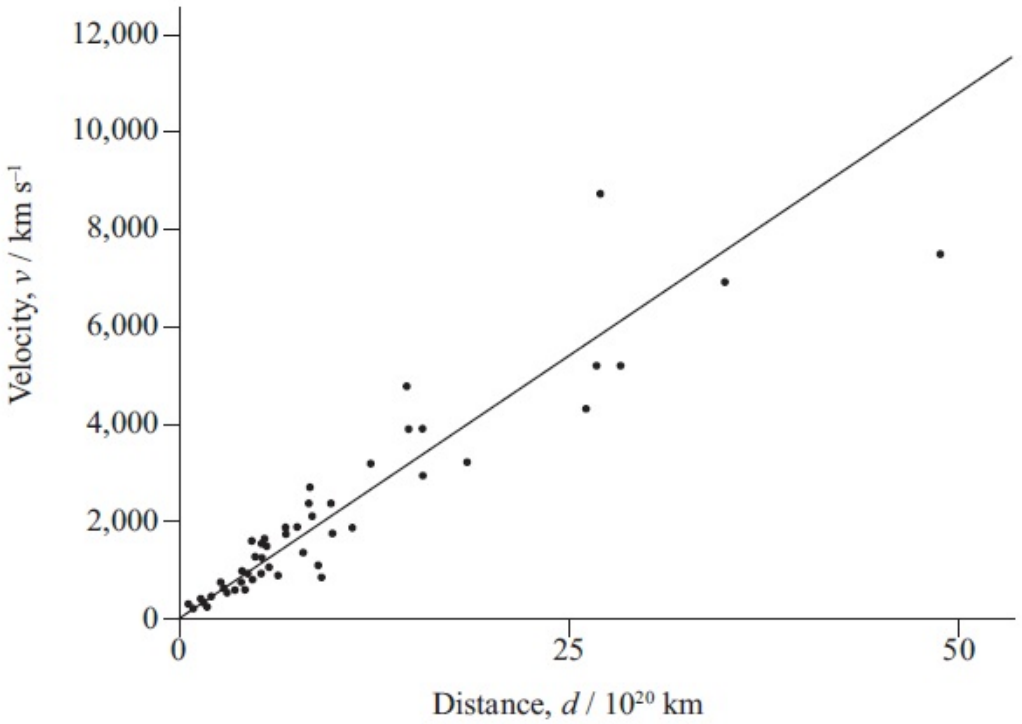
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(Total for question = 5 marks)

Q9.

The graph shows how the velocity varies with distance for a number of distant galaxies. All the galaxies are receding from Earth, and there appears to be a linear relationship between the velocity of recession and the distance to the galaxy.



(a) Use the graph to estimate an age for the Universe

(4)

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Age of the Universe = ...

*(b) Describe how astronomers would have determined the velocity of each galaxy.

(5)

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*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

(3)

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(Total for question = 12 marks)

Q10.

Light from all distant galaxies is found to be shifted towards longer wavelengths. The more distant the galaxy, the greater the shift in wavelength.

State the conclusions that we can draw from this.

(3)

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(Total for Question = 3 marks)

Q11.

A line in the hydrogen spectrum of a star in the Milky Way galaxy is observed to have a wavelength of 656.3 nm. In a laboratory on Earth this line has a wavelength of 654.9 nm.

Which of the following expressions gives the magnitude of the velocity of the star relative to Earth?

(1)

☒ **A** $\frac{656.3}{654.9} \times 3 \times 10^8 \text{ms}^{-1}$

☒ **B** $\frac{654.9}{(656.3 - 654.9)} \times 3 \times 10^8 \text{ms}^{-1}$

☒ **C** $\frac{654.9}{656.3} \times 3 \times 10^8 \text{ms}^{-1}$

☒ **D** $\frac{(656.3 - 654.9)}{654.9} \times 3 \times 10^8 \text{ms}^{-1}$

(Total for question = 1 mark)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

There are several different methods that can be used to determine the distance from our solar system to astronomical objects. These include the measurement of red shift, trigonometrical parallax and the use of standard candles.

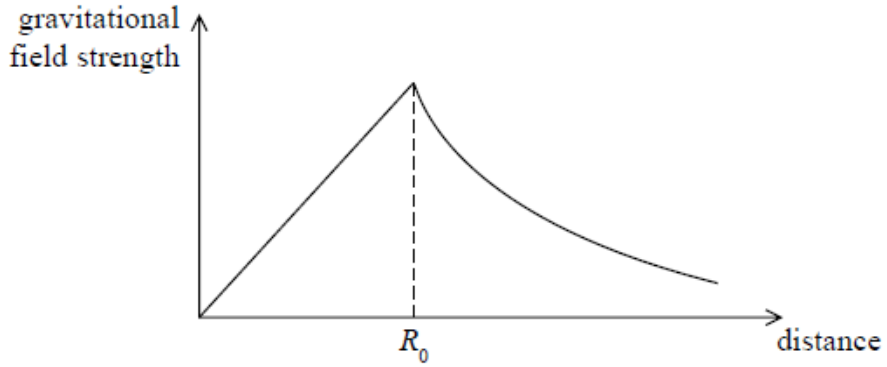
Which row of the table shows a suitable method for each of the objects named?

		Nearby star	Nearby galaxy	Very distant galaxy
☒	**A**	parallax	red shift	standard candle
☒	**B**	red shift	standard candle	parallax
☒	**C**	parallax	standard candle	red shift
☒	**D**	red shift	parallax	standard candle

(Total for question = 1 mark)

Q13.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



A scientist suggests that the period of oscillation for a body dropped through the tunnel would be the same as the orbital period for a body orbiting just above the surface of the Earth. Its radius of orbit is assumed to be R_0.

(i) Derive an expression for the period of oscillation of the body dropped through the tunnel.

(4)

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(ii) Derive an expression for the orbital period for a body that is orbiting the Earth with radius R_0.

(3)

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(Total for question = 7 marks)

Q14.

At the Culham Centre for Fusion Energy (CCFE) experiments are carried out to investigate nuclear fusion and the properties of plasmas. A plasma consists of ionised gas, containing positive ions and electrons.

In a plasma experiment 5.0 mg of deuterium, an isotope of hydrogen, occupies a volume of 98 m^3. The temperature of deuterium is raised to 1.3×10^8 K. In this experiment, the deuterium behaves as an ideal gas.

(i) Calculate the pressure due to the deuterium ions.

mass of deuterium ion = 3.3×10^{-27} kg

(3)

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Pressure = ...

(ii) Calculate the root mean square speed of the deuterium ions at this temperature.

(2)

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Root mean square speed = ...

(iii) The temperature of the plasma is monitored using the Doppler effect. Light from a laser is directed into the plasma and the wavelength of the light reflected is measured.

The Doppler shift observed when light is reflected by a deuterium ion is twice the Doppler shift that would be observed for a source of light moving at the same speed as the deuterium ion.

Calculate the maximum wavelength of light that would be detected after reflection from a deuterium ion moving at $1.5 \times 106\,\text{m}\,\text{s}^{-1}$.

wavelength of laser light = 1064 nm

(3)

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Maximum wavelength detected = ...

(Total for question = 8 marks)

Q15.

Almost a century ago Edwin Hubble was investigating the light spectra emitted from a large number of galaxies. He used redshift values obtained from these spectra to determine the velocity of the galaxies relative to the Earth. He also measured the distances to each galaxy using Cepheid variable stars, which are a type of standard candle. From these measurements Hubble was able to formulate a law linking the velocity of distant galaxies to their distance from the Earth.

(a) (i) Explain what is meant by redshift.

(2)

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*(ii) Explain how redshift can be used to determine the velocity of a galaxy relative to the Earth.

(3)

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(b) State what is meant by a standard candle.

(1)

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(c) Explain how Hubble's law can be used to find a value for the age of the universe.

(2)

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(d) Hubble's law is seen as one piece of evidence supporting the Big Bang theory of the origin of the universe. In this theory the universe has been expanding ever since it was created 14 billion years ago.

(i) Describe how you would expect the average density of matter in the universe to affect its ultimate fate.

(3)

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(ii) It is difficult for scientists to estimate the average density of the universe reliably. Explain why.

(2)

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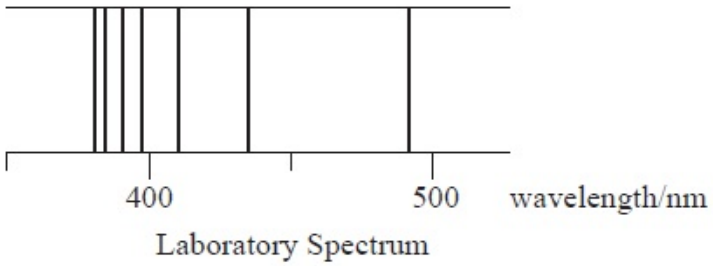
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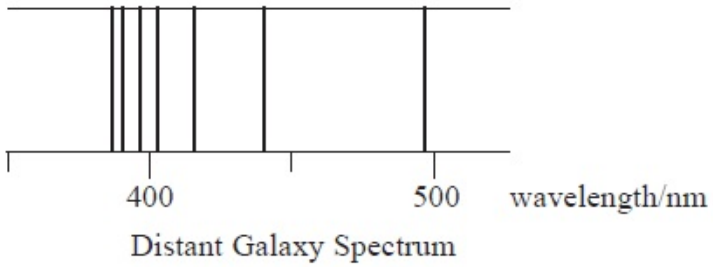
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(Total for question = 13 marks)

Q16. The diagram shows part of the hydrogen line spectra obtained for radiation emitted from hydrogen in the laboratory and received from hydrogen in a distant galaxy.



Laboratory Spectrum



Distant Galaxy Spectrum

The lines in the distant galaxy spectrum are all shifted in wavelength compared to the lines in the laboratory spectrum.

State why the lines are shifted and what we can conclude about this distant galaxy.

(2)

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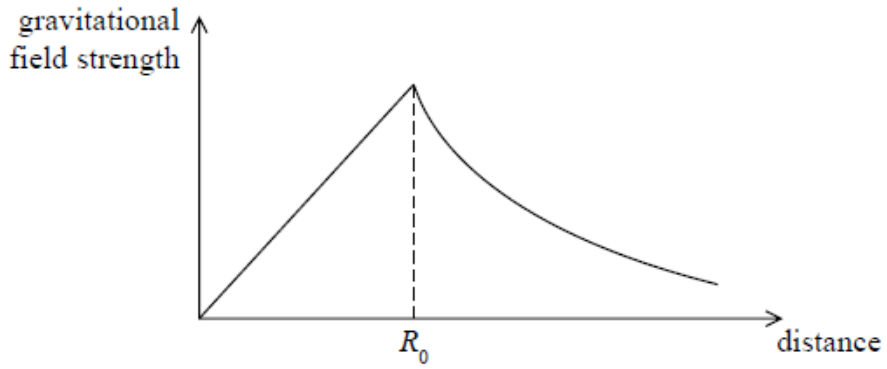
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(Total for Question = 2 marks)

Q17.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



A scientist suggests the following:

"If a tunnel were made through the centre of the Earth, an object dropped at one end would accelerate downwards until it reached the centre. It would then decrease in speed until it reached the other end of the tunnel with a speed of zero. The object would then return the other way, undergoing simple harmonic motion."

Using the graph between 0 and R_0, determine whether simple harmonic motion would occur.

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(Total for question = 4 marks)

Q18.

Astronomers observing stars at the centre of our galaxy have suggested that many of them are orbiting a supermassive black hole. The mass of this black hole is 9.2×10^{36} kg.

Trigonometric parallax and Hubble's law are two methods used to determine astronomical distances.
Explain whether either of these methods is suitable to determine the distance to S0-2.

(3)

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(Total for question = 3 marks)

Q19.

According to astronomers in Denmark and Australia a common type of active galactic nucleus (AGN) could be used as an accurate "standard candle" for measuring cosmic distances. The technique has been used to measure distances corresponding to redshifts significantly larger than was previously possible.

(a) (i) State what is meant by a standard candle.

(1)

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(ii) Explain how a standard candle is used to measure cosmic distances.

(2)

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(b) (i) State what is meant by redshift.

(1)

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(ii) Calculate the distance to a galaxy with a redshift $z = 0.12$

$H_0 = 2.1 \times 10^{-18}\ s^{-1}$

(2)

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Distance to galaxy = ...

*(c) Discuss how astronomers were led to propose the existence of dark matter and the consequences of its existence for the ultimate fate of the universe.

(3)

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(d) Explain why the observable universe has a finite size.

(2)

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(Total for Question = 11 marks)

Q20.

The distance to astronomical objects relatively close to the Sun is determined using trigonometric parallax. For objects beyond a certain distance standard candles are used.

(a) State what is meant by a standard candle.

(1)

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(b) Explain why trigonometric parallax is not used beyond a certain distance.

(2)

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(c) Describe how distances too large for the use of standard candles can be determined.

(3)

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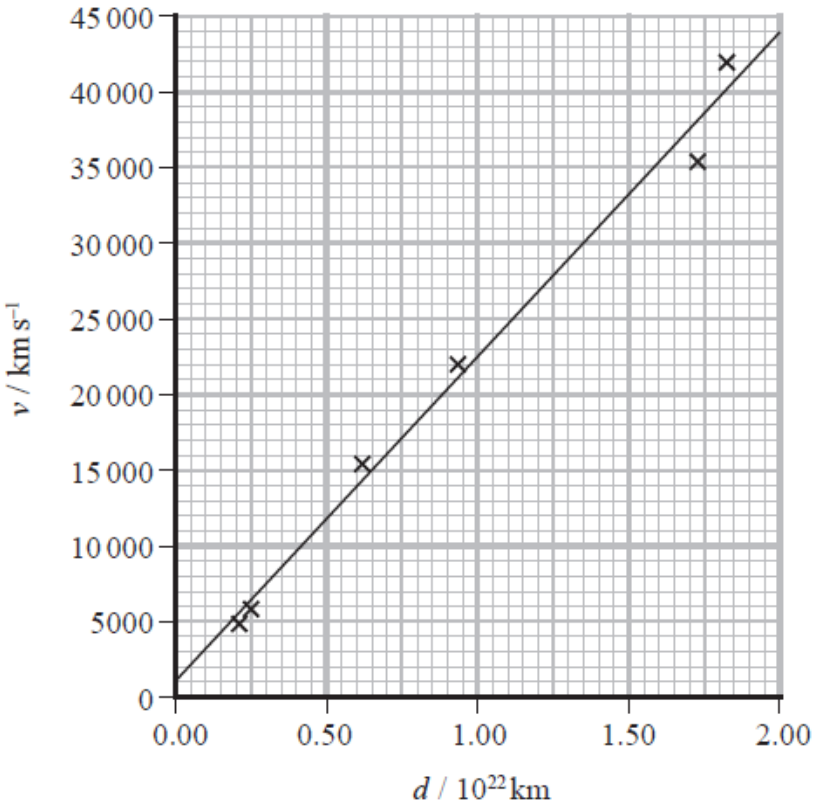
(Total for question = 6 marks)

	$\Delta\lambda$ is proportional to λ	(1)		

Q1.

In 1990, the Hubble Space Telescope (HST) was launched into a low Earth orbit above the Earth's atmosphere.

High resolution images from HST allow astronomers to make detailed measurements of very distant galaxies. The graph shows how the recessional velocities of distant galaxies depend on their distance from Earth.



Determine an age for the universe.

(3)

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Age for the universe = ...

(Total for question = 3 marks)

Q2.

About 100 years ago the first measurements of spectra from galaxies beyond the Milky Way were made. Wavelengths of spectral lines were observed to be shifted and Hubble discovered a rough correlation between the shift in the spectral line and the distance to the galaxy.

The graphs below show plots for data collected in 1929 (Figure 1) and 1931 (Figure 2).

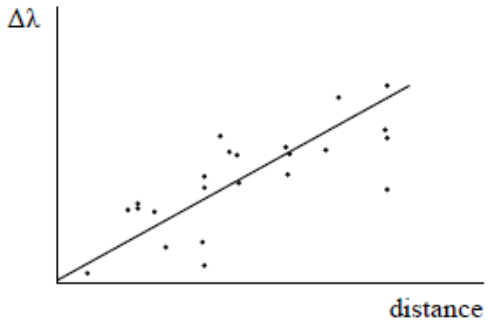


Figure 1

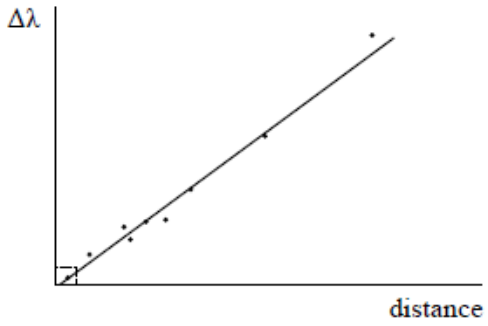


Figure 2

The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).

Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.

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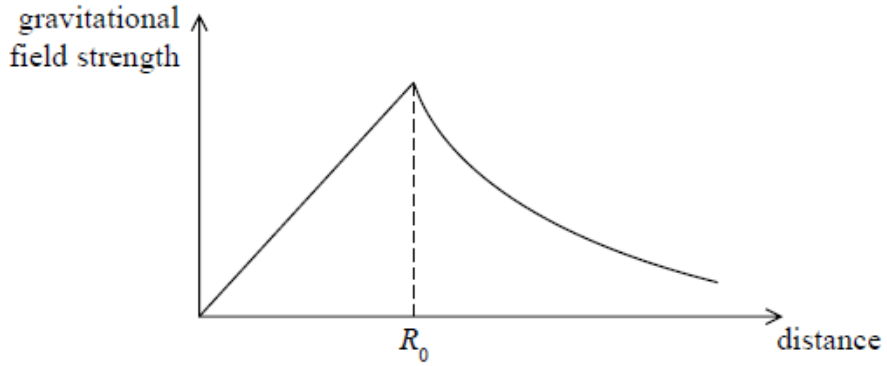
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(Total for question = 5 marks)

Q3.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



A scientist suggests that the period of oscillation for a body dropped through the tunnel would be the same as the orbital period for a body orbiting just above the surface of the Earth. Its radius of orbit is assumed to be R_0.

(i) Derive an expression for the period of oscillation of the body dropped through the tunnel.

(4)

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(ii) Derive an expression for the orbital period for a body that is orbiting the Earth with radius R_0.

(3)

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(Total for question = 7 marks)

Q4.

Almost a century ago Edwin Hubble was investigating the light spectra emitted from a large number of galaxies. He used redshift values obtained from these spectra to determine the velocity of the galaxies relative to the Earth. He also measured the distances to each galaxy using Cepheid variable stars, which are a type of standard candle. From these measurements Hubble was able to formulate a law linking the velocity of distant galaxies to their distance from the Earth.

(a) (i) Explain what is meant by redshift.

(2)

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*(ii) Explain how redshift can be used to determine the velocity of a galaxy relative to the Earth.

(3)

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(b) State what is meant by a standard candle.

(1)

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(c) Explain how Hubble's law can be used to find a value for the age of the universe.

(2)

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(d) Hubble's law is seen as one piece of evidence supporting the Big Bang theory of the origin of the universe. In this theory the universe has been expanding ever since it was created 14 billion years ago.

(i) Describe how you would expect the average density of matter in the universe to affect its ultimate fate.

(3)

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(ii) It is difficult for scientists to estimate the average density of the universe reliably. Explain why.

(2)

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(Total for question = 13 marks)