# A2 Level Physics

Chapter 16 – Astrophysics and Cosmology

16.3.2 Cosmology

Worked Examples

# The Parsec $(pc)$

## Exam Style Question 1

(a) Calculate the distance of 1 light-year (ly) in metres.

(b) Fig. 10.1 shows an incomplete diagram drawn by a student to show what is meant by a distance of 1 $parsec$ $(pc)$.

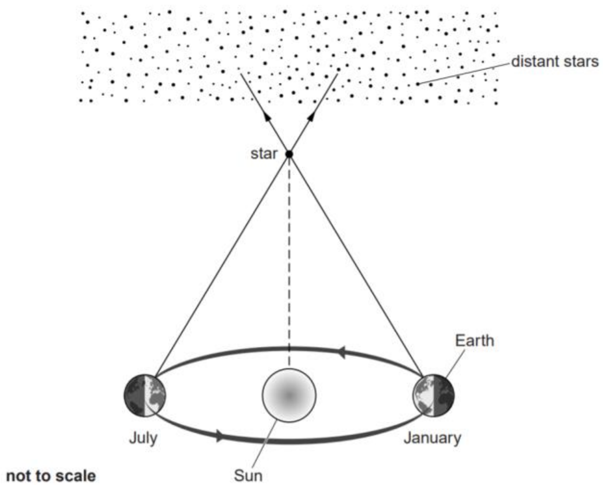



Fig. 10.1

Complete Fig. 10.1 by showing the distances of 1 $pc$ and 1 $AU$, and the parallax angle of 1 $second\ of\ arc$ $(1'')$.

(c) A recent supernova, $SN2011fe$, in the Pinwheel galaxy, $M101$, released $10^{44}$ $J$ of energy. The supernova is $2.1 \times 10^{7}$ $ly$ away.

(i) Calculate the distance of this supernova in pc.
$1\ pc = 3.1 \times 10^{16}\ m$

(ii) Our Sun radiates energy at a rate of $4 \times 10^{26}\ W$. Estimate the time in years that it would take the Sun to release the same energy as the supernova $SN2011fe$.

(d) One of the possible remnants of a supernova event is a black hole. State two properties of a black hole.

tutorpacks.co.uk

# The Parsec $(pc)$

## Exam Style Question 1

**(a) Calculate the distance of 1 light-year (ly) in metres.**

Remember light years is a measure of distance and not time therefore you can use $s = \frac{d}{t}$ and rearrange for $d$.

Where $s = speed = speed\ of\ light$

$t = time = 1\ year$

$$1\ light\ year = (2.9979 \times 10^{8}\ m\ s^{-1})(365.25\ days)(24\ hours)(3600\ seconds)$$

$$\therefore 1\ light\ year = 9.461 \times 10^{15} m$$

$$distance \approx 9.5 \times 10^{15}\ m$$

**(b) Complete Fig. 10.1 by showing the distances of 1 $pc$ and 1 $AU$, and the parallax angle of 1 $second\ of\ arc$ $(1'')$.**

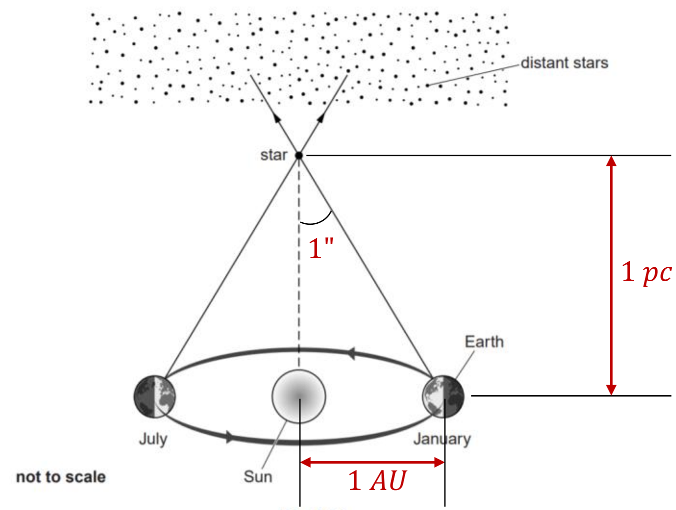



Fig. 10.1

tutorpacks.co.uk

# The Parsec $(pc)$

## Exam Style Question 1

(a) Calculate the distance of 1 light-year (ly) in metres.

(b) Fig. 10.1 shows an incomplete diagram drawn by a student to show what is meant by a distance of 1 $parsec$ $(pc)$.

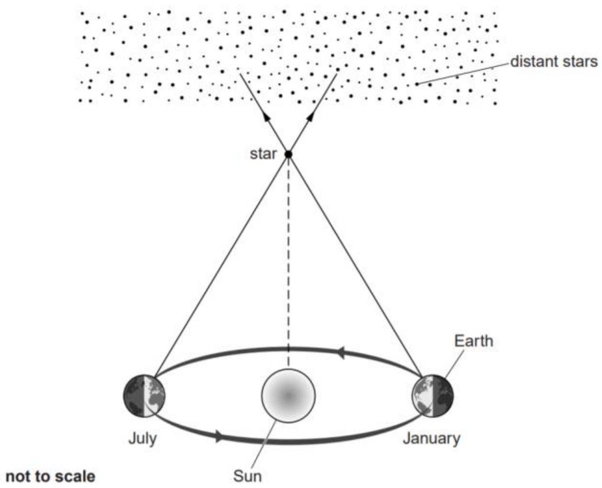



Fig. 10.1

Complete Fig. 10.1 by showing the distances of 1 $pc$ and 1 $AU$, and the parallax angle of 1 $second\ of\ arc$ $(1'')$.

(c) A recent supernova, $SN2011fe$, in the Pinwheel galaxy, $M101$, released $10^{44}\ J$ of energy. The supernova is $2.1 \times 10^{7}\ ly$ away.

(i) Calculate the distance of this supernova in pc.
$1\ pc = 3.1 \times 10^{16}\ m$

(ii) Our Sun radiates energy at a rate of $4 \times 10^{26}\ W$. Estimate the time in years that it would take the Sun to release the same energy as the supernova $SN2011fe$.

(d) One of the possible remnants of a supernova event is a black hole. State two properties of a black hole.

# The Parsec $(pc)$

## Exam Style Question 1

**(c) (i) Calculate the distance of this supernova in pc.**

Convert $2.1 \times 10^{7}\ ly$ in $m$:

$$distance = 2.1 \times 10^{7}\ ly \times 9.5 \times 10^{15}\ m$$
$$distance\ in\ m = 1.995 \times 10^{23}\ m$$
$$distance\ in\ pc = \frac{1.995 \times 10^{23}\ m}{3.1 \times 10^{16}\ m}$$
$$distance\ in\ pc = 6.4 \times 10^{6}\ pc$$

**(c) (ii) Estimate the time in years that it would take the Sun to release the same energy as the supernova $SN2011fe$.**

Use $P = \frac{E}{t}$ and rearrange for $t$

$$t = \frac{E}{P} = \frac{10^{44}\ J}{4 \times 10^{26}\ W}$$
$$t = 2.5 \times 10^{17}\ seconds$$

Convert seconds to years:

$$t = \frac{2.5 \times 10^{17}\ seconds}{3.16 \times 10^{7}\ seconds} = 7.9 \times 10^{9}\ years$$

**(d) One of the possible remnants of a supernova event is a black hole. State two properties of a black hole.**

- Very dense,
- Very strong gravitational field therefore light cannot escape from it.


tutorpacks.co.uk

# The Parsec $(pc)$

## Exam Style Question 2

(a) Define the parsec. Draw a diagram to illustrate your answer.

(b) The star Tau Ceti has a parallax of $0.275\ seconds\ of\ arc$. Calculate the distance of Tau Ceti from Earth

(i) in parsec (pc),

(ii) in light year (ly).

$$1\ pc = 3.1 \times 10^{16}\ m$$





# The Parsec $(pc)$

## Exam Style Question 2



**(a)Define the parsec. Draw a diagram to illustrate your answer.**

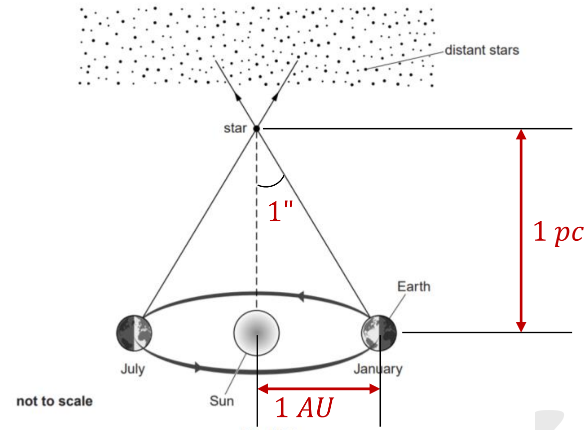



Fig. 10.1

Parsec definition:

- Distance from a base length of $1\ AU$ that subtends an angle of $1\ arc\ second$

OR

- Parsec is a distance that gives a stellar parallax of $1\ arc\ second$ or $\frac{1}{3600}°$.

**(b) The star Tau Ceti has a parallax of $0.275\ seconds\ of\ arc$. Calculate the distance of Tau Ceti from Earth**

**(i) in parsec (pc),**

Use $d = \frac{1}{p}$

$$distance\ (in\ pc) = \frac{1}{0.275\ seconds\ of\ arc}$$
$$distance = 3.64\ pc$$

# The Parsec $(pc)$

## Exam Style Question 2

(a) Define the parsec. Draw a diagram to illustrate your answer.

(b) The star Tau Ceti has a parallax of 0.275 $seconds\ of\ arc$. Calculate the distance of Tau Ceti from Earth

(i) in parsec (pc),

(ii) in light year (ly).

$$1\,pc = 3.1 \times 10^{16}\,m$$



# The Parsec $(pc)$

## Exam Style Question 2

**(ii) in light year (ly).**

Convert 3.64 $pc$ into metres:

$$3.64\,pc \times 3.1 \times 10^{16}\,m = 1.128 \times 10^{17}\,m$$

Convert $1.128 \times 10^{17}\,m$ to $ly$:

$$\frac{(1.128 \times 10^{17}\,m)}{9.5 \times 10^{15}\,m} = 11.9\,ly$$

$$\therefore distance\ in\ ly = 11.9$$

## Standard Candles and Luminosity

### Exam Style Question 3

(a) Explain the difference between the luminosity and the intensity of a star.

(b) Sirius A is the brightest star in the night sky. It is $8.6\ light\ years$ from Earth. Show that this distance is approximately $8 \times 10^{16}\ m$.

(c) Hence determine the intensity of Sirius A as seen from Earth.

The luminosity of Sirius A is $1.0 \times 10^{28}\ W$.





## Standard Candles and Luminosity

### Exam Style Question 3



**(a) Explain the difference between the luminosity and the intensity of a star.**

- Luminosity is equal to power where as intensity is equal to power per unit area.
- Luminosity is measured at star where as intensity is measured at Earth.

**(b) Show that this distance is approximately $8 \times 10^{16}\ m$.**

Remember light years is a measure of distance and not time therefore you can use $s = \frac{d}{t}$ and rearrange for $d$.

Where $s = speed = speed\ of\ light$

$t = time = 1\ year$

$$1\ light\ year = (2.9979 \times 10^{8}\ m\ s^{-1})(365.25\ days)(24\ hours)(3600\ seconds)$$

$$\therefore 1\ light\ year = 9.461 \times 10^{15} m$$

$$\therefore 8.6\ light\ years = (8.6)(9.461 \times 10^{15}\ m)$$

$$8.6\ light\ years = 8.13646 \times 10^{16}\ m$$

**(c) Hence determine the intensity of Sirius A as seen from Earth.**

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

$$I = \frac{(1.0 \times 10^{28}\ W)}{4\pi(8.1 \times 10^{16}\ m)^2}$$

$$I = 1.2 \times 10^{-7}\ W\ m^{-2}$$

# Standard Candles and Luminosity

## Exam Style Question 4

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

(b) Describe how astronomers use standard candles.

(c) The equation $I = \frac{L}{4\pi D^2}$ can be used to determine the $luminosity\ L$ of a star of known $distance\ D$ and $intensity\ I$. Use this equation to show that the base units of intensity are $kg\ s^{-3}$ .

(d) Calculate the luminosity of a star which has a measured intensity of $1370\ W\ m^{-2}$ and which is known to be $1.49 \times 10^{11}\ m$ from Earth.



# Standard Candles and Luminosity

## Exam Style Question 4

**(a) State what is meant by a standard candle.**
A standard candle is a stellar object of known luminosity.

**(b) Describe how astronomers use standard candles.**
Standard candle's brightness on Earth is determined.
Then using the inverse square law $\left(I = \frac{L}{4\pi D^2}\right)$ calculate the distance to the standard candle.

**(c) The equation $I = \frac{L}{4\pi D^2}$ can be used to determine the $luminosity\ L$ of a star of known $distance\ D$ and $intensity\ I$. Use this equation to show that the base units of intensity are $kg\ s^{-3}$ .**

$$luminosity, L = power, P = \frac{Energy, E}{time, t}$$

$$L = \frac{E}{t} = \frac{J}{s} = J\ s^{-1} = (kg\ m^2\ s^{-2})s^{-1} = kg\ m^2\ s^{-3}$$

So the SI units for luminosity is:

$$L = kg\ m^2\ s^{-3}$$

Now use it in $I = \frac{L}{4\pi D^2}$:

$$I = \frac{kg\ m^2\ s^{-3}}{m^2} = kg\ s^{-3}$$

**(d) Calculate the luminosity of a star which has a measured intensity of $1370\ W\ m^{-2}$ and which is known to be $1.49 \times 10^{11}\ m$ from Earth.**

Use $I = \frac{L}{4\pi D^2}$ and rearrange for $L$:

$$L = I\ 4\pi D^2$$

$$L = (1370\ W\ m^{-2})(4\pi)(1.49 \times 10^{11}\ m)^2$$

$$L = 3.82 \times 10^{26}\ W$$

# The Universe

## Exam Style Question 5

(a) State the cosmological principle.

(b) State some of the properties of the microwave background radiation observed from the Earth. Discuss how the background microwave radiation is linked to the big bang model of the universe.

(c) Calculate the age of our universe in years based on a critical density of the universe of $9.7 \times 10^{-27}\ kg\ m^{-3}$.





# The Universe

## Exam Style Question 5

**(a) State the cosmological principle.**
The universe is homogeneous and isotropic on a large scale.

**(b) Discuss how the background microwave radiation is linked to the big bang model of the universe.**

- The Big Bang model predicts that loads of EM radiation was produced in the very early universe. This radiation should still be observed today because it has no where else to go. Because the universe has expanded, the wavelengths of this cosmic background radiation have been stretched and are now in the microwave region. Therefore we observe microwaves rather than short wavelength E.M. waves.
- The background microwave radiation is largely isotropic and homogeneous, which agrees with the cosmological principle.
- These microwaves correspond to a temperature of $2.7\ K$ and the temperature of the universe is $2.7\ K$.

**(c) Calculate the age of our universe in years based on a critical density of the universe of $9.7 \times 10^{-27}\ kg\ m^{-3}$.**

Use $\rho_c = \frac{3H^2}{8\pi G}$ and rearrange for $H$

$$H = \sqrt{\frac{\rho_c 8\pi G}{3}}$$

$$H = \sqrt{\frac{(9.7 \times 10^{-27}\ kg\ m^{-3})(8\pi)(6.67 \times 10^{-11}\ N\ m^2\ kg^{-2})}{3}}$$

$$H = 2.328 \ldots \times 10^{-18}\ s^{-1}$$

Now use $age = \frac{1}{H}$

$$age = \frac{1}{2.328 \ldots \times 10^{-18}\ s^{-1}}$$

$$age = 4.295 \ldots \times 10^{17}\ s$$

Calculate the age of the universe in years

$$age = \frac{4.295 \ldots \times 10^{17}\ s}{(365\ days)(24\ hours)(3600\ seconds)}$$

$$age = 1.4 \times 10^{10}\ years$$

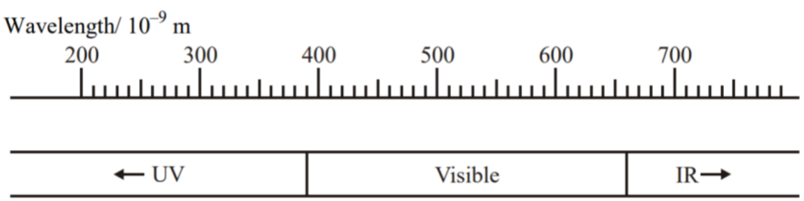
# Doppler Effect

## Exam Style Question 6

(a) State what is meant by the Doppler effect.

(b) Edwin Hubble reached a number of conclusions as a result of observations and measurements of red-shift. State two of these conclusions.

(c) The diagram gives values of wavelength for part of the electromagnetic spectrum.




A very hot distant galaxy emits violet light just at the edge of the visible spectrum. Estimate the maximum velocity the galaxy could have so that visible light could still be detected as it moves away from the Earth.

(d) The fate of the Universe is dependent on the average mass-energy density of the Universe. What is meant by the critical density of the Universe?



# Doppler Effect

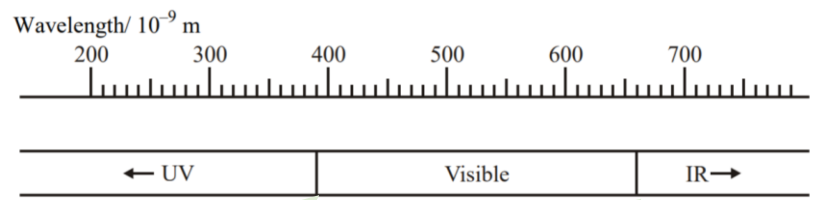
## Exam Style Question 6

**(a) State what is meant by the Doppler effect.**
Doppler effect is the change in frequency or wavelength due to relative motion between source and observer.

**(b) Edwin Hubble reached a number of conclusions as a result of observations and measurements of red-shift. State two of these conclusions.**

- Recession velocity is proportional to galaxy distance.
- Red shift is due to a galaxy moving away from Earth.
- Deduced that the universe is expanding.

**(c) Estimate the maximum velocity the galaxy could have so that visible light could still be detected as it moves away from the Earth.**




$390 \times 10^{-9}\ m$ is the minimum wavelength where visible light can still be observed.

$660 \times 10^{-9}\ m$ is the maximum wavelength where a very hot distant galaxy emits violet light just at the edge of the visible spectrum that is still observable in visible light.

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

$$\frac{(660 \times 10^{-9}\ m) - (390 \times 10^{-9}\ m)}{390 \times 10^{-9}\ m} = \frac{v}{(3 \times 10^{8}\ m\ s^{-1})}$$

$$v = \frac{(660 \times 10^{-9}\ m) - (390 \times 10^{-9}\ m)}{390 \times 10^{-9}\ m} \times (3 \times 10^{8}\ m\ s^{-1})$$

$$v = 2.1 \times 10^{8}\ m\ s^{-1}$$

**(d) What is meant by the critical density of the Universe?**
Density is large enough to prevent Universe expanding for ever but not too big to cause a collapse.

# The Universe

## Exam Style Question 7

(a) State Hubble's law.

(b) The redshift of a specific spectral line in the spectrum of a galaxy can be used to determine its recession velocity $v$. The fractional change $z$ in the wavelength of a spectral line is given by the equation

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

where $c$ is the speed of light in a vacuum.

The table of Fig. 11.1 shows data for some of our closest galaxies. The distance of the galaxy from the Earth is $d$.

| Galaxy | $z$ / $10^{-3}$ | $v$ / $10^3$ m s$^{-1}$ | $d$ / $10^{23}$ m |
|---|---|---|---|
| A | 1.12 | 336 | 1.50 |
| B | 1.61 | 483 | 2.14 |
| C | 1.85 | 555 | 2.46 |
| D | 2.26 | 678 | 3.00 |
| Messier 109 | 3.38 | | |

**Fig. 11.1**

(i) Complete the table by determining $v$ and $d$ for the galaxy Messier 109.

(ii) Fig. 11.2 shows the data for the first four galaxies plotted on a $v$ against $d$ graph.

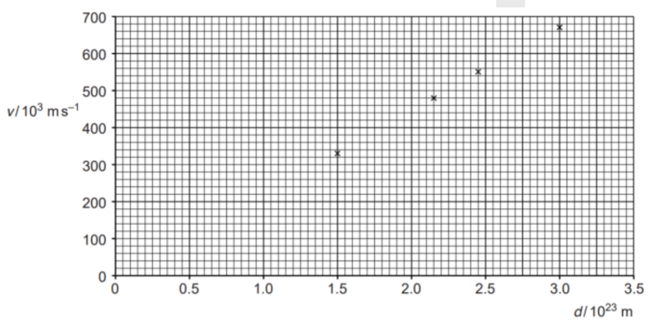



**Fig. 11.2**

Use Fig. 11.2 to determine the age of the Universe in years.
$1\,y = 3.16 \times 10^7\,s$

(c) One piece of observational evidence for the big bang is that galaxies are receding from each other. Explain what is meant by the big bang and suggest two other observations that support the big bang model of the Universe.



# The Universe

## Exam Style Question 7

**(a)State Hubble's law.**
Recessional speed (or the velocity of galaxy) is proportional to its distance from us.

**(b) (i) Complete the table by determining $v$ and $d$ for the galaxy Messier 109.**

| Galaxy | $z$ / $10^{-3}$ | $v$ / $10^3$ m s$^{-1}$ | $d$ / $10^{23}$ m |
|---|---|---|---|
| A | 1.12 | 336 | 1.50 |
| B | 1.61 | 483 | 2.14 |
| C | 1.85 | 555 | 2.46 |
| D | 2.26 | 678 | 3.00 |
| Messier 109 | 3.38 | **1014** | **4.49** |

**Fig. 11.1**

**1) Determine $v$ for Messier 109:**
Use $z = \frac{v}{c}$ and rearrange for $v$:

$$v = zc = (3.38 \times 10^{-3})(3 \times 10^8) = 1014000 = 1014 \times 10^3\ m\ s^{-1}$$

**2) Determine $d$ for Messier 109:**
We know from Hubble's law that $v \propto d$ so we can use basic math to figure out $d$ for Messier 109:

$$v = kd$$

$$k = \frac{v}{d} = \frac{678}{3} = 226$$

$$\therefore v = 226d$$

Now we can figure out $d$:

$$d = \frac{v}{226} = \frac{1014}{226} = 4.49$$

# The Universe

## Exam Style Question 7

(a) State Hubble's law.

(b) The redshift of a specific spectral line in the spectrum of a galaxy can be used to determine its recession velocity $v$. The fractional change $z$ in the wavelength of a spectral line is given by the equation

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

where $c$ is the speed of light in a vacuum.

The table of Fig. 11.1 shows data for some of our closest galaxies. The distance of the galaxy from the Earth is $d$.

| Galaxy | $z$ / $10^{-3}$ | $v$ / $10^3$ m s$^{-1}$ | $d$ / $10^{23}$ m |
|---|---|---|---|
| A | 1.12 | 336 | 1.50 |
| B | 1.61 | 483 | 2.14 |
| C | 1.85 | 555 | 2.46 |
| D | 2.26 | 678 | 3.00 |
| Messier 109 | 3.38 | | |

Fig. 11.1

(i) Complete the table by determining $v$ and $d$ for the galaxy Messier 109.

(ii) Fig. 11.2 shows the data for the first four galaxies plotted on a $v$ against $d$ graph.

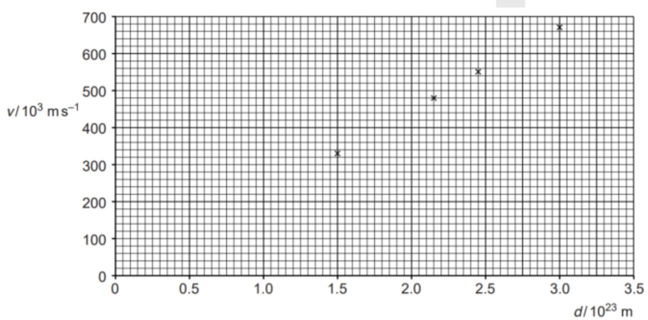



Fig. 11.2

Use Fig. 11.2 to determine the age of the Universe in years.
$1\ y = 3.16 \times 10^7\ s$

(c) One piece of observational evidence for the big bang is that galaxies are receding from each other. Explain what is meant by the big bang and suggest two other observations that support the big bang model of the Universe.



# The Universe

## Exam Style Question 7

**(b) (ii) Use Fig. 11.2 to determine the age of the Universe in years.**
$1\ y = 3.16 \times 10^7\ s.$

Recall $v = Hd$ therefore the $gradient = Hubble\ Constant, H$:

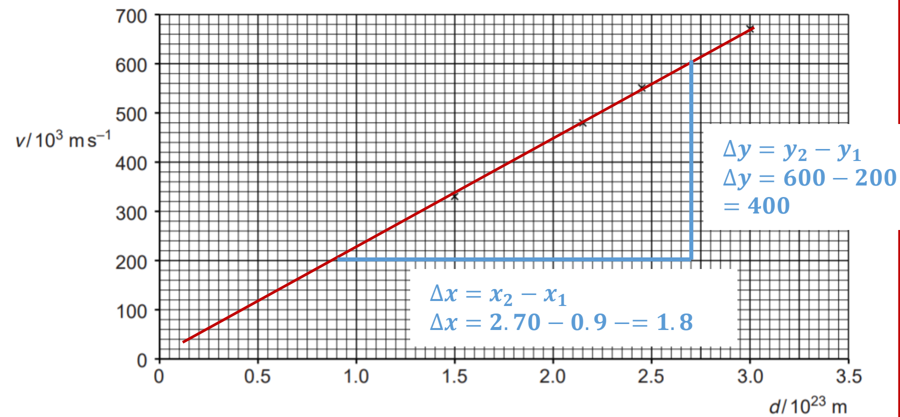



Fig. 11.2

$$gradient = \frac{\Delta y}{\Delta x} = \frac{400 \times 10^3\ m\ s^{-1}}{1.8 \times 10^{23}\ m} = 2.22 \ldots \times 10^{-18}\ s^{-1}$$

$$\therefore gradient = Hubble\ constant, H = 2.22 \ldots \times 10^{-18}\ s^{-1}$$

Now use $age\ of\ Universe = \frac{1}{H}$

$$age = \frac{1}{2.22 \ldots \times 10^{-18}\ s^{-1}} = 4.5 \times 10^{17}\ seconds$$

Now convert it to years:

$$age = \frac{4.5 \times 10^{17}\ seconds}{(365\ days)(24\ hours)(3600\ seconds)} = 1.42 \times 10^{10}\ years$$

# The Universe

## Exam Style Question 7

(a) State Hubble's law.

(b) The redshift of a specific spectral line in the spectrum of a galaxy can be used to determine its recession velocity $v$. The fractional change $z$ in the wavelength of a spectral line is given by the equation

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

where $c$ is the speed of light in a vacuum.

The table of Fig. 11.1 shows data for some of our closest galaxies. The distance of the galaxy from the Earth is $d$.

| Galaxy | $z$ / $10^{-3}$ | $v$ / $10^3$ m s$^{-1}$ | $d$ / $10^{23}$ m |
|---|---|---|---|
| A | 1.12 | 336 | 1.50 |
| B | 1.61 | 483 | 2.14 |
| C | 1.85 | 555 | 2.46 |
| D | 2.26 | 678 | 3.00 |
| Messier 109 | 3.38 | | |

Fig. 11.1

(i) Complete the table by determining $v$ and $d$ for the galaxy Messier 109.

(ii) Fig. 11.2 shows the data for the first four galaxies plotted on a $v$ against $d$ graph.

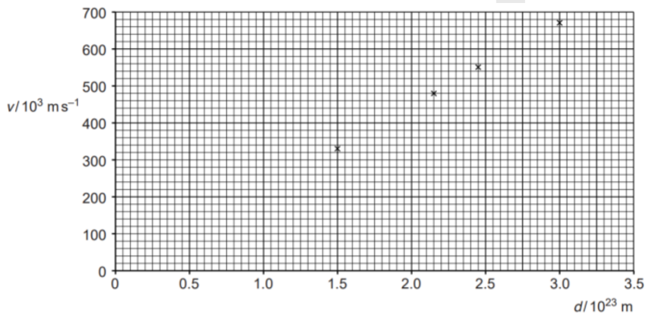



Fig. 11.2

Use Fig. 11.2 to determine the age of the Universe in years.
$1\ y = 3.16 \times 10^7\ s$

(c) One piece of observational evidence for the big bang is that galaxies are receding from each other. Explain what is meant by the big bang and suggest two other observations that support the big bang model of the Universe.

tutorpacks.co.uk

# The Universe

## Exam Style Question 7

**(c) Explain what is meant by the big bang and suggest two other observations that support the big bang model of the Universe.**

Big bang: It is how we explain the creation of the Universe. It is the idea that the universe began as just a single point and then expanded.

Evidence:
1) The universe is saturated with cosmic microwave background radiation (CMBR).
2) The redshift of distant galaxies means that the Universe is probably expanding. If galaxies have been moving apart then at some stage they must have been closer together.
3) Tiny variation in background temperature.

tutorpacks.co.uk

# The Universe

## Exam Style Question 8

(1) State the Cosmological Principle.

(2) Explain why our understanding of the very earliest moments of the Universe is unreliable.

(3) Describe and explain two pieces of evidence which suggest that the Universe did in fact begin with a big bang.





# The Universe

## Exam Style Question 8

**(1) State the Cosmological Principle.**

- Universe is isotropic (same in all directions).
- The universe is homogeneous (even distributed).

**(2) Explain why our understanding of the very earliest moments of the Universe is unreliable.**

- No experimental evidence and no physical evidence.
- State of matter unknown and laws of physics unknown.
- Energies unreproducible as very high temperatures are needed.

**(3) Describe and explain two pieces of evidence which suggest that the Universe did in fact begin with a big bang.**

- Star-light shows red-shift showing that the stars are receding from Earth.
- Recessional velocity is proportional to distance.
- Cosmological microwave background radiation (CMBR).
- Uniform intensity in all direction.

# The Fate of the Universe

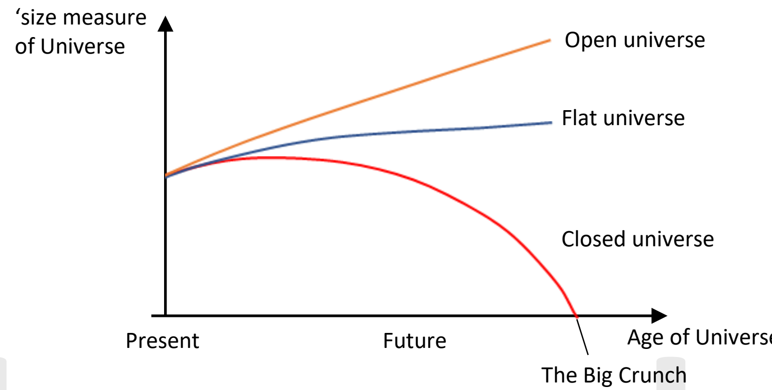
## Exam Style Question 9

The future of the Universe may be open, closed or flat. Explain the meaning of the terms in italics, using a graph to illustrate your answer.



# The Fate of the Universe

## Exam Style Question 9


- **Open Universe theory:** Density of universe < critical density
Theory suggests that the universe will expand forever.

- **Flat Universe Theory:** Density of universe = critical density
Theory suggests that the universe will expand towards a finite limit.

- **Closed Universe Theory:** Density of universe > critical density
Theory suggests the universe will eventually stop expanding and then contract leading to the big crunch.

# The Fate of the Universe

## Exam Style Question 10

(a) Explain what is meant by the critical density of the universe.

(b) Cosmologists have determined the Hubble constant to be $65\ km\ s^{-1}\ Mpc^{-1}$. Calculate the Hubble constant in $s^{-1}$ and hence determine the critical density of the universe.
$1\ pc = 3.1 \times 10^{16}\ m$

(c) (i) Explain the terms open, closed and flat when describing the possible evolution of the universe.

(c) (ii) Suggest a reason why it is difficult to predict the future of the universe.

(d) The precise amount of dark matter in the Universe is unknown. Explain how the presence of dark matter affects the average density of the Universe and thus has a role in determining the ultimate fate of the Universe itself.



# The Fate of the Universe

## Exam Style Question 10

**(a)Explain what is meant by the critical density of the universe.**
The critical density is the density for which the universe will expand towards a finite limit.

**(b) Calculate the Hubble constant in $s^{-1}$ and hence determine the critical density of the universe.**
$1\ pc = 3.1 \times 10^{16}\ m$

1) Calculate the Hubble Constant in $s^{-1}$

$$1\ kms^{-1} = 10^3\ ms^{-1}$$
$$1Mpc = 10^6 pc \times 3.086 \times 10^{16} m\ pc^{-1} = 3.086 \times 10^{22} m$$
$$\therefore H = 65 kms^{-1} Mpc^{-1} = \frac{65 \times 10^3 ms^{-1}}{3.086 \times 10^{22} m} = 2.1 \times 10^{-18} s^{-1}$$

So:

$$H = 70\ kms^{-1} Mpc^{-1} = 2.1 \times 10^{-18} s^{-1}$$

2) Calculate the critical density:

$$\rho_c = \frac{3H^2}{8\pi G} = \frac{3 \times (2.1 \times 10^{-18})^2}{8\pi \times 6.67 \times 10^{-11}} = 7.9 \times 10^{-27} kgm^{-3}$$

**(c) (i) Explain the terms open, closed and flat when describing the possible evolution of the universe.**

- **Open Universe theory:** Density of universe < critical density
Theory suggests that the universe will expand forever.
- **Flat Universe Theory:** Density of universe = critical density
Theory suggests that the universe will expand towards a finite limit
- **Closed Universe Theory:** Density of universe > critical density
Theory suggests the universe will eventually stop expanding and then contract leading to the big crunch.

**(c) (ii) Suggest a reason why it is difficult to predict the future of the universe.**
Hubble constant is not known accurately and due to the existence of dark matter, black holes, neutrinos and dark energy.

**(d) Explain how the presence of dark matter affects the average density of the Universe and thus has a role in determining the ultimate fate of the Universe itself.**
The critical density is condition for flat universe. Dark matter increases density of the Universe. As the density is greater than critical density the Universe will contract and lead to a big crunch.

**Please see '16.3.1 Cosmology notes' pack for revision notes.**



**For more revision notes, tutorials and worked examples please visit www.tutorpacks.co.uk.**



tutorpacks.co.uk