Dynamics and Space

Unit 1

Part 2

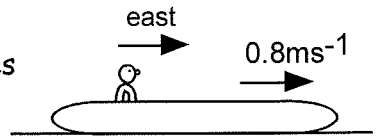
Special Relativity
Doppler
Hubble
Dark Matter
Dark Energy
&
The Big Bang

Relative Motion.

(1) Bob and Sue walk along a road, side by side both at a speed of $2ms^{-1}$

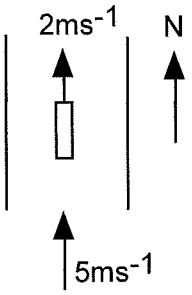
(a) What is their speed relative to the road?
(b) What is Bob's speed relative to Sue?
(c) Tim walks by in the same direction at $3ms^{-1}$. What is his speed relative to Bob
(d) Lynn walks past in the opposite direction at $2ms^{-1}$. What is her speed relative to Sue?

(2) In an airport people use a moving walkway. The walkway moves at a constant velocity of $0.8ms^{-1}$ due East. Determine the velocity of the following people relative to the ground:



(a) A woman standing stationary on the walkway
(b) A man walking east at $2ms^{-1}$
(c) A boy running west at $3ms^{-1}$

(3) A River flows North at $5ms^{-1}$ relative to the shore. A boat travels North at $2ms^{-1}$ relative to the river.



(a) What is the boats speed relative to the shore?
(b) A 2nd boat is travelling at $3ms^{-1}$ south relative to the river. what is its speed relative to the shore?
(c) What is the speed of the 2nd boat relative to the first?

(4) Can we say that something has an absolute velocity?

(5) At the end of the 19th century it was found that the speed of light was constant, no matter how the observer is travelling relative to the light source. As a consequence, state two quantities which Einstein knew needed to change to accommodate this constant light speed.

(6) A spacecraft moving at $1.2x10^8ms^{-1}$ fires a pulse of light. The light passes another spacecraft travelling in the opposite direction at $2x10^8ms^{-1}$. What speed does someone on this spacecraft measure the speed of the light to be?

(7) A scientist in a spacecraft travelling at $2x10^8ms^{-1}$ measures the speed of light at $3x10^8ms^{-1}$. An observer on the Earth views the same experiment. What speed does he measure for the speed of light?

(8) A spacecraft travels at a constant speed of $7.5x10^7ms^{-1}$. It emits a pulse of light when it is $3x10^{10}m$ from the Earth as measured by someone on Earth. Calculate the time it takes the pulse to reach the Earth according to a clock on Earth if the craft was

(a) Moving towards Earth (100s)
(b) Moving away from the Earth (100s)

Special Theory of Relativity

(9) The special theory of relativity is called special because it deals with objects moving with a special type of motion. What is special about this motion?

(10) Einstein's Special theory of Relativity is based on these 2 postulates. State missing words
The laws of physics are the _____ for all objects moving with a constant _____.
The speed of light is always c_____ no matter the speed of the observer or source.

(11) If two observers are moving relative to each other they are in different _____ of reference. State the missing word.

(12) Two people sit side by side on a bench. Are they in the same or different frames of reference?

(13) Ten people sit on a bus travelling at 30mph. Are they in the same or different frames of reference?

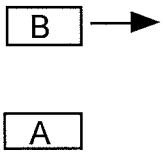
(14) A man in a car passes a stationary pedestrian at $12ms^{-1}$. Are they in the same or different frames of reference?

(15) A seated person on a bus sees a person walk down the isle to the front of the bus. Inside the bus are they in the same or different frames of reference?

(16) We denote the speed of light with the letter c. Convert the following terms into a speed

(a) 0.1c (b) 0.6c

(17) Observer A believes he is on a stationary spacecraft. Observer B moves past A to the right in a spacecraft travelling at 0.2c.



(a) Why are A and B in different frames of reference?
(b) A states that she is stationary and B moves to the right at 0.2c. Can observer B state that SHE is at rest and observer A is moving past her at 0.2c to the left.
(c) So in absolute term can we say for certain who is moving?

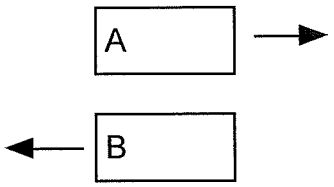
(18) Two observers are moving relative to each other. Each looks at their own watch. This time is called the _____ time. Then each looks at the other and each will measure the others watch moving _____. This is called the _____ time.

(19) When two observers move relative to each other, each observer will measure time in their own frame of reference as the _____ time. They will measure time in the OTHER frame as the _____time. This dilated time is _____ than the real time.

(20) An astronaut X is on a space craft moving at $2x10^8ms^{-1}$ relative to the Earth. He measures the time to make himself a cup of tea as 2mins. A person Y on Earth also measures the time it takes the astronaut to make the cup of tea

(a) Who measures the real time?
(b) Who measures the dilated time?

(21) Two people A and B moving relative to one another measure the time they take to make their own sandwich as 5mins. Person A looks at B and measures the dilated time for person B to make the sandwich as 6mins. What time does person B measure for person A to make his sandwich.



(22) In the formula which time is always the longest t' or t?

(23) On a spacecraft travelling past the Earth at $1.8x10^8ms^{-1}$an astronaut records a time for him to do an exercise as 15mins. A person on Earth measures the time with his own watch

(a) Is the 15mins the real or dilated time?
(b) Calculate the time the person on Earth records. (18.8min)

(24) The lifetime of star measured by an observer at rest relative to the star is 10billion years. A stationary observer B on earth views the star as moving away from Earth at $2.4x10^8ms^{-1}$.

(a) Why do we know that the 10billion years is the real time?
(b) Why is the time measured by a stationary person on Earth the dilated time?
(c) Calculate the lifetime of the star according to the person on Earth.
(17.1billon years)

(25) An astronaut travels past the Earth at $2.5x10^8ms^{-1}$. Inside the spacecraft he measures the time he takes to do an experiment as 2.6hrs.

(a) Is the 2.6hrs the dilated or real time?
(b) Calculate the time a stationary observer on Earth would measure for the astronaut to do the experiment. (4.7hrs)

(26) An athlete completes an 800m race in 46s as measured in the stadium on Earth
An observer in a spacecraft travels by the Earth at 0.82c. What time does the person on the spacecraft measure for completion of the 800m. (80.4s)

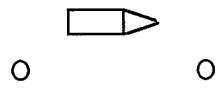
(27) An observer moving past the Earth at $8.2x10^7ms^{-1}$ looks out the window and measures the time for a hurricane on Earth to pass over an island as 7hrs.

(a) Is the 7hrs the dilated or real time?
(b) How long did the hurricane take to pass over the island as measured by someone on Earth? (6.7hrs)

(28) An stationary observer on earth views an atom travelling at $2.6 \times 10^8 ms^{-1}$. She measure the time for a radioactive decay as $4 \times 10^{-4} s$. Calculate the time for the decay if the atom was at rest relative to the observer. $(2.0 \times 10^{-4} s)$

(29) The light from a lighthouse sweeps a circle every 10s as measured on earth. An astronaut in a spacecraft travelling towards the Earth measures the time as 15s. What was the speed of the spacecraft? $(2.2 \times 10^8 ms^{-1})$

(30) A rocket passes two beacons that are at rest relative to the rocket and osbserver on earth. An astronaut in the rocket measures the time it takes the rocket to pass as 10s.
An observer on Earth measures the time as 40s. What is the speed of the spacecraft relative to the Earth $(2.9 \times 10^8 ms^{-1})$



(31) A spacecraft travels to a distant planet with a constant speed. A clock on board the craft measures the time for the journey as 1 year while an observer on Earth measures the time as 2 years. What is the speed of the spacecraft $(2.6 \times 10^8 ms^{-1})$

(32) By looking at the time dilation equation state what happens to the dilated time if the speed of the object equals the speed of light? Is this possible?

OE (33) A physics student notices that the digital clock in the family car loses one minute every year. He states that "This must be due to time dilation because the car is driven very fast on the motorway for much of the time"

Use your knwledge of physics o comment on this statement

Length Contraction

(34) When you are in the same frame of reference as the object you are measuring you will be measuring the _____ length of the object. What is the missing word?

(35) When two observers move relative to one another each will view the others length as being _____ than the real length. What is the missing word?

(36) If you are in the same frame of reference as the thing you are measuring are you measuring the real or contracted length?

(37) A rocket has a length of 20m as measured by an observer when at rest on Earth. The observer watches the rocket move past the Earth at a speed of $1.8 \times 10^8 ms^{-1}$.
Calculate the length of the rocket measured by someone on the Earth. (16m)

(38) An astronaut in a spacecraft travelling at $2.7 \times 108 ms^{-1}$ relative to the Earth measures the length of a table in the spacecraft as 3.7m. What length would someone on Earth measure? (1.6m)

(39) A spacecraft travels towards the Earth at 0.8c. A person on Earth measures the length of the spacecraft as 160m. The spacecraft lands.

(a) What length would he measure when at rest on the Earth. (267m)
(b) While travelling at 0.8c what length would someone on board measure?

(40) A metre stick is of length 1m when at rest on Earth. An astronaut passing the Earth measures the length of the metre stick as 0.5m. What is the speed of the astronaut relative to the Earth. ($2.6 \times 10^8 ms^{-1}$)

Miscellaneous Relativity Questions

(41) A pi meson has a lifetime of 2.6×10^{-8}s when at rest. A pi meson moves at 0.99c towards Earth.

(a) What is the lifetime of a pi meson as measured from Earth. (1.84×10^{-7}s)
(b) Calculate the distance the pi meson travels as measured by someone on Earth. (54.6m)

(42) A spacecraft is travelling at a constant 0.95c. The spacecraft travels at this speed for 1 year as measured by a person on Earth.

(a) Is this time the dilated or real time?
(b) Calculate the time measured by someone on the craft. (0.31years)
(c) Calculate the distance travelled as measured by someone on the craft (2.8×10^{15}m)

(43) A spacecraft travelling at $2.4 \times 10^8 ms^{-1}$ takes 5×10^{-5}s to pass a small marker on Earth as measured by an astronaut on the spacecraft

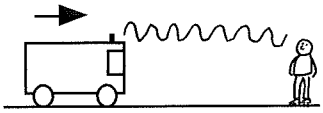
(a) What length does the astronaut calculate for the spacecraft? (120m)
(b) What length does a person on Earth calculate? (72m)

(44) A meson 10km above the Earth travels at 0.999c towards the Earth

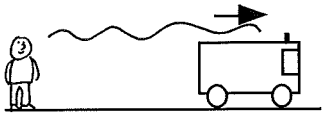
(a) Calculate the distance, according to the meson, it travels before hitting the Earth (447m)
(b) Calculate the time, according to the meson, it takes to hit Earth (1.49×10^{-6}s)
(c) Calculate the time a meson exists for according to a person on Earth. (3.33×10^{-5}s)

Doppler Effect and the Expanding Universe

(45) State the missing letters A to G.



An ambulance moves towards an observer. The wavelength of the sound __A__ so __B__ waves enter your ear each second. So the observer hears an __C__ in frequency



When the ambulance moves away from the observer the wavelength __D__ so __E__ waves enter the observers ear each second. So the observer hears a __F__ frequency

This is known as the __G__ effect.

(46) You are standing stationary at a railway station. A train travels towards you.

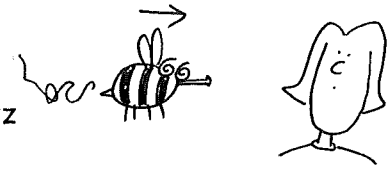
(a) Does the wavelength of the sound increase or decrease as it travels towards you?
(b) Does the frequency of the sound increase or decrease as it travels towards you?

(47) A police car creates a noise with a frequency of 500Hz. If the car drives towards you at a speed of $30ms^{-1}$ calculate the frequency of the sound you would hear.

(548Hz)

(48) An ambulance's siren creates a noise of frequency 280Hz. The ambulance moves away from the observer at a speed of $24ms^{-1}$. Calculate the frequency of the sound that the observer hears. (262Hz)

(49) A bee emits a buzz with a frequency of 398Hz. The bee flies towards a girl at $4ms^{-1}$. What frequency does she hear the buzz (403Hz)



(50) The frequency of the car's horn when stationary is 450Hz. A man stands at the side of a road and hears the horn of the approaching car. If he hears the frequency as 470Hz what is the speed of the car? ($14.5ms^{-1}$)

(51) A motor boat's horn emits a sound with a frequency of 510Hz. The motor boat travels away from the island at a constant speed and you hear the frequency as 480Hz. What is the speed of the receding motor boat? (21.3ms-1)

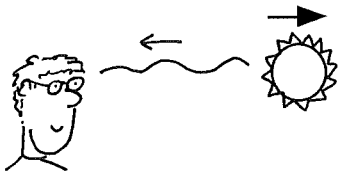
(52) An ambulance travels towards you at a **constant speed** of $20ms^{-1}$. At a distance of 50m from you the frequency you hear is 400Hz.

(a) What is the frequency you hear at (a) 25m and (b) 10m?
(b) If the ambulance accelerated towards you what would happen to the frequency you hear?

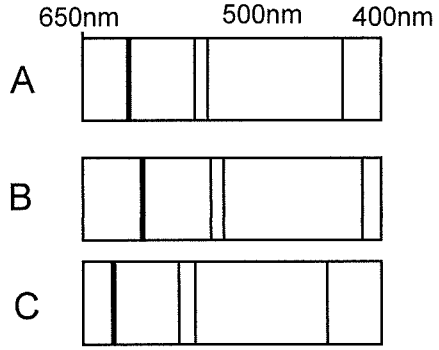
(53) A sound source moves away from a stationary observer. He hears the frequency as 10% lower than the frequency he would hear if the source was stationary. Calculate the speed of the source. (hint choose a freq) ($37.8 ms^{-1}$)

(54) On the planet Grun a stationary poobah emits a sound of frequency 1100Hz. The poobah moves towards a stationary glonk at $10 ms^{-1}$. The stationary glonk hears the frequency of 1200Hz. calculate the speed of sound on planet Grun. ($120 ms^{-1}$)

(55) When a star moves away from an observer on Earth the wavelength of the light __A__ so the light moves towards the longer _____B_____ red end of the spectrum. We say the light has _____C_____ shifted. Sate missing words.



(56) Diagram A show the line emission spectrum from a stationary sample of hot hydrogen gas measured on Earth..Diagram B and C show the hydrogen line emission spectra as observed from two distant stars.



(a) Are the lines in spectrum B shifted towards the blue or red end of the spectrum?
(a) What does this tell you about the motion of star B relative to the Earth?
(a) Are the lines in spectrum C shifted towards the blue or red end of the spectrum?
(a) What does this tell you about the motion of star C relative to the Earth?

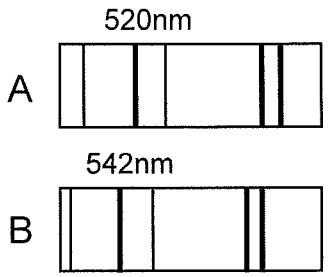
(57) (a) What do astronomers notice about the shift in spectral lines on the spectra of the light coming from most of the stars outside our galaxy?
(b) What does this tell you about the universe?
(c) Are stars actually moving apart <u>through space</u> or is it the space that is expanding?
(d) Why can't we use the Doppler formula to calculate the speed of stars?

(58) Why are the stars inside our galaxy or the tables in your classroom not flying apart?

(59) A spectral line on the hydrogen spectrum as viewed from a stationary source on Earth is 434nm. When the same line is viewed in the hydrogen spectra from a distant star its wavelength is 466nm

(a) Which wavelength 434 or 466nm is denoted as λ_{rest}
(b) What does this observed wavelength tell you about the distant star?
(c) Calculate the red shift z. (7.37×10^{-2})
(d) Therefore calculate the recessional velocity of the star ($2.21 \times 10^{7} ms^{-1}$)

(60) Diagram A shows the line spectra of a gas as viewed from a stationary source on Earth. Diagram B shows the line spectra from the same gas as viewed from a distant star. The position and wavelength of the same line on both spectra is shown



(a) Calculate the red shift z (0.042)

(b) Therefore calculate the recessional velocity of the star. ($1.26 \times 10^7 ms^{-1}$)

(61) The same line (520nm) is viewed from a star in the Andromeda galaxy. The wavelength measured was 514nm. What does this tell you about the star in Andromeda?

(62) The wavelength of a line in the calcium emission spectrum is 393.3nm when measured in a laboratory on Earth. The wavelength of the same line emitted from a distant galaxy is 396.2nm.

(a) Calculate the red shift z (7.4×10^{-3})

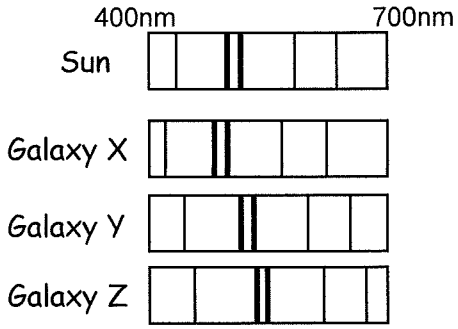
(b) Therefore calculate the recessional velocity of the galaxy. ($2.2 \times 106 ms^{-1}$)

(63) Galaxy X shows a red shift of 0.06. Galaxy Y shows a red shift of 0.09. Which one is moving away from the Earth the faster?

(64) An astronomer takes pictures of the spectrum of calcium gas from the sun and 3 different galaxies

(a) Which galaxy is moving towards the Earth?

(b) Of the other two which one is moving away from the Earth at the highest velocity

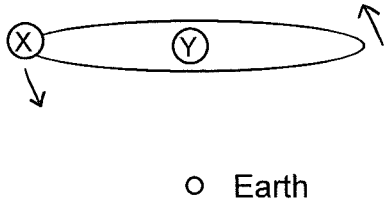


(65) A distant star is travelling away from Earth at a speed of 2.4×10^7ms-1.

(a) Calculate the red shift z. (8×10^{-2})

(b) A line in the hydrogen spectrum has a wavelength of 443nm when viewed from a stationary source on Earth. Calculate the wavelength of this line when observed in the hydrogen spectrum from the distant star. (478nm)

(66) Sometimes two stars rotate round each other in a binary star system as shown.
State and explain how the spectra of star X viewed from Earth would vary as it orbits the other star?



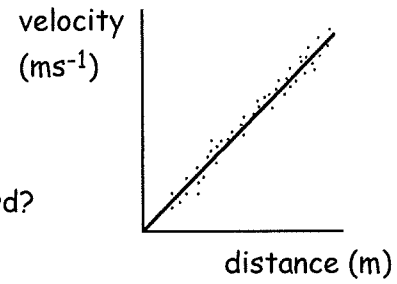
Hubble and the Expansion of Universe

(67) Convert the following into metres

(a) 18 light seconds (b) 8 light minutes

(c) 6.4 light years (d) 200million light years

(68) Hubble drew a graph of distance of galaxy from Earth vs its recessional velocity as shown.



(a) Hubble found that the velocity of a receding galaxy is_____ proportional to its distance from the Earth. What is the missing word?

(b) A galaxy is 35million light years away and receding at 800,000ms^{-1}. What speed would a galaxy a distance of 70million light be receding at?

(c) So Hubble found that not only is the universe expanding, its expansion is a_____. What is the missing word?

(d) Why is the Hubble constant an approximation?

(e) What estimate does Hubble's Law give to the age of the universe?

(69) A galaxy is a distance of $2.1x10^{22}$m from Earth. What is its velocity? ($48,300ms^{-1}$)

(70) A galaxy is receding from Earth at a velocity of $1.1x10^{7}ms^{-1}$. What is the distance of this galaxy from Earth ($4.8x10^{24}$m)

(71) The Galaxy Corona Borealis is 1000million light years from Earth. Use Hubble's law to determine its velocity. (NB turn light years into m) ($2..2x10^{7}ms^{-1}$)

(72) The velocity of a distant galaxy is $4.2x10^{6}ms^{-1}$. Use Hubble's law to determine its distance from Earth? ($1.8x10^{24}$m)

(73) A galaxy is moving away from earth at 0.074c. Calculate the distance this galaxy is from Earth. ($9.65x10^{24}$m)

(74) A galaxy shows a redshift in a spectrum of $3.1x10^{-2}$. Find

(a) Its velocity as it moves away from Earth ($9.3x10^{6}ms^{-1}$)

(b) The distance the galaxy is from Earth ($4.0x10^{24}$m)

(75) The wavelength of a spectral line viewed from a distant star is 620nm. On Earth this same line viewed from a stationary source is 570nm.

(a) Calculate the red shift. ($8.8x10^{-2}$)

(a) Calculate the speed the star is moving away from Earth. ($2.6x10^{7}$m)

(b) Use Hubbles law to calculate the distance the star is from Earth ($1.1x10^{25}$m)

(76) A galaxy is moving away from Earth at $5.8 \times 10^7 ms^{-1}$. A line in a spectra viewed on Earth has a wavelength of 476nm. What would be the wavelength of the same line viewed from the galaxy be? (568nm)

(77) A galaxy is 780million light years from Earth. A line in a spectra taken from viewing the hot gas on Earth is 634nm. What is the wavelength of this line when the spectra is viewed from the distant star (670nm)

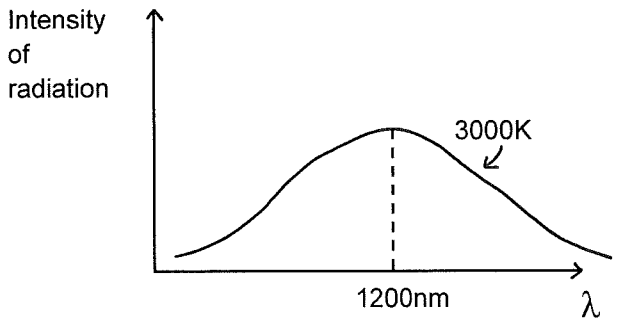
The Big Bang Theory

(78) Write down the missing words from this paragraph on the beginnings of the universe.

The Big Band is a theory which explains the o_____of the universe. Approximately _____ billion years ago all time, space and energy was squeezed into a space of zero volume called a s_____. Then in an extremely hot "explosion" the space started to e_____ outwards very rapidly. As the universe expanded it cooled and energy transformed into m_____, eventually forming a_____ then the elements h_____ and h_____. These gases were pulled together by g_____ to form s_____. When huge dying stars collapsed then exploded as supernovas all the other e_____ were made.

(79) (a) Why is the red shift seen in the spectra from distant stars evidence for the big bang?

(b) The following shows the black body curve taken from the recombination event 380,000years after the big bang, when light was first released into the universe in all directions.



(c) What was the temperature of the universe at this point?

(d) What was the peak wavelength of light being emitted at this time?

(e) In which family of electromagnetic radiation is this wavelength found

(f) Why did the wavelength of this light increase over the billions of years of the existence of the universe

(g) What electromagnetic family would you find the the peak wavelength of this back ground radiation NOW if the universe had been expanding for 13.8billion years?

(h) When was this cosmic microwave background radiation discovered?

(80) We know that helium is created inside stars.

(a) When we view the universe is there more or less helium than we would expect?
(b) So when do physisicts think all this extra helium was produced?
(c) Why was this the only other time when helium could possibly be made?

Dark Matter and Dark Energy

(81) The stars in our galaxy orbit the centre of the galaxy at a high speed.

(a) Which force is required to stop all these stars whizzing off into space?
(b) What causes this force?
(c) Is there enough mass in our galaxy to create this gravitational force?
(d) So what mass have we "invented" to make up for this shortfall?

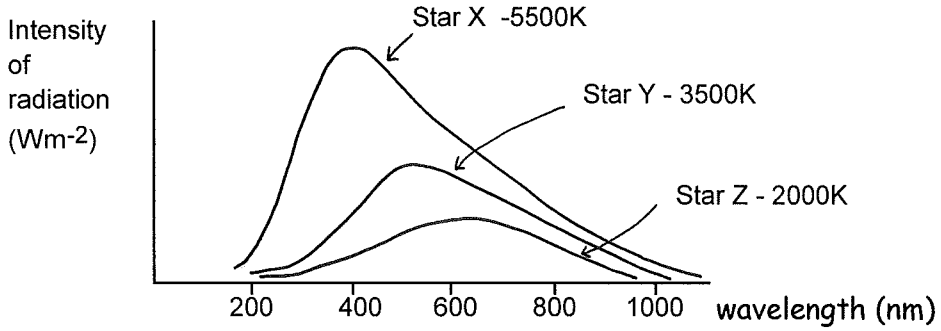
(82) Gravity should be attracting the galaxies back together and putting the brakes on the expansion of the universe, but it is not. Scientists believe there is a kind of anti gravity out there in the darkness of space supplying the energy to keep the universe expanding. What do we call this energy?

(83) Sketch a pie chart showing the approximate composition of the universe in terms of visible matter, dark matter and dark energy.

Star Temperature

(84) (a) What is a black body?
(b) Does a star act like a black body?

(85) Here are the black body curves of 3 stars



(a) Which star emits the greatest intensity of radiation per m^2
(b) What would this star look like - orangy, yellowy or bluish white?
(c) Account for this colour.
(d) What would be the colour star Z?
(e) What would be the colour of star Y?
(f) What is the relationship between the temperature of a star and the peak wavelength emitted?
(g) Another star emits light with a peak wavelength of 360nm. Estimate the temperature of this star.

OE (86) A student reads in a magazine the statement "In the beginning there was nothing and it exploded into the universe"

Use your understanding of Physics to comment on this statement.

Graphical Skills

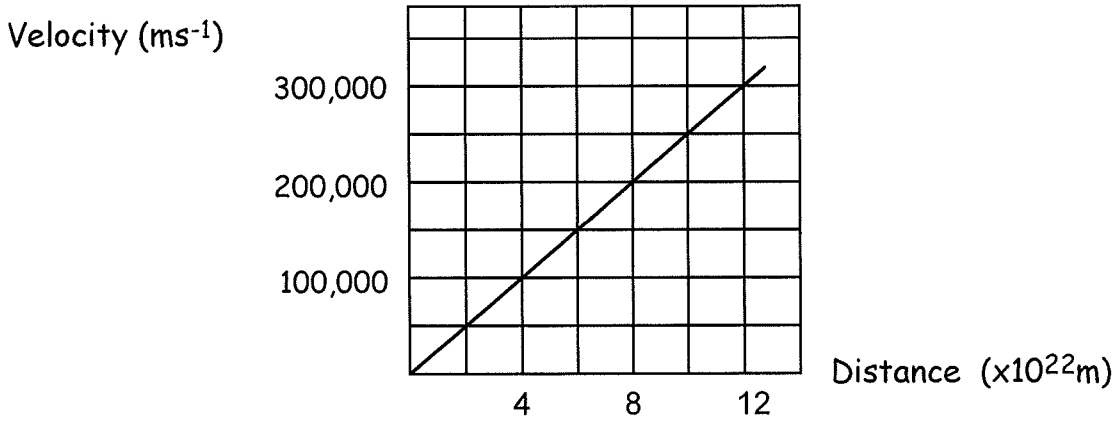
(87) A table relating two quantities A and B is drawn. If A/B from each row is a constant what can you say about the relationship between A and B
If A x B = a constant what can you say about the relationship between A and B

(88) WilhelmWien looked at the relationship between the peak wavelength emitted by a star and its temperature. He drew the following table

Temperature (K)	Peak Wavelength (nm)
3000	970
4000	730
5000	580
6000	480

(a) Show that the temperature is inversely proportional to the peak wavelength emitted.
(b) State a formula relating peak wavelength (λ_{max}) , Temp (T) and constant (b)
(c) **Sketch** the graph of Temperature vs peak wavelength.

(89) A student uses data he measures from stars in a group of galaxies cluster to draw a graph showing the distance of the galaxies and their recesional velocities.



(a) What value does v/d give you?
(b) What value does the gradient give you?
(c) Calculate the gradient of the line
(d) Use this gradient to show the relationship between Distance and Velocity.