TABLE OF CONTENTS

Paper 3 Section A (Practical)

3.1 Measurements and their errors.

3.1.1 use of SI units and their prefixes

Content

- Fundamental (base) units.
- Use of mass, length, time, amount of substance, temperature, electric current and their associated SI units.
- SI units derived.
- Knowledge and use of the SI prefixes, values and standard form.
- The fundamental unit of light intensity, the candela, is excluded.
- Students are not expected to recall definitions of the fundamental quantities.
- Dimensional analysis is not required.
- Students should be able to use the prefixes: t, g, m, k, c, m, μ, n, p, f.
- Students should be able to convert between different units of the same quantity, e.g. J and eV, J and kWh.

The fundamental base units are as follows:

The ampere (A) for electrical current, the candela (cd) for luminous intensity, the kelvin (K) for thermodynamic temperature, the kilogram (kg) for mass, the metre (m) for length, the mole (mol) for amount of a substance, the second (s) for time.

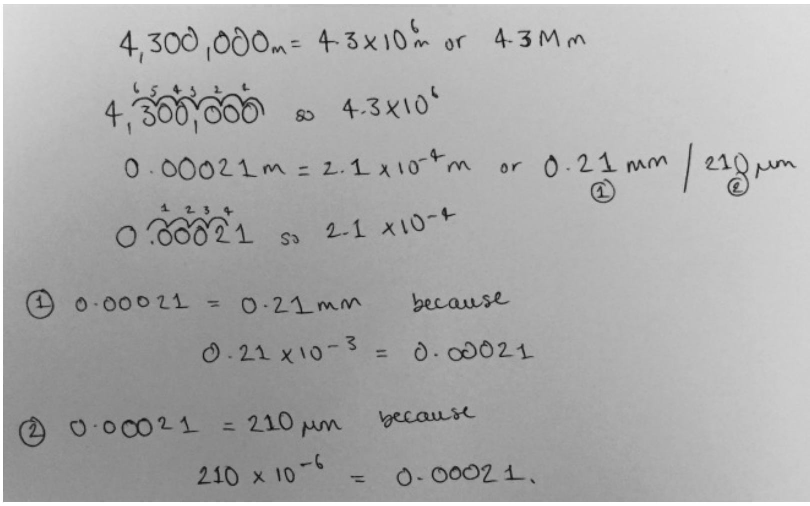
Examples of deriving SI units from other units are:

Joule = $kg.m^2.s^{-2}$, watt= $kg.m^2.s^{-3}$. These units can be derived from equations i.e. From the equation p=fv, where the unit of power is the newton. F=ma so F=$kg.m.s^{-2}$, so $kg.m.s^{-2}$ multiplied by ms^{-1} (which is the "v" from p=fv) equals $kg.m^2.s^{-3}$. So these are the derives SI units of power which has the unit of the watt.

SI prefixes, values and standard form.

Value	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Above is a table of the SI prefixes and values, with their respective symbols. The symbols can be used in place of using standard form, however sometimes you will be required to use standard form, which can be done as follows…



$4{,}300{,}000\,m = 4.3 \times 10^6\,m$ or $4.3\,Mm$

$4{,}300{,}000$ so 4.3×10^6

$0.00021\,m = 2.1 \times 10^{-4}\,m$ or $0.21\,mm$ ① / $210\,\mu m$ ②

0.00021 so 2.1×10^{-4}

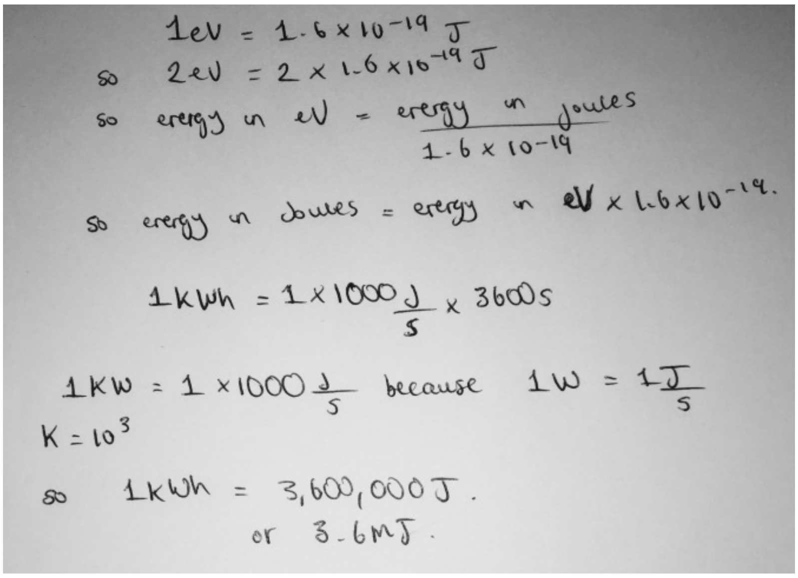
① $0.00021 = 0.21\,mm$ because

$0.21 \times 10^{-3} = 0.00021$

② $0.00021 = 210\,\mu m$ because

$210 \times 10^{-6} = 0.00021$.

Converting between J and eV, J and kWh.



$1\,eV = 1.6 \times 10^{-19}\,J$

so $2\,eV = 2 \times 1.6 \times 10^{-19}\,J$

so energy in eV = $\dfrac{\text{energy in joules}}{1.6 \times 10^{-19}}$

so energy in joules = energy in eV $\times 1.6 \times 10^{-19}$.

$1\,kWh = 1 \times 1000\,\dfrac{J}{s} \times 3600\,s$

$1\,kW = 1 \times 1000\,\dfrac{J}{s}$ because $1\,W = 1\,\dfrac{J}{s}$

$K = 10^3$

so $1\,kWh = 3{,}600{,}000\,J$.

or $3.6\,MJ$.

3.1.2 limitation of physical measurements

Content

- Random and systematic errors.
- Precision, repeatability, reproducibility, resolution and accuracy.
- Uncertainty:
  Absolute, fractional and percentage uncertainties represent uncertainty in the final answer for a quantity.
- Combination of absolute and percentage uncertainties.
- Determine the uncertainties in the gradient and intercept of a straight-line graph.
- Individual points on the graph may or may not have associated error bars.

Opportunities for Skills Development

- Students should be able to identify random and systematic errors and suggest ways to reduce or remove them.
- Students should understand the link between the number of significant figures in the value of a quantity and its associated uncertainty.
- Students should be able to combine uncertainties in cases where the measurements that give rise to the uncertainties are added, subtracted, multiplied, divided, or raised to powers. Combinations involving trigonometric or logarithmic functions will not be required.

Random and systematic errors.

A **random error** is one which is always present in data, and is due to readings that vary randomly, with no recognizable trend or bias. A random error could be caused by a faulty instrument, human error or a poor technique.

A **systematic error** is one which follows a pattern/trend, or a bias, and results in readings that systematically differ from the true mean reading. Systematic errors could be caused by a non-zero reading at the beginning i.e. on a voltmeter/ammeter. There could also be a consistent error in a technique used, or a calibration error in the instrument.

Precision, repeatability, reproducibility, resolution and accuracy.

Precision can be either precision of an instrument, or precision of a measurement. Precision of an instrument is the smallest non-zero value that can be measured, also referred to as the **resolution** of that instrument. The precision of a measurement is the degree of exactness of a measurement, usually referred to as the **uncertainty** of the readings used to obtain a measurement.

Uncertainty

This is the precision of a measurement due to the instrument used.

Absolute, fractional and percentage uncertainties represent uncertainty in the final answer for a quantity.

The **absolute uncertainty** is the size of the range of values that the ‘true’ value lies. For example, in a measurement of 10.0m, the uncertainty is ±0.1m. So the absolute uncertainty would be 10.0m ± 0.1m, as this is the range of values that could be the ‘true’ value. If you have a range of results ie 0.4, 0.5 and 0.6, the uncertainty is the range of results divided by 2. Also, anomalies must be ignored in these situations.

Fractional uncertainty is simply the calculating by dividing the uncertainty by the value of the data. For example: 1.2 s ± 0.1s, the fractional uncertainty would be equal to 0.1 / 1.2 = $0.08\dot{3}$.

Percentage uncertainty is just the fractional uncertainty multiplied by 100. So for the fractional uncertainty given above, the percentage uncertainty would be $8.\dot{3}$%. So this tells us that the value of 1.2 can deviate by ± $8.\dot{3}$%.

Combination of absolute and percentage uncertainties.

1. If you add or subtract the two (or more) values to get a final value

The absolute uncertainty in the final value is the sum of the absolute uncertainties. For example:

10.0 ± 0.1 mm + 4.0 ± 0.1 mm = 14.0 ± 0.2 mm
10.0 ± 0.1 mm - 4.0 ± 0.1 mm = 6.0 ± 0.2 mm

2. If you multiply one value with absolute uncertainty by a constant the absolute uncertainty is also multiplied by the same constant. For example:

2 x (10.0 ± 0.1 mm) = 20.0 ± 0.2 mm

3. If you multiply or divide two (or more) values, each with an uncertainty you add the % uncertainties in the two values to get the % uncertainty in the final value. For example:

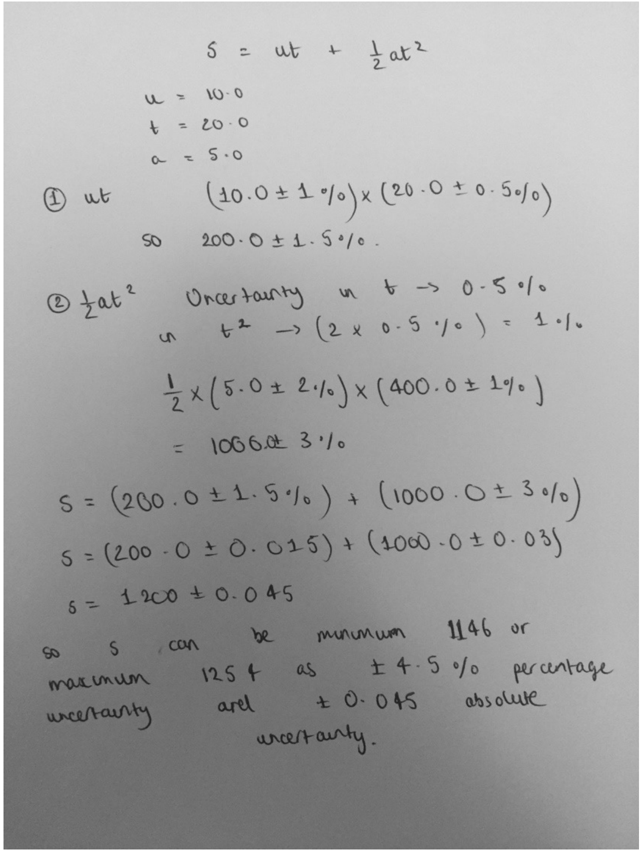
10.0 ± 0.1 mm x 4.0 ± 0.1 mm

This is
10.0 ± 1% x 4.0 ± 2.5%

So, the final result is
40.0 ± 3.5%

4. If you square a value, then you multiply the % uncertainty by 2. If you cube a value, then you multiply the % uncertainty by 3. If you need the square root of a value, you divide the % uncertainty by 2.

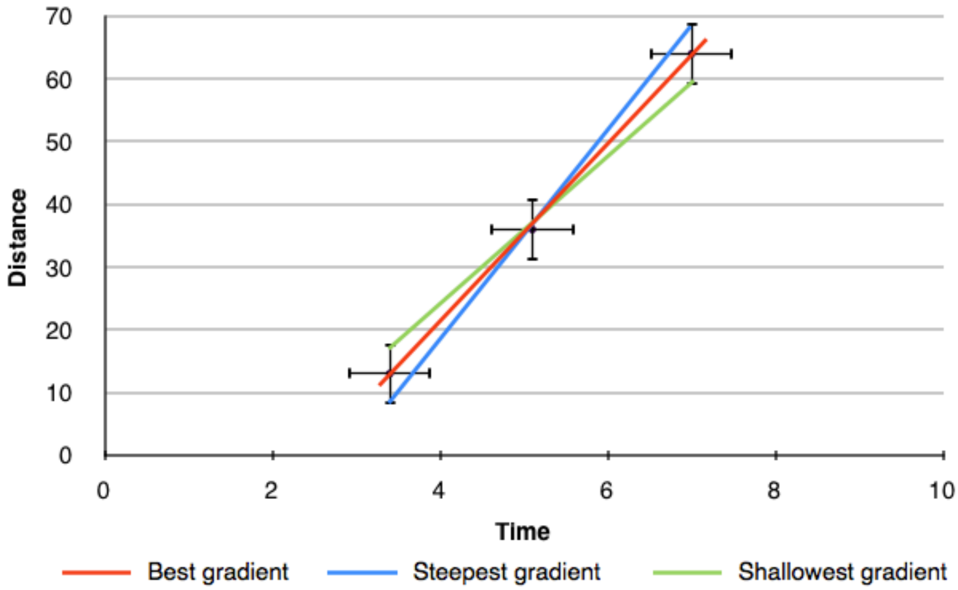
In the question to the right, you are told to find the absolute and percentage uncertainty in the value of s when using the equation $s = ut + at^2/2$. This is done by combining the uncertainties of ut, and $at^2/2$.



1. This question applies knowledge of uncertainties from the last topic.
2. First, we need to find the percentage uncertainty on 'ut'. Since 'ut' is two values multiplied together, we have to add their percentage uncertainties. This can be done by finding their fractional uncertainty and then multiplying this by 100. For example, for u: 0.1/10.0 = 0.01 which is the fractional uncertainty. We need the percentage uncertainty, which is 0.1 x 100, so 1%. We know that the percentage uncertainty on u is 1%, and on t is 0.5%, so the final percentage uncertainty on 'ut' is 200.0 ± 1.5%.
3. On $\frac{1}{2}at^2$, we have to find the percentage uncertainty on t, and add it to that of a. ½ does not carry an uncertainty. So we know that the uncertainty on t is 0.5%, so the uncertainty on t^2 is therefore 0.5% x 2, so 1%. Then we need to find the percentage uncertainty on a, which is 2%, and add this to that of t^2. This gives an answer of 1000.0 ± 3%.
4. Now we have the percentage uncertainty on the product of 'ut' and '$at^2/2$'. However these two quantities are added together in the equation $s = ut + at^2/2$, so to add the uncertainties we need to convert to fractional uncertainties.
5. The final answer is therefore 1200 ± 54 as an absolute uncertainty, or 1200 ± 4.5% as a percentage uncertainty. The absolute uncertainty is worked out using either the fractional or percentage uncertainty, as it it just the range of values that the answer could be, using the fractional or percentage uncertainty will give the same answer.

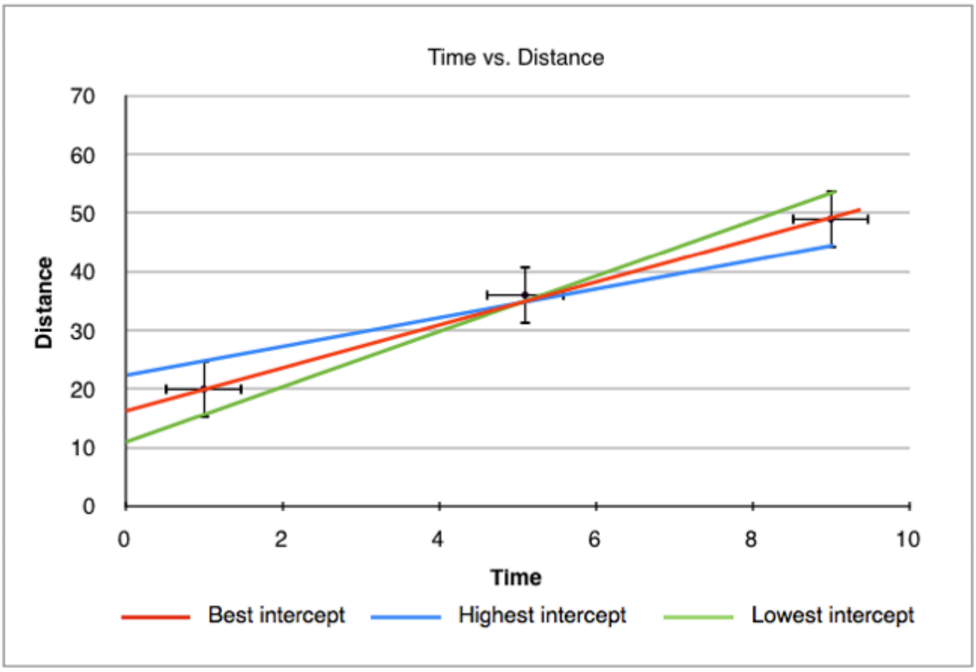
Determine the uncertainties in the gradient and intercept of a straight-line graph

To determine the uncertainty in the gradient of a graph you simply simply add error bars to the first and last point, and then draw a straight line passing through the lowest error bar of the one points and the highest in the other and vice versa. This gives two lines, one with the steepest possible gradient and one with the shallowest, we then calculate the gradient of each line and compare it to the best value. The figure below shows how this is done.



$$\text{percentage uncertainty} = \frac{|\text{best gradient} - \text{worst gradient}|}{\text{best gradient}} \times 100\%$$

To determine the uncertainty in the y – intercept we do the same thing as when calculating the uncertainty in gradient. This time however, we check the lowest, highest and best value for the intercept by drawing the different possible intercepts from the different gradients.



$$\text{percentage uncertainty} = \frac{|\text{best } y \textit{ intercept} - \text{worst } y \textit{ intercept}|}{\text{best } y \textit{ intercept}} \times 100\%$$

Individual points on the graph may or may not have associated error bars.

3.1.3 Estimation of Physical Quantities

Content

- Orders of magnitude.
- Estimation of approximate values of physical quantities.

Opportunities for Skills Development

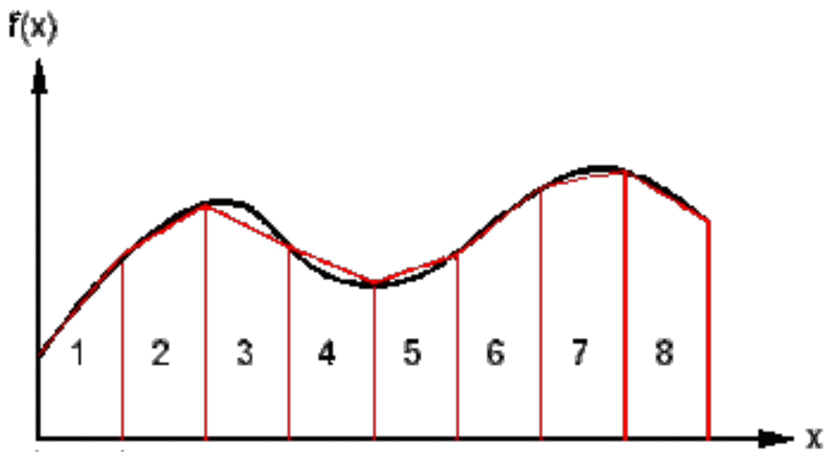
- Students should be able to estimate approximate values of physical quantities to the nearest order of magnitude.
- Students should be able to use these estimates together with their knowledge of physics to produce further derived estimates also to the nearest order of magnitude.

Orders of Magnitude

An order-of-magnitude estimate of a variable whose precise value is unknown is an estimate rounded to the nearest power of ten. For example, there are two orders of magnitude between 10^4 and 10^6, so a factor of 10^2 difference between them.

Estimation of approximate values of physical quantities

When making estimates, it is reasonable to give the figure to one or two significant figures since the estimate is not supposed to be completely precise. For example, the mass of a car to be 1000kg, or the length of a football pitch to be 100m. Or you could be asked to estimate the area under a graph of a curved line. This can be done by drawing trapeziums in, so you can calculate the area of regular trapeziums along the line. This is shown in the diagram below:



Guide to good experimental methods and practice

- Clear method i.e. specific time intervals, values measured etc.
    - Explain the method as if you are explaining it to someone with absolutely no subject and experimental knowledge.
- Equipment required e.g. metre rule, stopwatch etc.
    - How to use the equipment?
        - Are you going to use the metre rule vertically upright to measure something? With a set square to ensure verticality…
- What variables must be controlled e.g. temperature, light intensity etc.
- How can you make results as accurate as possible?
    - Reducing **parallax** error e.g. stand eye level to measuring equipment
    - If liquid is involved, STIR the liquid regularly to ensure even distribution of thermal energy (uniform heating) throughout.
    - Repeat measurements and calculate a mean
        - For example, of diameter of a wire (using micrometer, vernier callipers)
    - Make sure equipment does not have a zero error.
    - Take heat source away when making measurements (if there is one in the question) and depending on context of question.
- Find uncertainty on measurements
- Can you plot a graph from your results?
    - Can you find a relationship between your data that will yield a straight line when plotted on a graph?
        - Find proportionality between variables
        - Compare to $y = mx + c$
        - Take natural logs to both sides

Guide to graphs

- Check units of graph
- If question asks for only the gradient, it will require no units as the gradient is just a measure of how one variable changes with respect to another.
    - If it requires the quantity, make sure to give units
- **Check to see if graph starts at 0 when you are calculating the gradient**

Exam Questions

Edexcel Jan 2010 Unit 3B Question 5di

Question:

State what further measurements the student would need to take to determine the resistivity of the wire. (in previous questions you gained results regarding length and resistance of the wire)

Answer:

Remember it says **measurement**, not a calculable value, so you would need to **MEASURE** diameter.

Exam tip:

WHEN ASKED FOR MEASUREMENTS, DO NOT GIVE QUANTITIES THAT MUST BE CALCULATED!

Edexcel Jan 2011 Unit 6 Q4bi)c)

Question:

Explain why a graph of $\ln\Delta\theta_0$ against t should be a straight line.

Answer:

We were told $\Delta\theta = \Delta\theta_0 e^{-kt}$ in a previous question, so $\ln\Delta\theta = -kt + \ln\Delta\theta_0$. If we compare this with the equation of a line $y = mx + c$, you can see that the gradient is equal to '-k'. Since k is a constant, your gradient will be a constant, yielding a straight line.

Exam tip:

WHEN ASKED ABOUT RELATIONSHIPS BETWEEN VARIABLES AND THEIR REPRESENTATION ON A GRAPH, THINK ABOUT PROPORTIONALITY OR COMPARISON TO y = mx + c IN ORDER TO FIND OUT WHETHER IT COULD BE A STRAIGHT LINE.

Question:

Your teacher suggests using a temperature sensor and a data logger in place of the thermometer and stop clock.

State an advantage of using a temperature sensor and a data logger in this experiment.

Answer:

Takes simultaneous readings/plots graph automatically

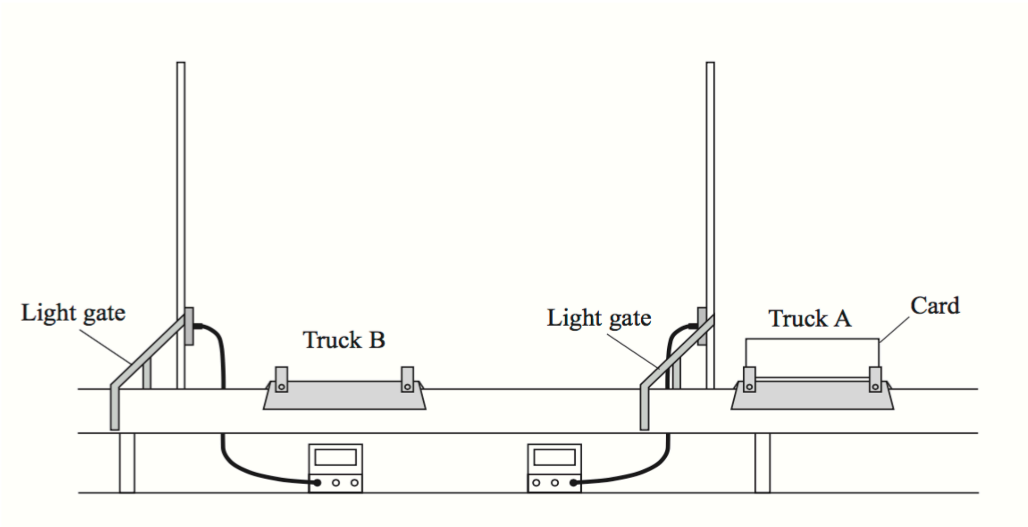
Exam tip:

ADVANTAGES EXPERIMENTALLY – EASE OF DATA COLLECTION

Edexcel Jan 2011 Unit 6 Q2a

Question:

A student has an air track which has two trucks, A and B, supported by a cushion of air. He does an experiment to see whether momentum is conserved when the two trucks collide.



Using an air track reduces friction on the trucks. State why this is important in a momentum conservation experiment.

Answer:

Conservation of momentum only applies in there are no (resultant) external forces

Question:

The student uses two light gates as shown in the diagram. Truck A carries a card of negligible mass and length *l*. A light gate records the time *t* taken by the card to pass through it.

Explain how you would show that the air track is horizontal before starting the experiment.

Answer:

Truck A given a (gentle) push (1)
The times shown on both timers are similar/calculated velocities are similar (1)
OR
Put truck on track, check if it remains stationary (1) Check in more than one position/use both trucks (1)
OR
Use spirit level (1) Check bubble in middle/check in more than one position (1)
OR

Check height of track above bench with rule and set square (1)
At both ends (1)

Question:

Truck B carries no card and is placed so that it is stationary between the light gates. Truck A is set off towards truck B. As the card passes through the first gate it records a time t_1. Truck A then collides with truck B. They stick together and move through the second gate which records the time t_2

Both trucks have the same mass. Explain why $t_2 = 2t_1$ if momentum is conserved.

Answer:

Mass doubles
(So) velocity halves

time = (card) length/velocity

(so time is doubled)

allow mathematical proof which hides *v* ratio e.g. $mu = 2mv$ then we know that $u = l/t_1$, and $v = l/t_2$ so substitute these values in and solve for $t_2 = 2t_1$

Question:

The student records the following data for 5 separate collisions:

t_1/s	0.34	0.15	0.21	0.28	0.24
t_2/s	0.70	0.35	0.39	0.55	0.52
t_2/ t_1	2.1	2.3	1.9	2.0	2.2

Use this data to discuss whether momentum can be considered to be conserved in this experiment.

Answer:
(We know that since $t_2 = 2t_1$ for conservation of momentum, $t_2/t_1 = 2$)

1. Mean ratio $t_2/t_1 = 2.1$ (1)
2. Uncertainty is + 0.2 (1)
3. Uncertainty range includes 2.0 (1)
4. (Hence, yes, momentum is conserved)

<u>Alternatives for last 2 marks</u>

1. Calculates % difference as 5% (1)
2. 5% is less than the experimental uncertainty of 9.5% (1)
3. (Hence, yes, momentum is conserved)

Edexcel AS Specimen 1 Q11b

Question:

The length of a tooth from another dinosaur is approximately 10cm.

Scientist A measures this length with a metre rule, and scientist B measures this length with calipers.

Scientist B claims that his measurement will produce a more accurate value for the length of the tooth.

Comment on the claim made by scientist B.

Answer:

- Accuracy relates to how close the measurement is to the true value
- Callipers reduce random/measurement errors in determining the value, giving a lower uncertainty in the measurement than that for a metre rule
- so scientist B has not made a more accurate measurement he has made a measurement with lower uncertainty

Edexcel AS Specimen 2 13b

Question:

The refractive index of glass may be determined by measuring angles of incidence and angles of refraction for light passing into a glass block.

Explain how the choice of the width of the ray of light and the range of the angles of incidence can ensure the accuracy of the result

Answer:

- A narrow ray should be used
- Because it reduces uncertainty in the position (angle) of the ray (accept allows position to be determined with greater precision)
- A range of large angles should be used
- Because the precision of the measurement will be determined by the protractor
- For larger angles the percentage uncertainty will be smaller
- A smaller uncertainty in the final answer from sin i/sin r

Exam tip:

WHEN ASKED ABOUT ACCURACY, TALK ABOUT HOW UNCERTAINTY (PRECISION OF MEASURING INSTRUMENTS FOR INSTANCE), WILL AFFECT THE ACCURACY OF THE RESULT.

ACCURACY RELATES TO HOW CLOSE THE MEASUREMENT IS TO THE TRUE VALUE

Edexcel AS Specimen 2 Q17a)d)

Question:

The student wants to determine the mass of one of the rubber bands. He places five rubber bands on a balance and obtains a reading of 2 g. He divides the reading on the balance by five to determine the mass of one rubber band.

Explain how he could improve his result.

Answer:

- Balance measures to 1 g
- More rubber bands should have been placed on the balance to obtain a reading of at least 10g
- To make the reading more precise thus reduce uncertainty on the measurement

Question:

The student thinks the calculated value of maximum velocity is too high because the band does not travel as far as expected.

Explain how the student could determine the initial velocity with the use of a video camera and why light gates would not be suitable

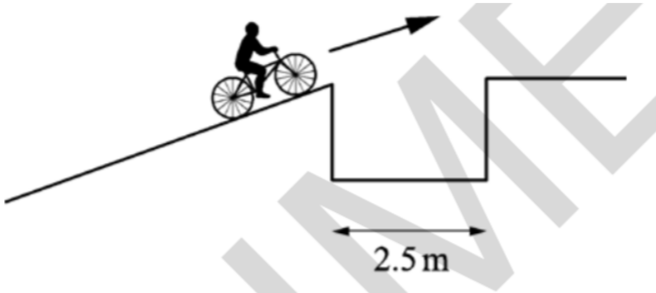
Answer:

- Video the band over a short distance so it determines the initial speed
- **Or** because its speed will rapidly reduce because of air resistance **(1)**
- Include a scale or object of known length in the area filmed **(1)** analyse the video to determine the time taken to travel the known distance **and** calculate the speed using the measured time in speed = distance/time **(1)**
- (Light gates would not be suitable because) the band is not sufficient in size to interrupt the light gate beam

OCR (A) A Level Specimen 1 Q17c

Question:

The cyclist continues to move up the slope at 6.0 ms^{-1} and approaches a gap of width 2.5 m as shown in **Fig. 17.2**.



A student has calculated that the cyclist will be able to clear the gap and land on the other side. Another student suggests that this calculation has assumed there is **no** drag and has not accounted for the effect caused by the front wheel losing contact with the slope before the rear wheel.

Without calculation, discuss how drag and the front wheel losing contact with the slope will affect the motion and explain how these might affect the size of the gap that can be crossed successfully.

Answer:

- Drag reduces velocity **or** increases time to cross **or** some kinetic energy of cyclist goes to heat. Very short crossing time
- Longer crossing time results in cyclist at lower point on other side of gap
- Moment on bicycle
- Rotation lowers height of front wheel

OCR (A) A Level Specimen 1 Q18a

Question:

A group of scientists have designed an alloy which is less dense than copper but may have similar mechanical properties. A researcher is given the task to determine the Young modulus of this alloy in the form of a wire.

Write a plan of how the researcher could do this in a laboratory to obtain accurate results. Include the equipment used and any safety precautions necessary.

Answer:

Equipment used safety

- Wire fixed at one end with load added to wire
- Suitable scale with suitable marker on wire.
- Micrometer screw-gauge or digital/vernier callipers for measuring diameter of wire
- Reference to safety concerning wire snapping

Measurements

- Original length from fixed end to marker on wire
- Diameter of wire.
- Measure load.
- New length of wire when load increased.

Calculation of Young modulus

- Find extension (for each load) OR strain
- Determine cross-sectional area of wire or stress
- Plot stress-strain graph OR graph of load-extension
- Young modulus = gradient OR Young modulus equals gradient x original length/area
- Calculate Young modulus from single set of measurements of load, extension, area and length

Reliability of results

- Measure diameter in 3 or more places and take average.
- Put on initial load to tension wire and take up ‘slack’ before measuring original length.
- Take measurement of extension while unloading to check elastic limit has not been exceeded
- Use long wire (to give measureable extension and reduce percentage uncertainty)
- Scale or ruler parallel to wire. Readings read off parallel to scale (reduce parallax error)

Edexcel (IAL) Unit 6 June 2014 Q4b

Question:

Plan an experiment to determine how the resistance of a thermistor changes as its temperature is increased from 0 °C to 100 °C.

Your plan should include:

(i) the apparatus required, **(2)**

(ii) how you would obtain the temperature range, **(1)**

(iii) the precautions you would take to ensure accurate measurements. **(2)**

You may draw a diagram if you wish.

Answer:

Apparatus - **Max 2** Thermometer Ohmmeter **or** ammeter and voltmeter (Must have circuit diagram for V & A with psu) heat source (can be awarded in diagram or list)	(1) (1) (1)
Method use ice(to get to 0 °C) **and** heat(to get to 100 °C)	(1)
Precaution - **Max 2** Anything appropriate such as removing heat source when reading stirring Keep thermometer close to thermistor **Or** Keep thermometer away from sides/bottom Do not allow repeat readings	(1) (1) (1)

Edexcel Unit 6 Jan 2011 Q3aii

Question:

V/V	*W*/mJ			Mean *W*/mJ	*C*/mF
4.5	19.57	19.51	19.63		
6.0	36.14	36.12	36.22		

Calculate the percentage difference between your two values of *C*

(They were calculated to be 1.93 and 2.01 for 4.5V and 6V respectively)

Answer:

Percentage difference between values calculated
using mean *C* as denominator

e.g. (2.01 – 1.93)/1.97 = 4(.1)%

Question:

The uncertainty in the values of potential difference in the table is 0.1 V.

Estimate the uncertainty in your mean value of *W* when using the 4.5 V battery.

Answer:

Use half range to estimate uncertainty (1) [must include unit]
Uncertainty is 0.06 mJ

Question:

Use these uncertainties to estimate the percentage uncertainty in the value of *C* obtained using the 4.5 V battery.

Answer:

- Calculates percentage uncertainties in *V* and *W*
- Combines percentages appropriately

$W = 0.3\%$ & $V = 2.2\%$
$C = [0.3+(2\times2.2)]\%=4.7\%$

(Remember if you square a value its percentage uncertainty is multiplied by 2).

Question:

Explain whether the unknown capacitor could be a 2200μF capacitor with a tolerance of 20%

Answer:

- Calculates lower limit of range of 2200μF as 1760μF
- States that that (mean *C* – uncertainty on C) lies within range

Edexcel June 2010 Unit 6 Q4a

Question:

You are to plan an experiment to investigate the ability of gamma rays to penetrate lead. You are then to analyse a set of data from such an experiment.

You have a source of radiation and a detector and counter. Describe briefly a simple experiment to confirm that the source emits gamma radiation.

Answer:

- Record background count (rate)
- Place thick aluminium/thin lead between source & detector **OR** Distance greater than 25 cm between source and detector
- Count rate detected above background

Question:

You are provided with sheets of lead and apparatus to support them safely between the source and the detector.

The thickness of lead affects the count rate. Describe the measurements you would make to investigate this.

Your description should include:

- A variable you will control to make it a fair investigation
- How you will make your results as accurate as possible
- One safety precaution

Answer:

Keep distance between the source and detector constant

Any **four** from:

- Record count (rate) for different thicknesses
- Record count for a specified time
- Subtract background count
- Take several readings at each thickness
- Measure thickness with micrometer screw gauge/Vernier calipers

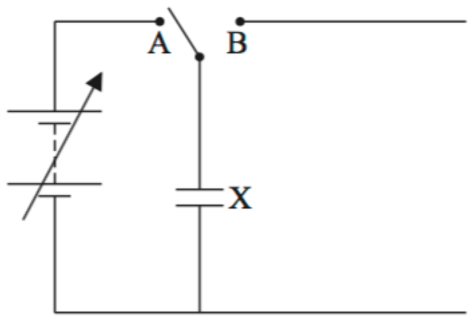
One of:

- Keep people away from source
- Use tongs to handle source
- Use tongs to handle lead sheets
- Ensure source held securely
- Limit exposure time to source

Edexcel (IAL) Unit 6 June 2016

Question:

Part of an electric circuit is shown.



When the switch is connected to terminal A the capacitor X is connected to the variable power supply.

(a) (i) Add a second capacitor Y to the circuit so that it is connected in parallel with X when the switch is moved to B.

(1)

(ii) Add a voltmeter so that the potential difference (p.d.) across X can be measured when the switch is in either position.

(1)

(b) The capacitance of X is C_X. If C_X is known, this circuit can be used to determine the capacitance C_Y of capacitor Y using the equation

$$V_2 = \frac{C_X}{C_Y}(V_1 - V_2)$$

where

- V_1 is the p.d. across X when it is connected to the power supply
- V_2 is the p.d. across X when Y is connected in parallel with it.

Write a plan for an experiment using this circuit and a graphical method to determine C_Y.

Your plan should include

(i) the readings you would take

(2)

(ii) the graph you would plot and how you would use the graph to determine C_Y

(2)

(iii) how you would ensure the capacitors would not be damaged during the experiment

(1)

(iv) a precaution you would take to ensure the results are accurate.

(1)

Answer:

2(a)(i)	Y connected correctly	**(1)**
2(a)(ii)	Voltmeter connected correctly	**(1)**
2(b)(i)	**2b to be marked holistically** Record V_1 and V_2 For various values of the supply/V_1	 **(1)** **(1)**
2(b)(ii)	Plot a graph of V_2 (on the y-axis) against ($V_1 - V_2$) (on the x-axis) $C_Y = C_X$ / gradient	**(1)** **(1)**
2(b)(iii)	Supply p.d. does not exceed working p.d. for either capacitor/C **Or** Capacitors are connected with polarity correct (if electrolytic)	 **(1)**
2(b)(iv)	Ensure that capacitor Y is discharged before each reading (accept both capacitors are discharged) **Or** check for zero error on voltmeter	 **(1)**

Edexcel (IAL) Unit 6 Jan 2016 Q1bi

Question:

The volume V_2 of the bung is given by

$$V_2 = \frac{\pi h}{12}\left(D^2 + d^2 + Dd\right)$$

where D, d and h are the dimensions shown on the diagram.
The student uses callipers to take measurements of the bung.

(i) Describe how h should be measured.

Answer:

- Holds top and bottom of bung between jaws (perpendicularly) **or** callipers are parallel to h (1)
- Repeat at different orientations for mean
  Or do not compress
  Or check for zero error8

Key exam tips:

- **REMEMBER TO CONVERT TO KELVIN FROM CELCIUS WHEN DEALING WITH NUCLEAR PHYSICS QUESTIONS!**
  - **pV = nRT = NkT - The 'T' is in KELVIN not Celsius.**
- **CASSEGRAIN TELESCOPE - ENSURE RAYS DO NOT CROSS BEFORE THEY LEAVE THE SECONDARY MIRROR! (SO, AS THEY LEAVE.)**
- **GIVE SPECIFIC DETAILS IE CALCULATIONS OR FIGURES TO PRESENT YOUR CONCLUSION! FOR EXAMPLE:**

AQA June 2015 Unit 5 Q1c

Question:

Discuss the level of detail the IRTF would be able to detect on the surface of Vesta, when Vesta is 1.73 x 10^{11}m from Earth. (We already know that the angular resolution of the IRTF is The smallest angle the telescope can resolve is 3.3 × 10^{-7} radian, and that Vesta subtends an angle of approximately 3 x 10^{-6} radian from Earth.)

Answer:

- Minimum angular resolution is better/smaller than the size of the asteroid.
- Details of about 1/10 the angular size of Vesta/ 50km can be seen

- **GIVE SPECIFIC DETAILS – FOR EXAMPLE:**

Question:

The black body temperature of each star is approximately 9200 K.
Explain why a Hydrogen Balmer line was chosen for the analysis of wavelength variation

Answer:

- The temperature (9200K) indicates that the star is in spectral class A.
- Hydrogen Balmer lines are strongest in A class stars and therefore would be more easily measured

  - **BE EXPLICIT IN WHAT YOU SAY! DIRECTLY STATE THAT 9200K IS RELATED TO SPECTRAL CLASS A!**
- **WHEN DEALING WITH m-M = 5LOG(d/10) REMEMBER TO CONVERT DISTANCE INTO PARSECS!**
- **ALSO, REMEMBER A LOWER VALUE ON THE APPARENT MAGNITUDE SCALE = BRIGHTER TO THE NAKED EYE AS SEEN FROM EARTH!**
  - **THIS MEANS THAT AN APPARENT MAGNITUDE OF 1 IS BRIGHTER THAN AN APPARENT MAGNITUDE OF 2.**

- **WHEN USING $P = \sigma AT^4$ REMEMBER THAT 'A' WILL BE $4\pi R^2$ (IF IT IS A SPHERE, FOR EXAMPLE AN IDEALISED STAR)**

And finally, some good old-fashioned notes…

Oscillations

- Perform 3 sets of measurements for each different oscillation, (you will get more marks if you do 2 sets of repeats).
- Measure at least 30 periods in total.
- Preferably make each measurement 20 periods long.
- Precaution: minimise oscillations in any other plane other than the one being observed ("Careful release to avoid unwanted modes of oscillation"). Explain how you did this.
- Always write times to two d.p., never to the nearest second.
- Precaution: do small amplitude oscillations
- Precaution: say that you did several periods at once to minimise reaction time errors.
- Precaution: use a fiducial marker at the centre of the oscillation.

Moments

- Precaution: balance the ruler being used first.
- Use distances from the pivot of greater than 25 cm (250 mm).
- Weigh the unknown and known masses in your hands before using the ruler, and place the lighter mass as far from the pivot as possible.
- Measure distances from the pivot to the centre of mass of the object.
- All measurements should be to 1 mm accuracy.
- To make sure the rule is balanced, pull each end down. If it comes up again then the rule must have equal moments acting on it on either end.

Density Measurements

- When using a micrometer, one full rotation of the barrel is 0.5 mm (50 on the barrel scale).
- The micrometer reads to 0.01 mm accuracy.
- Vernier callipers can read to 0.05 mm accuracy. However, it is advisable to quote the figure to 0.1 mm accuracy, as this will give a larger uncertainty, which will make comparisons in later parts of the question easier.
- If measuring a very small dimension, measure several "thicknesses" of it. Remember to divide by the number of thicknesses after the measurement!
- Precaution: check the zero error on the micrometer and/or Vernier callipers. Wipe the jaws of the micrometer to remove grease.
- Give answers to 2 or 3 s.f. it is meaningless to write, for example, "density is 7785.654 kg m^{-3}"!
- Always take at least 3 readings for each measurement and take an average.
- When measuring string diameters or foil thicknesses (or similar), use a minimum of 10 thicknesses.

Miscellaneous

- With a measurement that varies substantially each time you test it, take at least 4 readings. An example is sand falling from a funnel.
- For Experiment C, 8 readings are normally sufficient (sometimes even 6). Extra time at the end can be used for writing up the other experiments or planning them.
- Show clearly on diagrams your measurements, e.g. to the centres of mass of objects when doing a moments experiment.
- In any experiment that involves loading and unloading, state that you checked the original height on unloading each time.
- In any experiment involving, e.g. a funnel and sand, state that you kept the funnel vertical.

- Precaution: with many experiments, you can state that you did something to avoid parallax error.
- When measuring angles, measure from the underside of, e.g., the board you are measuring the angle of, compared to the horizontal bench.
- To measure a height with a ruler and a set square, hold the ruler vertically using the set square against the bench and the flat side of the ruler.
- Show any angles measured on diagrams, including ones of forces.

Uncertainties

- % Uncertainty = $\frac{error}{measurement}\times 100$
- When multiplying or dividing quantities, add their % uncertainties together.
- When adding or subtracting quantities, add their absolute errors together, then divide by the result of the addition/subtraction of the measurement, e.g. for $(d + x)$, where $x = 10mm \pm 0.1mm$, and $d = 5mm \pm 0.02mm$, the absolute errors added = 0.102 mm. Therefore the % uncertainty is:
- $= \frac{0.102}{(10+5)}\times 100$
- If you have to calculate the error in, e.g. $x - \pi d$, the absolute error in *d* must be multiplied by pi and then added to the absolute error in *x*. The percentage uncertainty is this total error divided by the calculated $x - \pi d$ and the result multiplied by 100.
- If a measurement is to be raised to a power, then multiply the % uncertainty in the measurement by the power to get the % uncertainty in the overall term.
- If two values, for say, a density are available, calculate the % difference between them. If a value is given by the examiner, then use this as the "correct" value, and calculate the % difference the following way: $\frac{x-c}{c}\times 100$ where *x* is your measured value, and *c* is the examiner's value. If you have obtained two values, then the expression changes: $\frac{x_1 - x_2}{\bar{x}}\times 100$ where x_1 and x_2 are your measured values, and $\bar{x}$ is the median of the two, (not necessarily the mean!).
- Compare the % difference with your % uncertainty. Any relationship suggested, such as that the two densities should be equal, can be considered correct if your % difference is less than your % uncertainty. This will gain you marks!
- If your % uncertainties look small, check that you have multiplied by 100!

Electrical Experiments

- With capacitor discharges, either take readings every 5 seconds for the first part of the discharge, or I think that every 10 seconds is sufficient.
- If a range is specified over which you should take measurements, do not exceed it: you will be penalised.
- With an analogue ammeter, use the top scale. This reads (generally), from 20, to 0, to 10. These are in fact divisions of 10 m A, and the meter actually reads from -20 to 100 m

A. If you are out by a factor of 10, (e.g. you get a calculated cell voltage of 0.15 V), check that you have read the meter correctly. Always remember that the polarity on the meter must be correct.

- Any small discrepancy in your results can be explained by "electrical resistance at the contacts in the circuit".
- With most electrical experiment where a curve will be obtained (e.g. the V/I characteristic of a diode), 9 points on a smooth curve are sufficient.

Graphs

- With any graph, a minimum of 6 to 8 points are needed, and you must have at least 4 points on a curve.
- When measuring the gradient of a graph, carry your tangent on to the sides of the graph paper, however big your graph. The triangle you use should be greater than 10 cm in length and height, although in some mark schemes 100 cm^2 is fine.
- Your graph does not have to go through the origin. If the data does not indicate that it does so, do not force it to. Comment on the fact that there must have been a systematic error.
- When choosing values to read of a graph, it is better to take them from the middle part of the curve, as this is where you will have more points per change in y co-ordinate.
- When describing your "plan" in Experiment C, state that the graph you plot will be a straight line through the origin (if this is the case!), of gradient = to an expression which will help you confirm the relationship suggested by the examiner.
- Turning points on graphs require at least 4 points.
- If points near the origin deviate substantially from your line of best fit, point out that for small measurements there is a greater uncertainty.

Experiments Involving Temperature

- Readings should be accurate to fractions of a degree.
- Stir any liquid being heated.
- Insulate the apparatus if possible.
- The thermometer should not be touching the sides of the container it is in, and should be in the middle of the liquid you are measuring the temperature of.
- Precaution: read the thermometer at eye level to avoid parallax error.
- The bulb of the thermometer should be completely submerged.

Comment on the result obtained being the right order of magnitude

Paper 3 Section 3B (Astrophysics)

3.9 Astrophysics

3.9.1 Telescopes

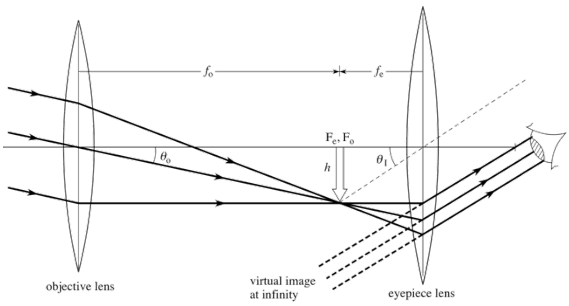
3.9.1.1 Astronomical telescope consisting of two converging lenses

Content

- Ray diagram to show the image formation in normal adjustment.
- Angular magnification in normal adjustment.
- $M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$
- Focal lengths of the lenses.
- $M = \frac{f_o}{f_e}$

Ray diagram to show the image formation in normal adjustment.

The ray diagram for an astronomical telescope consisting of two converging lenses (refracting telescope) is shown below.



The three rays of light travel in parallel. The middle ray will continue on its path without changing direction, since it is passing through the centre of the objective lens, whereas the other two will refract to the common point f_0f_e. A parallel, dotted line from this point needs to be drawn so that it goes through the centre of the eyepiece lens. The three rays of light will then refract at the eyepiece lens, travelling to the parallel line that has been drawn in. The point f_0f_e must be drawn so that it is at least 2/3 of the way along the principal axis.

Angular magnification in normal adjustment.

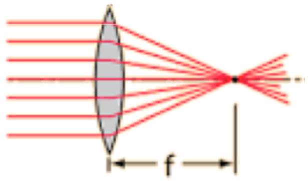
Angular magnification, in words, is the ratio of the angle subtended at the eye by the image formed by an optical instrument (telescope), to the angle subtended at the eye by an object when not being viewed through that instrument. The equation for angular magnification is

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

So if the angular magnification were 100, and the angle subtended by the image at the eye were 2 x 10^{-6} rad, then the angle subtended by the object at the unaided eye would be 2 x 10^{-8}.

Focal length of the lens

For a convex lens, the point at which all refracted rays of light will pass through is called the focal point. The diagram shows this point below.



$$\mathbf{M} = \frac{f_o}{f_e}$$

Angular magnification can also be calculated using the equation shown above.

3.9.1.2 Reflecting telescopes

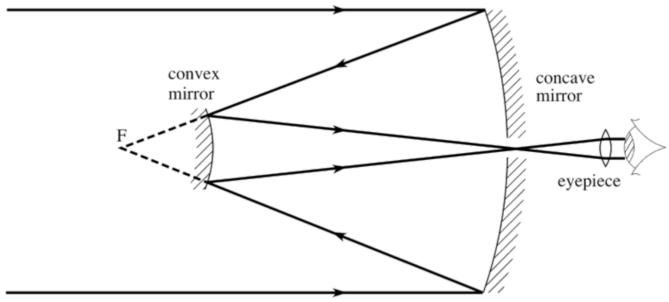
Content

- Cassegrain arrangement using a parabolic concave primary mirror and convex secondary mirror.
- Ray diagram to show path of rays through the telescope up to the eyepiece.
- Relative merits of reflectors and refractors including a qualitative treatment of spherical and chromatic aberration.

Cassegrain arrangement using a parabolic concave primary mirror and convex secondary mirror.

The Cassegrain arrangement is a type of reflecting telescope, it uses a parabolic concave primary mirror, with a convex secondary mirror that work as shown below.

Ray diagram to show path of rays through the telescope up to the eyepiece.

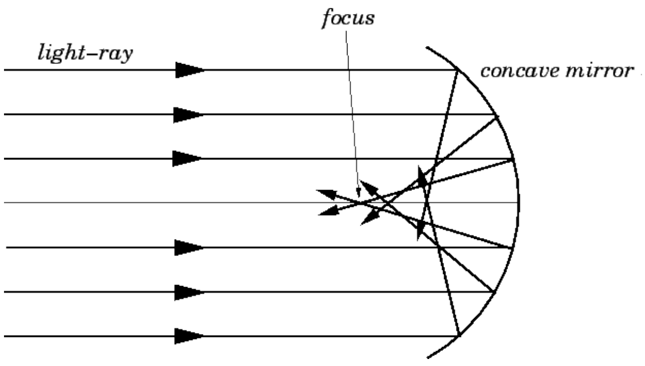


ENSURE RAYS DO NOT CROSS BEFORE THEY LEAVE THE SECONADRY MIRROR! (SO, AS THEY LEAVE.)

Relative merits of reflectors and refractors including a qualitative treatment of spherical and chromatic aberration.

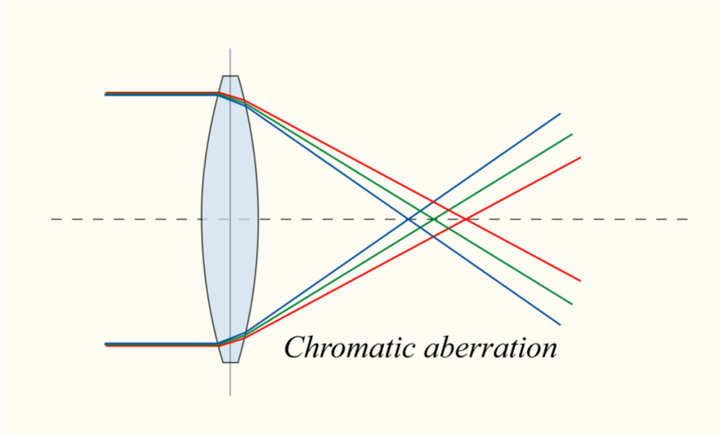
Spherical Aberration

Spherical aberration occurs when the concave mirror reflects rays of light coming in parallel to each other by different amounts. This defect would mean that the image formed, if this occurred in a Cassegrain telescope, would cause an unfocused image.



Chromatic Aberration

This occurs when different wavelengths of light are refracted by different amounts. Since red has the longest wavelength (on the visible light spectrum), it is refracted the least. Blue has a shorter wavelength so is refracted more.



The advantages of reflecting telescopes are as follows:

1. They do not suffer from chromatic aberration as all wavelengths of light reflect in the same way, as opposed to a refracting telescope where for example blue will refract more than red.
2. You can provide support for the objective mirror along the back side of it, so they can be made very large, thus they can collect more light.

Disadvantages are as follows:

1. The reflector is open to the outside, so the optics need constant cleaning.
2. The secondary convex mirror blocks a certain amount of light so less light can be collected by the telescope.
3. The secondary mirror can produce diffraction effects.

Advantages of refracting telescopes:

1. The surfaces within the telescope are sealed, thus they will need cleaning very infrequently.
2. The tube will not be affected by changes in temperature or air currents, so images produced are usually sturdier and sharper than that of a reflector telescope.

Disadvantages of refracting telescopes:

1. Refracting telescopes suffer from chromatic aberration, this causes colour distortion, where there will be other blurred colours surrounding an image like the one shown below.

2. The objective lens can only be supported at its ends, so if the glass is too heavy it will distort under its own weight.
3. It is very difficult to make a glass lens with no imperfections, and to make a glass lens with perfect curvature.

AQA June 2015 Unit 5 Q1c

Question:

Discuss the level of detail the IRTF would be able to detect on the surface of Vesta, when Vesta is 1.73 x 10^{11}m from Earth. (We already know that the angular resolution of the IRTF is The smallest angle the telescope can resolve is 3.3 × 10^{-7} radian, and that Vesta subtends an angle of approximately 3 x 10^{-6} radian from Earth.)

Answer:

- Minimum angular resolution is better/smaller than the size of the asteroid.
- Details of about 1/10 the angular size of Vesta/ 50km can be seen

***EXAM TIP*:**

GIVE SPECIFIC DETAILS IE CALCULATIONS OR FIGURES TO PRESENT YOUR CONCLUSION!

3.9.1.3 Single dish radio telescopes, I-R, U-V and X-ray telescopes

Content

- Similarities and differences of radio telescopes compared to optical telescopes. Discussion should include structure, positioning and use, together with comparisons of resolving and collecting powers.

Similarities and differences of radio telescopes compared to optical telescopes. Discussion should include structure, positioning and use, together with comparisons of resolving and collecting powers.

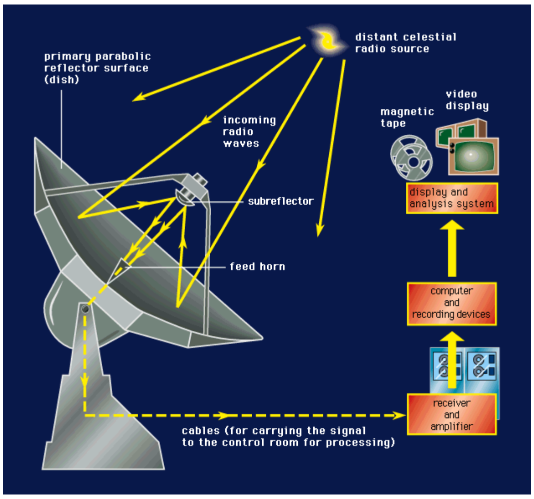
Radio telescopes have the structure shown below. They are similar to a reflecting telescope in that they use a primary parabolic surface to reflect the incoming radio waves towards a secondary sub reflector, obviously the reflector uses light waves instead. This then reflects the radio waves towards the feed horn, where it can be processed to produce an image.

Radio telescope are also usually much larger than optical telescopes, since radio waves have much larger wavelengths, a larger surface is required to capture more radio waves. The larger radio waves are pretty much stationary due to their vast size, so are relatively inefficient at tracking a source in the sky compared to an optical telescope. However smaller radio telescopes are able to track sources.

Radio telescopes tend to be located in remote areas, as they suffer from artificial interferences like those produced by mobile phones. Water vapour in the atmosphere can also interfere with the signal, absorbing the radio waves, thus to avoid this some are placed in space.

Radio telescopes have a much lower resolving power because the wavelength of electromagnetic radiation received by the radio telescope is much larger than the wavelength received by an optical telescope (roughly 10^3m in a radio telescope, and 0.5×10^{-6} in an optical telescope). This is why the radio telescopes need to be so large. The Rayleigh Criterion tells us this (covered in the next topic), where resolving power $\theta = \lambda/D$, where D is equal to the diameter, and λ the wavelength.

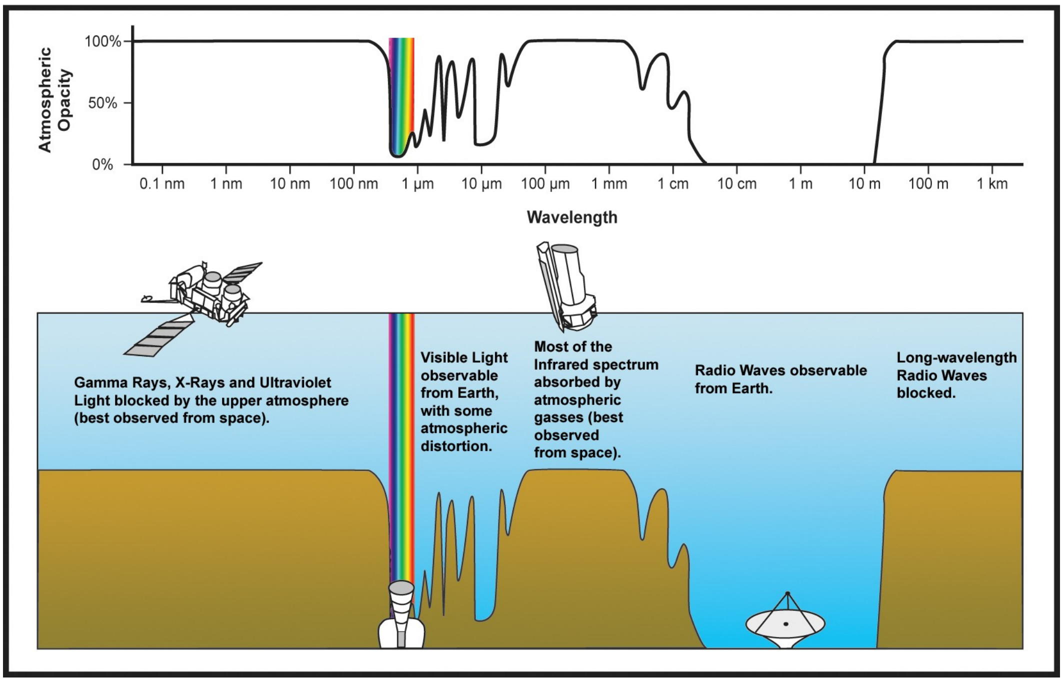
The collecting power of a telescope is proportional to its (objective) diameter^2. Therefore the radio telescopes are able to collect much more radiation, as their diameters are much larger.



The types of telescope that we can use on the surface of the Earth are limited by the electromagnetic radiation that is able to pass through the atmosphere. Gamma rays, X rays and UV radiation are all blocked by the Earth's atmosphere. The UV radiation is absorbed by the ozone layer.

Incoming infrared radiation is partially blocked at certain wavelengths by water vapour in the atmosphere. Most radio wavelength pass through from the microwave region to early radio waves. However longer wavelength radio waves are all blocked by the atmosphere.

This limits the types of telescopes that we can use to detect electromagnetic radiation on the surface of the earth. Thus satellites in space are used typically to look at these other parts of the electromagnetic spectrum with telescopes.



3.9.1.4 Advantages of large diameter telescopes

Content

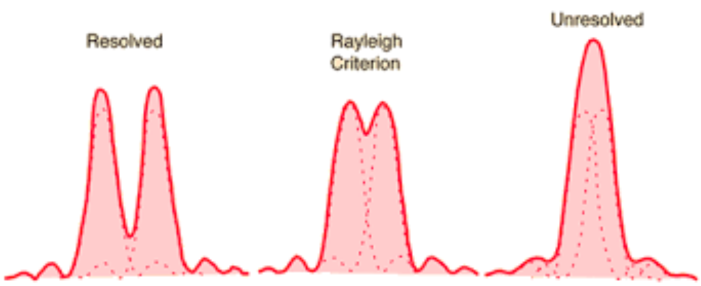
- Minimum angular resolution of telescope.
- Rayleigh criterion, $\theta \approx \frac{\lambda}{D}$
- Collecting power is proportional to *diameter²*.
- Students should be familiar with the rad as the unit of angle.
- Comparison of the eye and CCD as detectors in terms of quantum efficiency, resolution, and convenience of use.
- No knowledge of the structure of the CCD is required.

Minimum angular resolution of telescope.

The minimum angular resolution of a telescope is the minimum distance that two objects can be recognised as separate objects.

Rayleigh criterion $\theta \approx \frac{\lambda}{D}$

This is given by the equation shown above. It is simply that the minimum angular resolution of a telescope is equal to the wavelength of the radiation divided by the diameter. In words, the criterion states that an image will just be resolved if the first minimum of the diffraction pattern of one source coincides with the central maximum of another source. The image below shows different scenarios of interactions of diffraction patterns.



Collecting power is proportional to diameter².

If asked to compare the collecting power of a telescope of diameter 26m, and a telescope of diameter of 13m, you would do $26^2/13^2$. This gives you that the collecting power of the 26m diameter telescope is 4 x larger.

Students should be familiar with the rad as the unit of angle.

One radian is equal to just under 57.3 degrees. The radian is the standard unit of the angle and is represented by the symbol 'rad'.

Comparison of the eye and CCD as detectors in terms of quantum efficiency, resolution, and convenience of use.

The CCD is a silicon chip divided into picture elements, called pixels. Photons of light hit the CCD and excite electrons, causing them to be released from the semiconductor. The number of electrons liberated (and therefore the charge) is proportional to the intensity of the light. These electrons are trapped in 'potential wells', and they produce an electron pattern which is identical to the image formed on the CCD. When exposure is complete the charge is processed to form an image.

Quantum efficiency is the ratio of the number of photons detected to the number of photons incident on a detector. It basically tells us how well a detector can capture photons and make them further available for amplification and imaging. To get a percentage you must multiply this ratio by 100.

The quantum efficiency of a CCD is typically 80%, whereas the quantum efficiency of our eye is less than 1%.

Defining the resolving power of a CCD can not be done using Rayleigh's criterion, like with optical systems. The resolving power is reliant on the number of pixels and their size, relative to the size of the image projected on it. If you have smaller pixels, the resolution will be clearer. On the other hand, the angular resolution of the eye can be found using the Rayleigh criterion. Typically, the angular resolution of the eye is between 2.9×10^{-4} rad and 5.8×10^{-4} rad.

CCD's are very convenient as the images can be stores digitally, and sent around the world instantly for review, and easy retrieval.

No knowledge of the structure of the CCD is required.

3.9.2 Classification of stars

3.9.2.1 Classification by luminosity

Content

- Apparent magnitude, *m*.
- The Hipparchus scale.
- Dimmest visible stars have a magnitude of 6
- Relation between brightness and apparent magnitude. Difference of 1 on magnitude scale is equal to an intensity ratio of 2.51
- Brightness is a subjective scale of measurement.

Apparent magnitude, m.

Apparent magnitude is the brightness of an object as seen from earth. The lower the value of apparent magnitude, the brighter the star.

The Hipparchus scale.

In his scale of apparent magnitude, a smaller number means that the object is brighter. His scale was from 1 to 6, where 1 is the brightest.

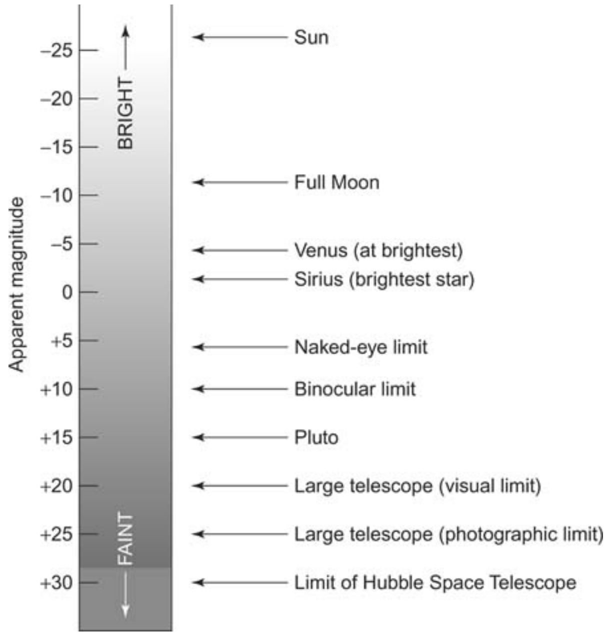
Dimmest visible stars have a magnitude of 6.

This follows on from the last point.

Relation between brightness and apparent magnitude. Difference of 1 on magnitude scale is equal to an intensity ratio of 2.51.

Because of the way light is perceived by an observer, it turns out that equal intervals in brightness are actually equal ratios of light intensity received. Therefore the scale is logarithmic, whereby an increase in one on the apparent magnitude scale corresponds to an increase in intensity by roughly 2.51. So a difference of two on the scale is 2.51^2 and so on. Another thing word noting is that a difference of 5 on the scale (2.51^5) is equal to an increase in intensity of 100. In summary, a second magnitude star is 2.51 times brighter than a third magnitude star, and 6.31 times brighter than a fourth magnitude star. The scale has now been adapted so that the brightest stars on the scale to the human eye can have an apparent magnitude of around -26 (the sun), and the faintest stars around 6. This is because when Hipparchus made the scale, a full definition on what a star actually was had not been made, so with new knowledge that the sun is a star, it has the highest apparent magnitude. Since our eyes have not developed, the dimmest stars of magnitude 6 are still the dimmest.

The diagram below shows the apparent magnitude scale.



Brightness is a subjective scale of measurement.

Brightness is subjective: if ten people were asked to place a number of stars in order, they would more than likely all give different orders. This is an important point to keep in mind as it comes up frequently in exam questions.

3.9.2.2 Absolute magnitude, M

Content

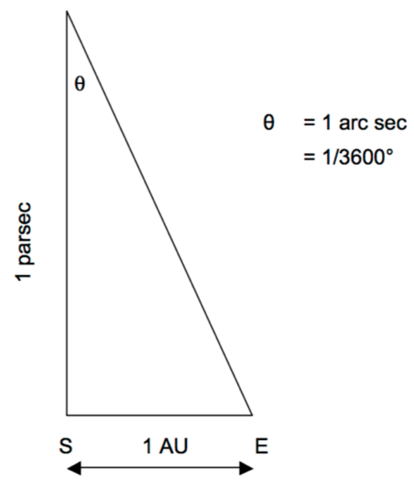
- Parsec and light year
- Definition of M, relation to m, $m - M = 5 \log \frac{d}{10}$

Parsec and light year

The light year is distance travelled by light in a vacuum in one year. It can be converted into metres by multiplying the speed of light in a vacuum (3×10^{8} ms^{-1}) by the the time in one year (365 x 24 x 60 x 60), which gives 9.46×10^{15} m.

The parsec is a unit of measurement equal to 3.08×10^{16} m, or 3.26 light years. One parsec is the distance at which one astronomical unit subtends an angle of one arcsecond. One arcsecond is 1/3600°. One astronomical unit is the mean distance from the Sun to the Earth, which has the value 1.5×10^{11} m.

The diagram below shows how the distance of one parsec is calculated.



Definition of M, relation to m; m – M = 5 log $\frac{d}{10}$

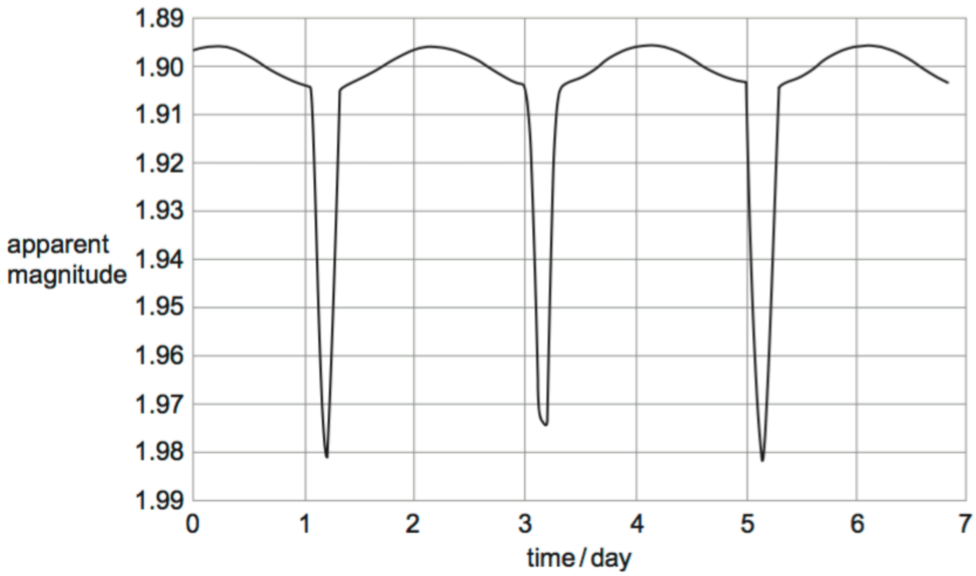
The absolute magnitude of a star is the apparent magnitude it would have at a distance of 10 parsecs from an observer. The equation '$m - M = 5 \log \frac{d}{10}$' relates m to M, where m is the apparent magnitude, M is the absolute magnitude and d is the distance measured in parsecs (pc).

Therefore,Stars which are closer than 10 pc have a brighter (more negative) apparent magnitude than absolute magnitude, and this is the opposite for stars further than 10pc away. If the apparent magnitude is equal to the absolute magnitude, then the star must be 10pc away.

AQA June 2015 Unit 5 Q2c

Menkalinan is an eclipsing binary star system in the constellation of Auriga. **Figure 1** shows the variation in apparent magnitude with time (light curve) for Menkalinan.

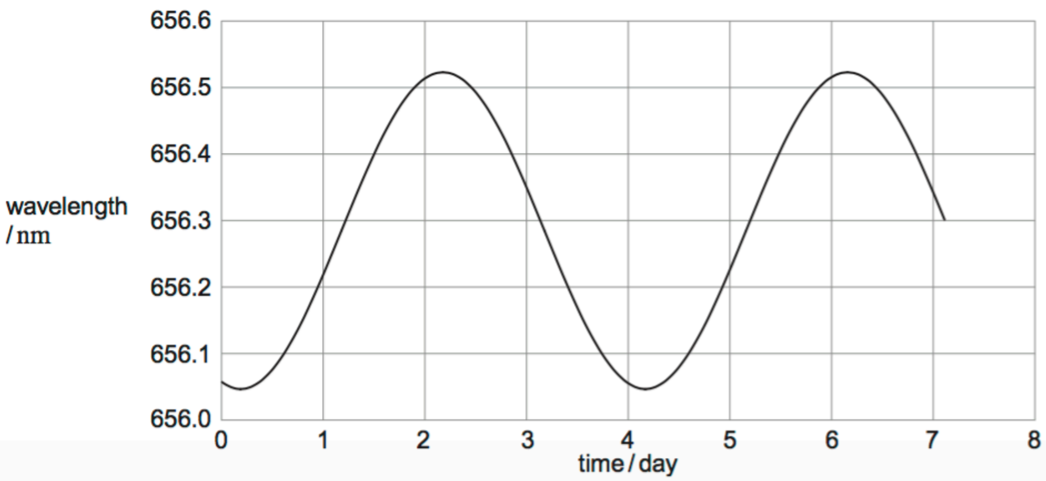
Figure 1



Analysis of the spectrum of one of the stars shows a periodic variation in wavelength

Figure 2 shows the results for one of the spectral lines in the Hydrogen Balmer series. The wavelength for this line as measured for a source in a laboratory on the Earth is 656.28 nm.

Figure 2



Question:

The distance from the Earth to Menkalinan is 7.7×10^{17}.
Calculate the value of the absolute magnitude of Menkalinan when it appears dimmest

Answer:

$m – M = 5 \log (d/10)$
d (in parsec) = $7.7 \times 10^{17} / 3.08 \times 10^{16} = 25$ pc dimmest m = 1.981
dimmest M = $1.981 – 5 \log(25/10) = -0.009$

Exam tips:

WHEN DEALING WITH m-M = 5LOG(d/10) REMEMBER TO CONVERT DISTANCE INTO PARSECS!

ALSO, REMEMBER A LOWER VALUE ON THE APPARENT MAGNITUDE SCALE = BRIGHTER TO THE NAKED EYE AS SEEN FROM EARTH! THIS MEANS THAT AN APPARENT MAGNITUDE OF 1 IS BRIGHTER THAN AN APPARENT MAGNITUDE OF 2.

OCR (A) A Level Specimen 1 Q23a)c)

This isn't directly mentioned in the spec but questions have been asked before that test similar content.

Question:

State and explain how stellar parallax is used to measure distances in space.

Answer:

- Apparent motion or displacement of a star relative to the position of more distant stars
- Caused by the Earth's orbit around the Sun.
- An angle of parallax of 1 arcsecond when displacement of Earth is 1AU corresponds to distance 1 pc

Question:

Suggest why hydrogen spectral lines might often be used to measure a star's velocity

Answer:

Hydrogen is most common element in stars or Hydrogen has most intense (spectral) lines.

Intensity of light from other elements may be too low for accurate measurement

AQA June 2015 Q2c

'The distance from the Earth to Menkalinan is 7.7×10^{17}m.

Calculate the value of the absolute magnitude of Menkalinan when it appears dimmest.'

- M – M = 5 log (d/10)
- D (in parsec) = 7.7 x 10 /3.08 x 10= 25 pc
- Dimmest m = 1.981
- Dimmest M = 1.981 – 5 log(25/10) = -0.009

3.9.2.3 Classification by temperature, black-body radiation

Content

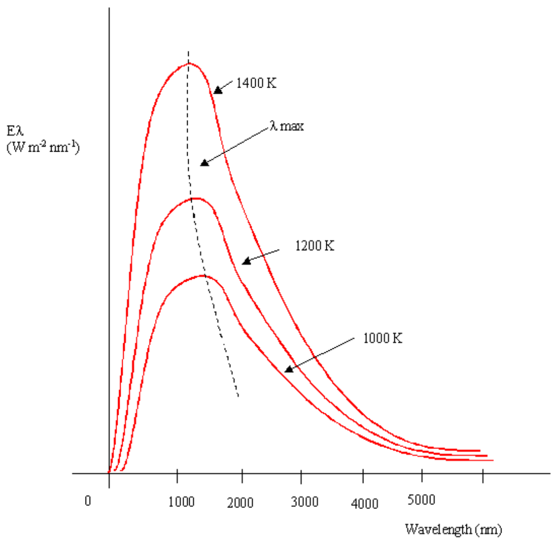
- Stefan's law and Wien's displacement law.
- General shape of black-body curves, use of Wien's displacement law to estimate black-body temperature of sources.
- Experimental verification is not required.
- $\lambda_{MAX}T$ = constant = 2.9×10^{-3} mK.
- Assumption that a star is a black body.
- Inverse square law, assumptions in its application.
- Use of Stefan's law to compare the power output, temperature and size of stars $P = \sigma AT^4$.

Stefan's law and Wien's displacement law.

Stefan's law states that the total thermal energy radiated by a blackbody radiator per second per unit area is proportional to the fourth power of the surface temperature. The equation for Stefan's law is $P = \sigma AT^4$ where P is total energy radiation per second per unit area (power), with unit Watts (W), σ is Stefan's constant with units $Wm^{-2}K^{-4}$, A is surface area (m^2) and T is surface temperature in Kelvin (K). **Wien's displacement law** states that λ_{max} T = constant = 0.0029 mK where 'mK' is the unit of the constant. λ_{MAX} is the wavelength of maximum power output, with the unit metre (m), and T is surface temperature in Kelvin (K).

General shape of black-body curves, use of Wien's displacement law to estimate black-body temperature of sources.

A black-body is a body that absorbs all wavelengths of electromagnetic radiation and can emit all wavelengths of electromagnetic radiation. The area under a black-body curve is the total energy radiated per unit time per unit surface area.



The general shape of a black-body curve is shown above. As temperature of an object increases, the peak of the graph moves towards the shorter wavelengths

It can be used to calculate black-body temperature by taking the value of $\lambda_{max,}$ then doing $0.0029 / \lambda_{max}$ to find T, from the equation $\lambda_{max} T = 2.9 \times 10^{-3}$.

Experimental verification is not required.

$\lambda_{MAX}T$ = constant = 2.9×10^{-3} mK.

$\lambda_{max} T$ = constant = 0.0029 mK where 'mK' is the unit of the constant. λ_{MAX} is the wavelength of maximum power output, with the unit metre (m), and T is surface temperature in Kelvin (K).

Assumption that a star is a black body.

In calculations we assume that stars act as black body's, sometimes questions will ask what assumptions have been made in calculations regarding black bodies.

Inverse square law, assumptions in its application.

Any source that spreads its influence equally in all directions without a limit to its range obeys the inverse square law. Therefore, if the source reduces to a quarter of its original value when distance is doubled, it obeys this law. This law can give information on the intensity of a light source at different distances, so if the sun is used to provide energy for solar cells on a space probe, the equation can be used to determine what happens as the probe gets further from the sun. It can also be used to determine the power output of different objects, for example Doppler shift information suggests some quasars are billions of light years away, then using the inverse-square law it can be shown that the power output of a quasar must be equivalent to that of a whole galaxy.

Assumptions in the inverse square law is that it assumes that no light is absorbed or scattered between the source, and that the observer and the source can be treated as a point.

Use of Stefan's law to compare the power output, temperature and size of stars $P = \sigma AT^4$

This law tells us that, if two stars have the same black body temperature, so are the same spectral class, the star with the brighter absolute magnitude has the larger diameter.

3.9.2.4 Principles of the use of stellar spectral classes

Content

- Description of the main classes:

Spectral class	Intrinsic colour	Temperature / K	Prominent absorption lines
O	blue	25 000 – 50 000	He^+, He, H
B	blue	11 000 – 25 000	He, H
A	blue-white	7 500 – 11 000	H (strongest) ionized metals
F	white	6 000 – 7 500	ionized metals
G	yellow-white	5 000 – 6 000	ionized & neutral metals
K	orange	3 500 – 5 000	neutral metals
M	red	< 3 500	neutral atoms, TiO

- Temperature related to absorption spectra limited to Hydrogen Balmer absorption lines: requirement for atoms in an $n = 2$ state.

Description of the main classes

When the light created within a star passes through its atmosphere absorption of particular wavelengths takes place. This produces gaps in the spectrum of the light from the star resulting in an absorption spectrum. The wavelengths are related to frequency ($c = f\lambda$) and therefore to particular energies ($\Delta E = hf$). Electrons in the atoms and molecules of the star's atmosphere are absorbing the light, and therefore jumping to higher energy levels. The difference in these energy levels are discrete and therefore the frequencies of the absorbed light are discrete

The relationship between temperature and spectra is due to the effect of energy (different temperatures), on the state of the atoms or molecules. At low temperatures the energy may not be high enough to excite atoms, or to break molecular bonds, so you get titanium oxide or just neutral atoms. At higher temperatures atoms may have too much energy to form molecules, to ionisation can take place. Then, the abundance of hydrogen and helium in the atmosphere of the hottest stars mean that their spectral lines dominate.

Temperature related to absorption spectra limited to Hydrogen Balmer absorption lines: requirement for atoms in an n = 2 state.

The electrons begin in the $n = 2$ state, so must first be given enough energy, so must be very hot. To observe Balmer lines, electrons must be in this state, so at high temperatures many electrons are performing Balmer transitions. At very high temperatures, electrons may begin at $n = 3$ or will be ionised, so there will be less transitions, but at low temperatures energy level changes are rare.

AQA June 2015 Q2b

Question:

'The black body temperature of each star is approximately 9200 K.

Explain why a Hydrogen Balmer line was chosen for the analysis of wavelength variation.'

Answer:

- The temperature (9200K) indicates that the star is in spectral class A.
- Hydrogen Balmer lines are strongest in A class stars and therefore would be more easily measured.

Edexcel AS Paper 1 Specimen Q14b

Question:

When the light from a star is dispersed to form a spectrum, dark lines are seen at a number of frequencies. This is known as an absorption spectrum and is caused by the presence of certain elements in the star.

Explain how the absorption spectrum is created.

Answer:

- If photon energy is equal to an energy level difference (ground state to n=1 for instance) in the elements present
- Then the photon can be absorbed by an electron and the electron is excited/moves to higher level
- So the absorption spectrum is created because the frequencies of the absorbed photons are missing from the continuous spectrum produced by the star.

AQA June 2007 Unit 5

Question:

Describe how Balmer absorption lines are produced.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

Answer:

- Hydrogen (in atmosphere of star) has electrons in n = 2 state
- Light of particular frequencies (from star passing through atmosphere) is absorbed corresponding to energy differences between orbits (e = hf)

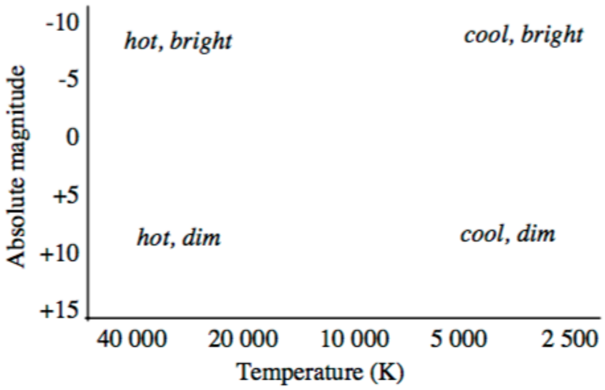
- When electrons return to lower energy states, energy released in all directions so reduced intensity in original direction (or different frequencies emitted as electrons can return to lower states in different steps)
- Producing gaps in spectra

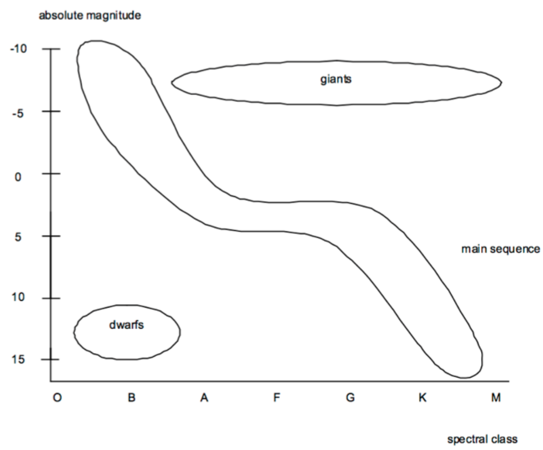
3.9.2.5 The Hertzsprung-Russell (HR) diagram

Content

- General shape: main sequence, dwarfs and giants.
- Axis scales range from –10 to +15 (absolute magnitude) and 50 000 K to 2 500 K (temperature) or OBAFGKM (spectral class).
- Students should be familiar with the position of the Sun on the HR diagram.
- Stellar evolution: path of a star similar to our Sun on the HR diagram from formation to white dwarf.

General shape: main sequence, dwarfs and giants.





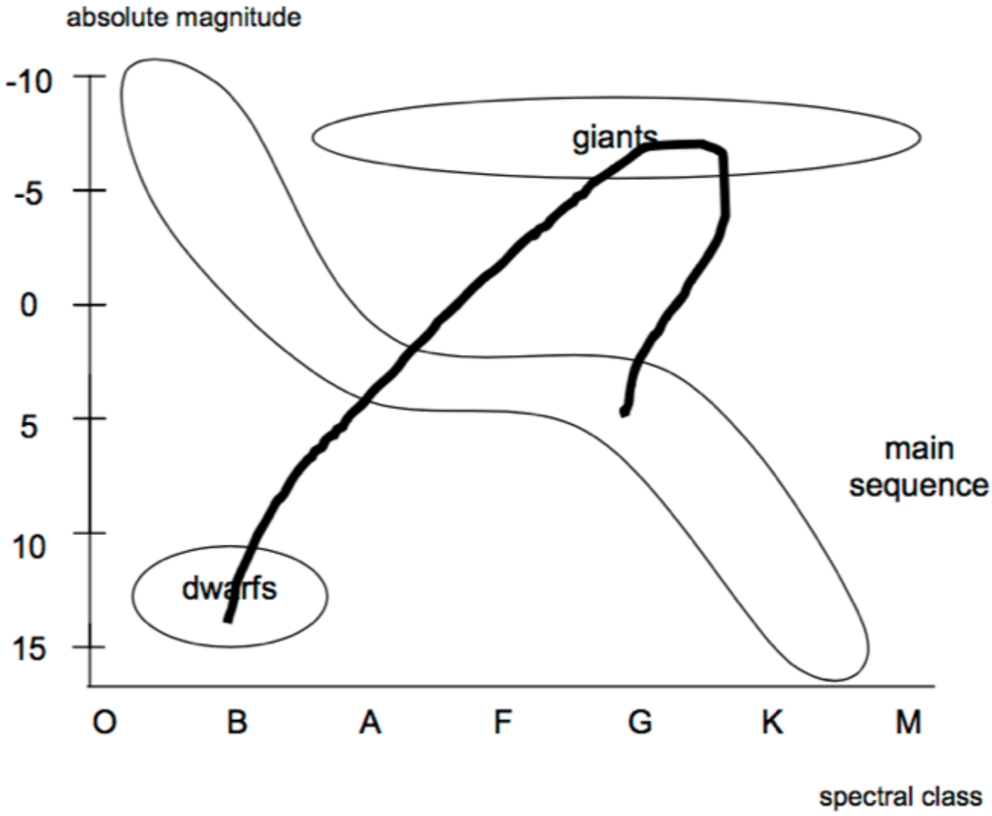
The Hertzsprung-Russell diagram has +15 at bottom of y axis and -10 at top, where the y axis is absolute magnitude. The graph is flat between the absolute magnitudes of 0 and 5. The sun lies at G on the x axis, and a value of around +5 on the y axis. The x axis will either be spectral class or absolute temperature in Kelvin. The x axis must begin at 50,000K at O, and finish on 2500K on the far right of the axis, just further than M. The scale falls from 50000 to 20000, 10000, 5000 and then finally 2500. The value of 20,000 will be just to the right of B, 10,000 will be slightly closer to F than A, 5000 will be just to the right of G (the star has a surface temperature of around 6000K and so lies at G. The 2500 will lie just to the right of M.

Students should be familiar with the position of the Sun on the HR diagram.

As already mentioned, the position of the star is at an absolute magnitude of +5, and spectral class G.

Stellar evolution: path of a star similar to our Sun on the HR diagram from formation to white dwarf.

The graph below shows the path of a star similar to our sun on the HR diagram.



AQA June 2015 Unit 5 Q3bi)ii)

Question:

Which of the following regions of the Hertzsprung-Russell diagram does 40 Eridani B belong to? (We already know its surface temperature to be approximately 1.6×10^4 K, its radius is around 9.5×10^6 and that its power output is around 4.2×10^{24} W)

Answer:

- It has a high temperature
- But is relatively small, so it will have a low absolute magnitude

(This puts it into the bottom left region of the HR diagram)

Also when thinking about its 'relative size', its radius is comparable to that of the Earth, thus it is relatively small, compared to the Sun, for instance.

3.9.2.6 Supernovae, neutron stars and black holes

Content

- Defining properties: rapid increase in absolute magnitude of supernovae; composition and density of neutron stars; escape velocity > *c* for black holes.
- Gamma ray bursts due to the collapse of supergiant stars to form neutron stars or black holes.
- Comparison of energy output with total energy output of the Sun.
- Use of type 1a supernovae as standard candles to determine distances. Controversy concerning accelerating Universe and dark energy.
- Students should be familiar with the light curve of typical type 1a supernovae.
- Supermassive black holes at the centre of galaxies.
- Calculation of the radius of the event horizon for a black hole, Schwarzschild radius (R_S), $R_S \approx 2GM/c^2$.

Defining properties: rapid increase in absolute magnitude of supernovae; composition and density of neutron stars; escape velocity > c for black holes.

One of the defining properties of **supernovae** is that they have a rapid increase in absolute magnitude, so a rapid increase of brightness of the star. The defining properties of neutrons stars are that they are extremely dense, with a density of nuclear matter (neutrons) and are relatively small i.e. only 12km in diameter. They have very strong magnetic fields so are powerful radio sources, and combined with their spinning produce pulsars. For black holes, their escape velocity is greater than the speed of light, so even light cannot escape black holes. The boundary at which the escape velocity is equal to the speed of light is called the Event Horizon. The radius of the event horizon is called the Schwarzschild radius, R_s. The density of black holes however, is not very large, and actually the more massive a black hole, the less dense it is.

Gamma ray bursts due to the collapse of supergiant stars to form neutron stars or black holes.

As a supergiant star runs out of nuclear fuel (in the form of Hydrogen), its mass begins to flood into its core. Eventually this results in a core far too heavy, such that the core cannot withstand its own gravitational force. An intense and incredibly bright gamma ray burst will follow, ejecting most of its mass in this process too. What you are left with will either be a neutron star or a black hole.

Comparison of energy output with total energy output of the Sun.

Energy output of a (type 1a) supernovae may be 10 billion times that of the sun.

Use of type 1a supernovae as standard candles to determine distances. Controversy concerning accelerating Universe and dark energy.

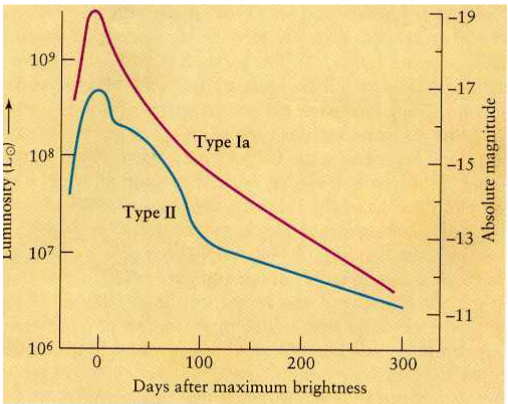
A type 1a supernovae is known as a standard candle, characterised by the fact their absolute magnitude always peaks at the same value and is always known. These types of supernovae are also characterised by a massive increase in brightness and exhibit a rapid decrease in 'value' of absolute magnitude. Their apparent magnitude can also be measured, so the equation m – M = 5log(d/10) can be used to calculate the distance in parsecs to the supernovae. The peak absolute magnitude value is -19.3, and it occurs after around 20 days.

Type 1a supernovae are due to an exploding white dwarf star which is part of a binary star system. The white dwarf increases in mass as it attracts material from its companion, and eventually reaches a size which allows fusion to start again, which causes the star to explode. This occurs when the star reaches a critical mass and produces a very consistent light curve.

However, there is some controversy regarding evidence that the universe seems to be accelerating at faster than the speed of light. This evidence comes from the red shift of galaxies, so 'dark energy' has been determined the culprit of this. There is however, another piece of controversy, as nothing is known about 'dark energy' as it could just be a fudge factor.

Students should be familiar with the light curve of typical type 1a supernovae.

The picture below illustrates a light curve for a typical type 1a supernovae, as well as a type II although you do not need to know about type II supernovae. The absolute magnitude peaks at around -19.3, usually occurring after approximately 20 days.



http://www2.arnes.si/~gljsentvid10/snove.html Supermassive black holes at the centre of galaxies.

It is said that there is a supermassive black hole at the centre of all galaxies. These black holes may have the mass several millions of times the mass of the sun.

Calculation of the radius of the event horizon for a black hole, Schwarzschild radius (R_S), $R_S \approx 2GM/c^2$.

This equation gives the calculation of the radius of the event horizon for a black hole.

Edexcel June 2010 Unit 6 Q3a

Question:

In 2006 astronomers determined a new value for the Hubble constant. They calculated the velocity of recession v for a number of stars at a distance d from the Earth. They used units of kms^{-1} for v and Mpc (Megaparsecs) for d.

What might an astronomer actually measure to calculate a value for v?

Answer:

- Red shift
- OR Doppler shift
- OR frequency of electromagnetic radiation/light
- OR wavelength of electromagnetic radiation/light

3.9.3 Cosmology

3.9.3.1 Doppler effect

Content

- $\frac{\Delta f}{f} = \frac{v}{c}$ and $z = \frac{\Delta \lambda}{\lambda} = -\frac{v}{c}$ for v << c applied to optical and radio frequencies
- Calculations on binary stars viewed in the plane of orbit.
- Galaxies and quasars.

$\frac{\Delta f}{f} = \frac{v}{c}$ and $z = \frac{\Delta \lambda}{\lambda} = -\frac{v}{c}$ ***for v << c applied to optical and radio frequencies***

The Doppler effect occurs in everyday life, for example when an ambulance passes you the change in pitch of the siren demonstrates this. As the ambulance travels towards you, the sound waves 'bunch' together, so essentially their wavelength decreases thus frequency increases as they travel at the same speed and c = fλ. The opposite occurs as the ambulance travels away from you.

This effect can also be applied to light, however in everyday situations the effect is not noticeable. An observer would be required to travel at very fast speeds, close to the speed of light, to observe these effects.

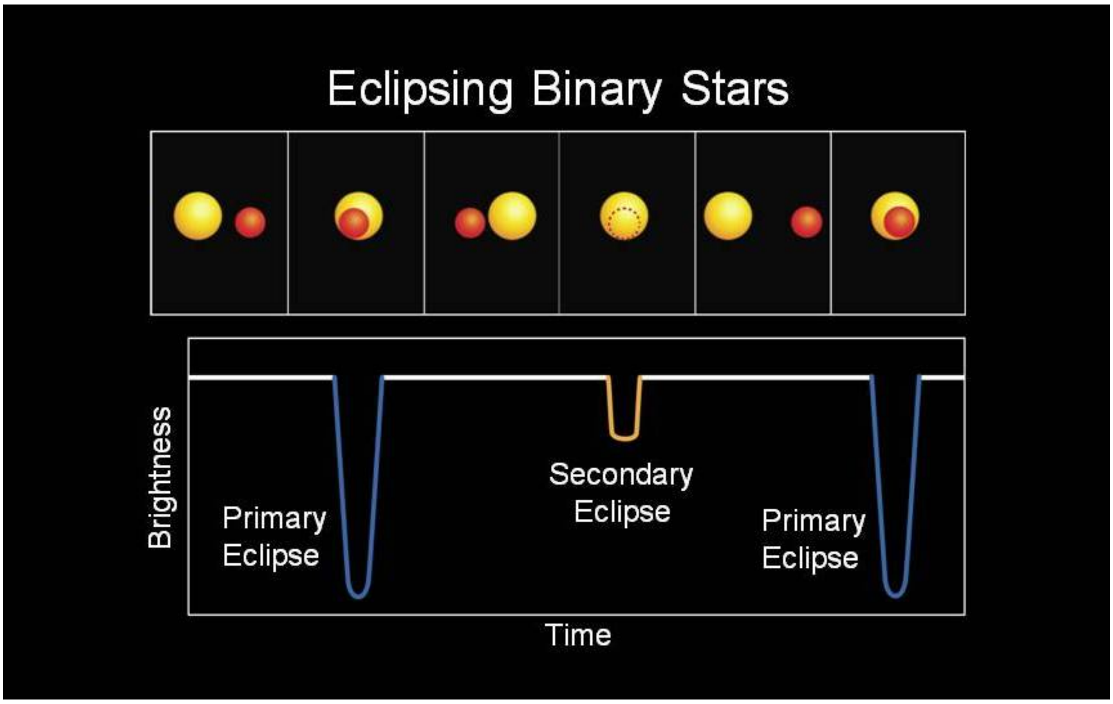
Redshift is a phenomenon that describes what occurs when the source of the light is moving away from the observer. This is because the wavelength appears to stretch out, ie increase, and red is at the longer wavelength end of the visible spectrum hence the name redshift.

You can calculate redshift, denoted by the symbol z, by z = Δf/f = v/c, where v is the speed of the source, and Δf is the change in frequency both with their usual units. Redshift can also be calculated in terms of wavelength, by using the equation Δλ/λ = -v/c. Remember that velocity towards the observer is taken to be positive, so for objects moving towards you they will have a negative redshift. Redshift is the apparent shift to longer wavelengths, but for approaching sources the wavelength decreases so this is why there needs to be a negative sign. If the equation were to simply describe the Doppler shift, then this would not be necessary. Also, it is important to note that redshift has no units, as it is a ratio of two quantities with the same units.

Calculations on binary stars viewed in the plane of orbit.

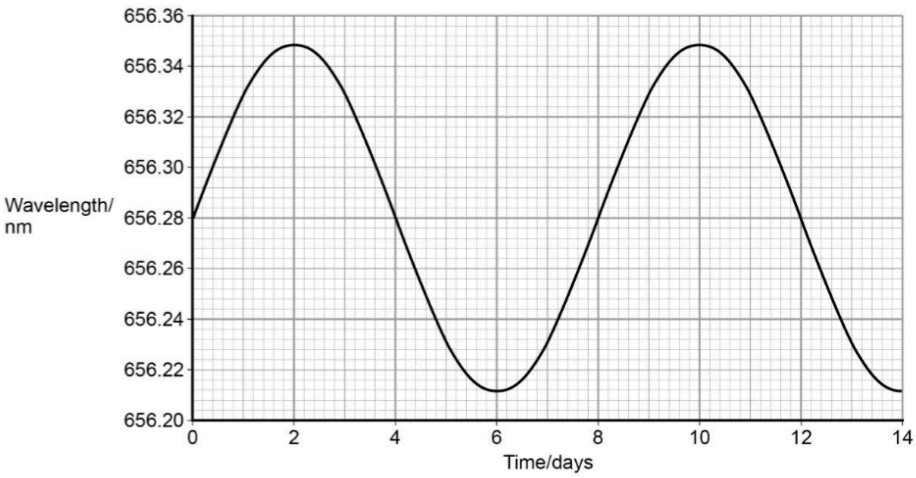
A binary star system is a system of two stars rotating about a common centre of mass. The Doppler effect can be used in cosmology when studying an eclipsing binary star system, when one star passes in front of another, we can observe an eclipse, ie a dip in the brightness received (a higher value of apparent magnitude).

The example below shows two stars that emit different amounts of light (ie have a different surface temperature $P = \sigma A T^4$. When the apparent magnitude is at it lowest value, so brightness is highest, both stars can be seen. This diagram below gives the apparent magnitude and corresponding positions of the stars.



https://www.nasa.gov/mission_pages/kepler/news/kepler-34-35.html

The two stars A (orange) and B (red) are orbiting around a common centre of mass, thus each star will orbit around a given point. This means that you are able to observe a Doppler shift on each star. Take for example, star A, as it orbits around the common centre of mass. To an observer from Earth, at given times star A would appear to be retreating relative to the Earth, and at other times towards the Earth as it orbits. This observable change in wavelength can be measured and plotted on a graph of wavelength against time.



http://filestore.aqa.org.uk/resources/physics/AQA-7407-7408-TG-A.PDF

When the maximum wavelength is reached, the star is receding from the observer at its maximum velocity. At this point the two stars are next to each other. Also, the orbital period of the star would be 8 days (one full cycle). You can calculate the recessional velocity by using $\Delta\lambda/\lambda = -v/c$, with $\Delta\lambda = (656.35 - 656.28) \times 3 \times 10^8 / 656.28 = 3.2 \times 10^4$ ms^{-1}.

If you also know the time period, you can calculate the diameter of the orbit using the circular motion equation $\omega = v/r$, which can be rearranged to $2\pi r = vT$ (using $\omega = 2\pi/T$). So $3.2 \times 10^4 \times 8 \times 24 \times 3600 = 2.21 \times 10^{10}$ m. Thus diameter = 7.04×10^9 m.

These calculations can only be applied to binary stars viewed in the same geometrical plane of orbit.

Galaxies and quasars

Some of the largest red shifts measured are those of the quasars. 'Quasi-stellar radio sources' are star-like objects with a very strong radio emission. This is where the name quasars came from. Although it was realised that the large majority of quasars were not predominantly radio emitters, so quasars are now referred to as 'quasi-stellar objects'. Tens of thousands of quasars have been discovered, with most predominantly emitting their energy in the infrared region of the electromagnetic spectrum. More detail on quasars is given in 3.9.3.3.

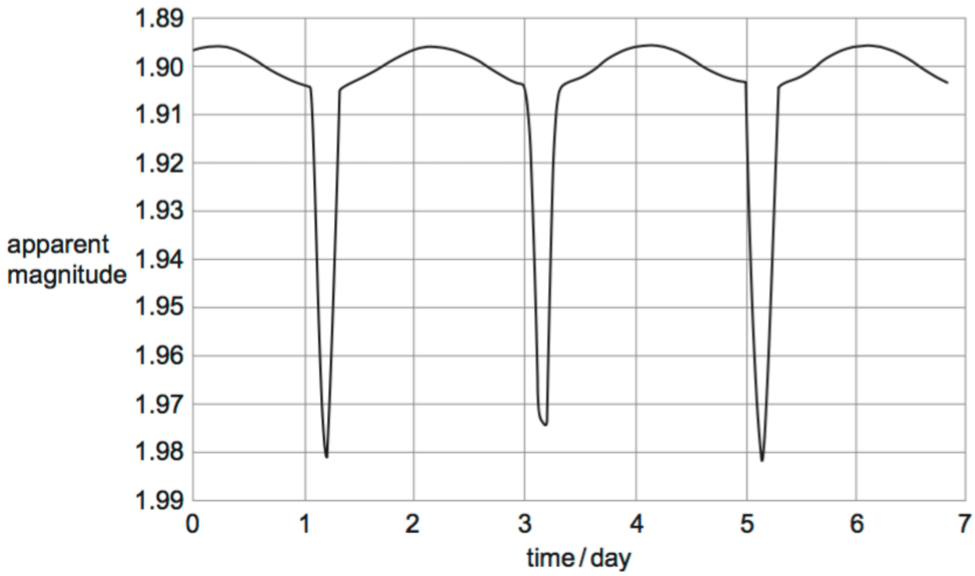
In terms of galaxies, the stars contained within very distant galaxies can not be resolved individually, thus only the behaviour of the galaxy can be studied. The spectrum of light absorbed on Earth from these galaxies are usually always significantly redshifted. This gives the indication that the universe is expanding.

The redshift of galaxies and quasars can be calculated as the ratio of the objects (ie the galaxy's) recession velocity to the speed of light. This is represented as $z = -v/c$. The z is a positive number for redshifts because the recessional velocity is a negative number, making the equation positive.

AQA June 2015 Unit 5 Q2ab

Menkalinan is an eclipsing binary star system in the constellation of Auriga. **Figure 1** shows the variation in apparent magnitude with time (light curve) for Menkalinan.

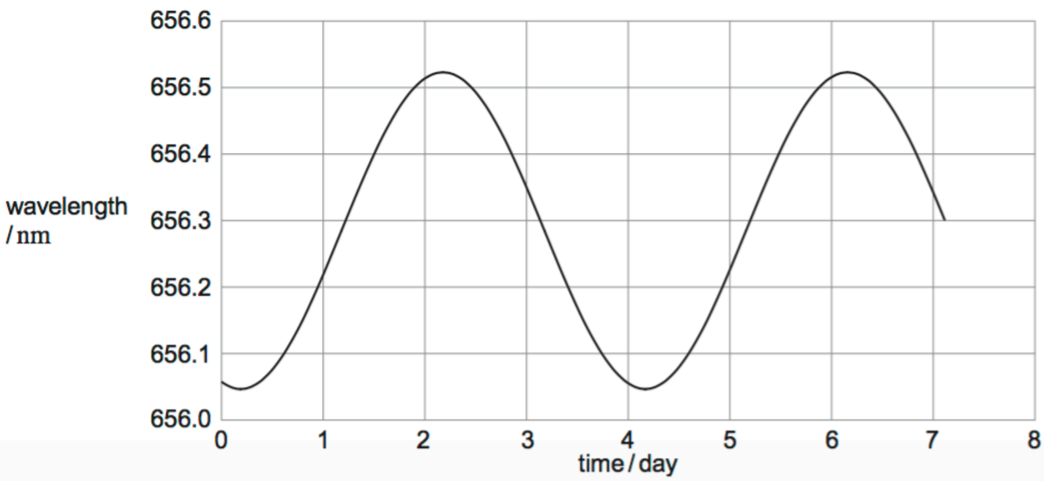
Figure 1



Analysis of the spectrum of one of the stars shows a periodic variation in wavelength

Figure 2 shows the results for one of the spectral lines in the Hydrogen Balmer series. The wavelength for this line as measured for a source in a laboratory on the Earth is 656.28 nm.

Figure 2



Question:

Describe the physical processes that give rise to the shape of each graph. Go on to show how the information in the graphs can be used to determine properties, such as the speed and period, of the Menkalinan binary system. You should include appropriate calculations in your answer.

The quality of your written communication will be assessed in your answer.

Answer:

'The explanations expected in a good answer should include most of the following physics ideas'

- The time period, T, is the time from the first dip in the light curve to the third dip.
- This is approximately 4 days
- This is one full cycle for the wavelength graph.
- One full cycle is approximately 4 days.
- When one star passes in front of the other the amount of light received changes.
- The brightest (lowest value of) apparent magnitude occurs when both stars can be seen.
- The dips occur when one star is in front of the other.
- The similarity in the dips suggests that both stars have similar temperatures/sizes
- The variation in wavelength is due to the Doppler effect.
- The peaks and troughs occur when the stars are moving at their greatest velocity away from / towards us.
- The biggest change in wavelength is 656.52 nm - 656.28 nm = 0.24 nm
- The orbital speed, is therefore $\Delta\lambda$ x c /λ
- = 0.24 x 3 x 108/656.28 = 1.1 x 10^5 ms-1
- The orbital radius is therefore v/(2π/T) = 6.1 x 10^9 m

Question:

The black body temperature of each star is approximately 9200 K.
Explain why a Hydrogen Balmer line was chosen for the analysis of wavelength variation

Answer:

- The temperature (9200K) indicates that the star is in spectral class A.
- Hydrogen Balmer lines are strongest in A class stars and therefore would be more easily measured

Exam tip:

GIVE SPECIFIC DETAILS, FOR EXAMPLE, THAT 9200K IS ASSOCIATED WITH SPECTRAL CLASS A!

AQA June 2007 Unit 5 Q5

Explain what is meant by

Question:

A white dwarf,

Answer:

- collapsed core of giant star
- OB class, therefore hot (therefore white)
- high value of absolute magnitude, therefore dim (therefore small) star

Question:

Quasar,

Answer:

- Very large power output
- Large shift or very distant
- Small for its power output or rapid variations in power output

3.9.3.2 Hubble's law

Content

- Red shift $v = Hd$
- Simple interpretation as expansion of universe; estimation of age of universe, assuming H is constant.
- Qualitative treatment of Big Bang theory including evidence from cosmological microwave background radiation, and relative abundance of hydrogen and helium.

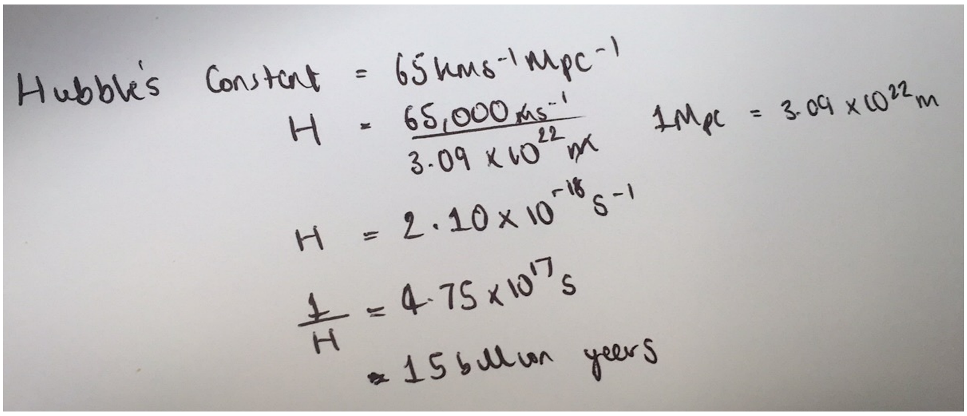
Red shift v = Hd

The equation v = Hd is referred to as Hubble's Law. It states the relationship with recessive velocity and distance to the galaxy. v is recessive velocity and d is distance to the galaxy. H is Hubble's constant, the currently accepted value is $65 kms^{-1}Mpc^{-1}$. Thus for this constant, the units used for velocity are kms^{-1} and for distance mega parsecs (Mpc). Drawing a graph of velocity against distance and calculating the gradient will give you Hubble's constant.

Simple interpretation as expansion of universe; estimation of age of universe, assuming H is constant.

The basic interpretation of a graph of velocity against distance is that the universe is expanding. The further away the galaxy, the faster it moves, so for every distant galaxy it will seem as if the galaxy in front is moving away from it at a faster speed. This does suggest however, that the expansion rate is constant but recent observations suggest that the galaxies are accelerating away from each other. And so consequently, the rate of expansion of the universe is increasing.

The picture below illustrates how you can calculate an estimate for the age of the universe using Hubble's constant, and assuming H is in fact, constant. I have used $H = 65kms^{-1}Mpc^{-1}$, other values may be used in other examples.



Only if the universe has expanded at a constant rate H is a constant. Using Type 1a supernovae as standard candles, distant galaxies have been shown to be less bright than originally predicted. The data suggest in fact, that the rate of expansion is not only increasing, but accelerating. The constant would therefore not hold true, and the actual age of the universe would be much older. Cosmologists have stipulated that '**dark energy**' is the cause of this expansion, and that the energy exerts a repulsive force within the universe that causes apparently void space to expand. Its influence must then grow as the universe expands.

Qualitative treatment of Big Bang theory including evidence from cosmological microwave background radiation, and relative abundance of hydrogen and helium.

Evidence comes from two main sources, outlined below:

1. One piece of evidence states that the high energy gamma electromagnetic radiation produced shortly after the Big Bang, should have over time been redshifted to wavelengths in the microwave region. This radiation should fill the universe, and was detected inadvertently in the 1960s. Later experiments showed that the black-body temperature was around 2.73K, which is what should be expected if the radiation were to be emitted in the gamma region soon after the Big Bang. Also, the distribution of the radiation is not completely uniform, which supports the idea that these variations in energy-density allowed for gravitational forces to act and go on to produce the galaxies we now see. From the evidence a more accurate age of the universe – 13.7 billion years, was put forward.
2. The universe is around 73% hydrogen and 25% helium, so the ratio of helium to hydrogen is around 3:1. These results are consistent with the predictions by the model. Helium is produced by nuclear fusion but this requires extremely hot temperatures, so as the temperature drops the ability to fuse elements is diminished, resulting in the relative abundance of 3:1, with around 2% of the universe being made of other elements. All other elements were produced within stars by later fusion-processes.

Other indirect evidence for the Big Bang is Hubble's relationship, which supports the idea of an expanding universe via red shift observations of distant galaxies.

AQA June 2014 Section 5 Q2a

Question:

'The term Big Bang was first used in 1949 by the astronomer Fred Hoyle to refer to, what was then, a controversial theory describing the formation of the Universe.

Explain what is meant by the Big Bang theory. Your answer should include:

- A description of the main aspects of the theory
- An explanation of the different pieces of evidence that support the theory.

The quality of written communication will be assessed as part of your answer.'

Answer:

For 6 marks:

- **Examples of the points made in the response:**
- The universe has expanded from a single hot dense point
- This expansion started approximately 13 billion years ago.
- Evidence comes from the Hubble relationship and observations of the red shift of distant galaxies.
- This shows that the galaxies are moving outwards from a single common point.
- (Conclusive) evidence comes from the cosmological microwave background radiation (which disproved the steady state theory)
- This follows a black body radiation curve which corresponds to a temperature of 2.7 K
- This can be interpreted as the left over "heat" of the big bang,
- Hydrogen and helium is present in the Universe in the ratio 3:1
- This supports the idea that a very brief period of fusion occurred when the Universe was very young, which is consistent with the Big Bang theory.

The information conveyed by the answer is clearly organised, logical and coherent using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.
The candidate describes the big bang theory as the Universe expanding from an extremely dense and hot point over the past 13.6 billion years. The candidate also describes the evidence from, the relative abundances of H and He and the measurement of the microwave background radiation and states they support the big bang theory. Hubble's Law may also be used to support the idea that the Universe is expanding

OCR (A) A Level Specimen 1

Question:

The Big Bang theory is an explanation for the start of the Universe.

Explain how the cosmic microwave background radiation supports the Big Bang theory for the start of the Universe. Comment on the relevance of the data in **Fig. 23.1** concerning the Big Bang theory

Answer:

Big Bang theory

- Predicts that all galaxies will be receding.
- Galaxy velocity proportional to distance from

Red Shift

- Radiation from Virgo shows increase in wavelength or red shift
  Change in wavelength caused by motion of galaxy or reference to Doppler Effect
- Evidence that Virgo is receding from Earth.
- Support for Big Bang theory.

Blue Shift

- Andromeda shows blue shift
- Andromeda approaching Earth
- Caused by gravitational attraction.

CMBR

- Formed as gamma radiation at Big Bang
- Galactic red shift to microwave wavelength
- Intensity is uniform in all directions
- Corresponds to a temperature of 2.7K
- (Very small) ripples in intensity corresponding to formation of first stars or galaxies.

AQA June 2015 Unit 5 Q4c

Question:

NGC 3842 is 3.3×10^8 light years from the Earth, and is receding at a velocity of 6.3×10^6 ms^{-1}

Answer:

The easiest way to calculate this is to have v in the units 'ms^{-1}' and distance in 'm', as shown below.

so $H = \frac{v}{d}$ so $\frac{ms^{-1}}{m} = s^{-1}$

$\therefore$ $$H = \frac{6.3 \times 10^6 \ ms^{-1}}{[(3.3 \times 10^8) \times (9.46 \times 10^{15})] \ m}$$

$$H = 2.02.. \times 10^{-15} \ s^{-1}$$

$$\frac{1}{H} \simeq 5.0 \times 10^{17} \ s$$

3.9.3.3 Quasars

Content

- Quasars as the most distant measurable objects.
- Discovery of quasars as bright radio sources.
- Quasars show large optical red shifts; estimation involving distance and power output.
- Formation of quasars from active supermassive black holes.

Quasars as the most distant measurable objects.

We also now know that quasars are the some of the most distant objects because of their very larger redshift. Applying the inverse-square law to the light enables predictions of the power output of quasars to be the equivalent to the power output of multiple galaxies.

Discovery of quasars as bright radio sources

Quasars were actually first discovered as extremely powerful radio sources; as optical telescopes were unable to resolve these objects.

Quasars show large optical red shifts; estimation involving distance and power output

Quasars show large optical redshifts; these suggest they are travelling at speeds of well above 0.1x the speed of light. One example is that of Quasar 3C 273, whose hydrogen Balmer lines measure at a wavelength of roughly 760nm, whereas the value on Earth of these same Balmer lines gives a value of 656nm. The redshift value is given at 0.16 and its distance is around 650Mpc away.

Their typical power output tens to be around **10^{42}W**.

Formation of quasars from active supermassive black holes.

Quasars are believed to come from active supermassive black holes present in young active galaxies. The supermassive black hole draws in a vast amount of matter in something called an acceleration disc. Matter spins around in this disc and continually accelerates. As it spins faster, it will gain more kinetic energy and will heat up. As the matter warms, it rubs against other bits of matter to which there is friction between, and this gives us what we perceive to be visible light.

3.9.3.4 Detection of exoplanets

Content

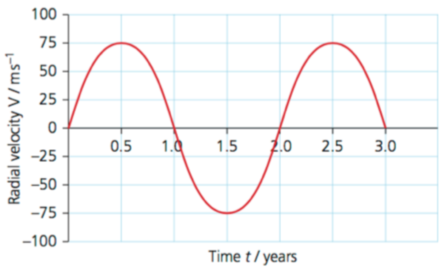
- Difficulties in the direct detection of exoplanets.
- Detection techniques will be limited to variation in Doppler shift (radial velocity method) and the transit method.
- Typical light curve.

Difficulties in the direct detection of exoplanets.

To begin, exoplanets are planets that orbit a star other than the Sun. What makes them difficult to detect is that, like our planet, they give off almost no light relative to the luminosity of the star they orbit. The only significant light that gives away their existence is light from the star that they orbit which reflects off them.

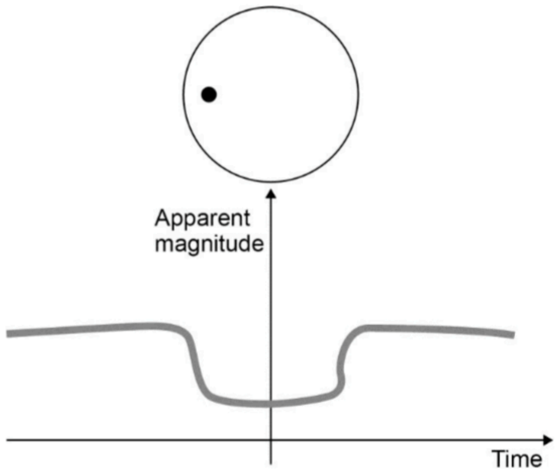
Detection techniques will be limited to variation in Doppler shift (radial velocity method) and the transit method.

- The **radial velocity method** relies on the fact both the star and planet orbit around a common centre of mass. For our solar system, the common centre of mass actually lies within the sun, so clearly the orbit of the sun around this point is not very visible. The Doppler shift can be measured in the light from the star as it 'wobbles' about this point, where differences in the spectral lines from usual values shows this shift.
- The radial velocity curve shows the velocity of the star; an example is given below. The period of the exoplanet will be the same as the period of the star on the curve.



http://resources.collins.co.uk/Wesbite%20images/AQA/Physics/sb2module/9780007597642_Astrophysics.pdf

- The transit method involves the dimming of its apparent magnitude (increase in value), as the brightness of a star decreases when an exoplanet travels across its face. When a planet passes in front of a star to an observer on Earth, the event is described as a 'transit'.



http://filestore.aqa.org.uk/resources/physics/AQA-7407-7408-TG-A.PDF

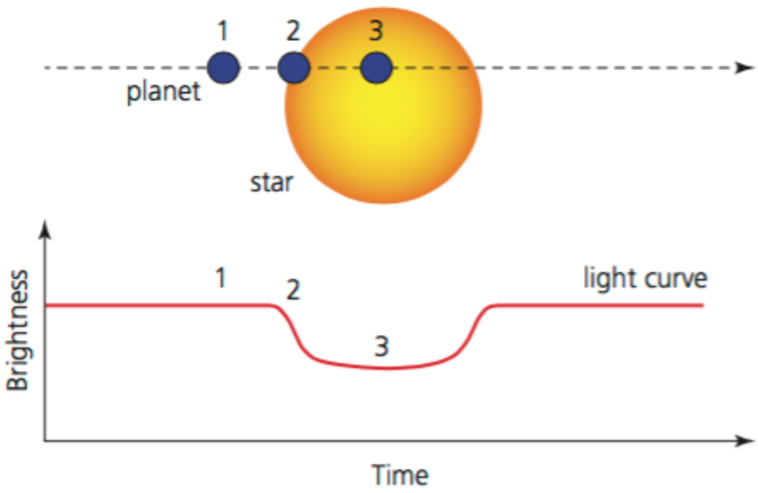
- The graph above, of apparent magnitude against time is called a light curve. It illustrates the dimming of apparent magnitude as a planet transits a star.
- There will be a fractional drop in brightness, that will be in proportion to the size of the planet. You can find the area of the star that must be occupied for this fractional drop in brightness to occur.

Example: A star of diameter 10^{24} m dips in brightness by 0.001% when an exoplanet transits. Calculate the radius of the exoplanet.

- Area of star $\pi \times (10^{12})^2 = 3.14 \times 10^{12}\ m^2$
- Brightness dip of 0.001% so this means that 0.001% of the area is being blocked by the exoplanet.
- $3.14 \times 10^{12} \times 0.001\%$ = area of exoplanet
- So $3.14 \times 10^{7}\ m^2 = \pi (r_{exoplanet})^2$
- So rearrange for $r_{exoplanet} = 3.16 \times 10^{3}$ m

Typical light curve

A typical light curve is shown below, and the corresponding positions of the exoplanet whilst in the transit.



AQA Paper 3B Section 'A' Specimen Paper 2014 Q4.123

Question 4.1

'In 1999 a planet was discovered orbiting a star in the constellation of Pegasus.

State one reason why it is difficult to make a direct observation of this planet.'

Answer 4.1

- Star much brighter than reflected light from planet
- Planet very small and distant – subtends very small angle compared to resolution of telescopes

Question 4.2

'The initial discovery of the planet was made using the radial velocity method which involved measuring a Doppler shift in the spectrum of the star.

Explain how an orbiting planet causes a Doppler shift in the spectrum of a star'

Answer 4.2.

- Planet and star orbit around common centre of mass that means the star to moves towards/away from Earth as planet orbits
- Causes shift in wavelength of light received from star

Question 4.3

'The discovery was confirmed by measuring the variation in the apparent magnitude of the star over a period of time.

Explain how an orbiting planet causes a change in the apparent magnitude of a star. Sketch a graph of apparent magnitude against time (a light curve) as part of your answer.'

Answer 4.3

- Light curve showing constant value with dip
- When planet passes in front of star (as seen from Earth), some of the light from star is absorbed and therefore the amount of light reaching Earth reduced
- Apparent magnitude is a measure of the amount of light reaching Earth from the star

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