OCR (A) A-Level Physics

5.5 Astrophysics and Cosmology

Flashcards

Define planets.

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Objects with mass sufficient for their own gravity to force them to take a spherical shape, where no nuclear fusion occurs, and the object has cleared its orbit of other objects.

Define dwarf planets.

PMT
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Define dwarf planets.

Planets where the orbit has not been cleared of other objects.

Define planetary satellites.

Define planetary satellites.

Bodies that orbit a planet.

Define asteroids.

Define asteroids.

Objects which are too small and uneven in shape to be planets, with a near circular orbit around the sun.

Define comets.

Define comets.

Small, irregularly sized balls of rock, dust, and ice. They orbit the sun in eccentric elliptical orbits.

Define Solar systems.

Define Solar systems.

The systems containing stars and orbiting objects like planets.

Define galaxies.

Define galaxies.

A collection of stars, dust, and gas. Each galaxy contains around 100 billion stars and is thought to have a supermassive black hole at its centre.

Define nebulae.

Define nebulae.

Gigantic clouds of dust and gas. They are the birthplace of all stars.

How are protostars formed?

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In nebulae, there are regions that are more dense than others. Over time, gravity draws matter towards them and, combined with the conservation of angular momentum, causes them to spin inwards to form a denser centre.

GPE is converted into thermal energy, which heats up the centre. The resultant sphere of very hot, dense dust and gas is a protostar.

How are main sequence stars formed from protostars?

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For a star to form, the temperature and pressure must be high enough for hydrogen gas nuclei in the protostar to overcome the electrostatic forces of repulsion and undergo nuclear fusion to convert hydrogen into helium. When fusion begins, the protostar becomes a main sequence star, where the outward pressure due to fusion and the inward force of gravity are in equilibrium.

Describe how a low-mass main sequence star becomes a red giant.

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Low-mass stars are classed as having a core mass between 0.5M☉ and 10M☉. As these stars have a smaller, cooler core, they remain in the main sequence for longer. Once the hydrogen supplies are low, the gravitational forces inwards overcome the radiation and gas pressures, so the core collapses inwards and the outer layers expand and cool. The core of the red giant becomes hotter (as GPE becomes thermal energy) and begins to fuse helium into heavier elements (up to carbon), as hydrogen continues to be fused in the layers around the core.

Describe the evolution of a red giant to a white dwarf.

Describe the evolution of a red giant to a white dwarf

When the star runs out of fuel, it expels its outer layers, creating a planetary nebula. The core that remains contracts further, becoming a dense white dwarf. The white dwarf has a temperature of around 3000K, and no fusion occurs. Photons which were produced earlier in the evolution leak out, dissipating heat.

As the star core collapses, electron degeneracy pressure (caused as two electrons cannot exist in the same state) prevents the core from collapsing. As long as the core mass is below $1.44M_\odot$, then the white dwarf star is stable – this is the Chandrasekhar limit.

Describe the evolution of a high-mass main sequence star into a red supergiant.

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Where a star's mass in is excess of 10 $M_{\odot}$, its evolution takes a different path. As hydrogen supplies deplete, the core contracts. Since the mass is greater, when GPE becomes thermal energy, the core gets much hotter than a red giant, allowing helium fusion into elements heavier than carbon (up to iron) to take place. The outer layers expand and cool, forming a red supergiant.

Describe the process of the death of a high-mass star.

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When all of the fuel in a red supergiant is used up, fusion stops (as iron fusion does not release energy, it is unable to fuse further). Gravity becomes greater than the outward pressure due to fusion, so the core collapses in on itself very rapidly and suddenly becomes rigid (as the matter can no longer be forced any closer together). The outer layers fall inwards and rebound off of the rigid core, launching them out into space as a shockwave. The remaining core of a supernova is either a neutron star or black hole, depending on its mass.

Describe the evolution of a red supergiant to a neutron star and black hole

Describe the evolution of a red supergiant to a neutron star or black hole

If the remaining core mass is greater than $1.44M_\odot$, gravity forces protons and electrons to combine and form neutrons. This produces an extremely small, dense neutron star.

If the remaining core mass is greater than $3M_\odot$, the gravitational forces are so strong that the escape velocity of the core becomes greater than the speed of light. This is a black hole, which even photons cannot escape.

What does a Hertzsprung-Russell diagram look like?

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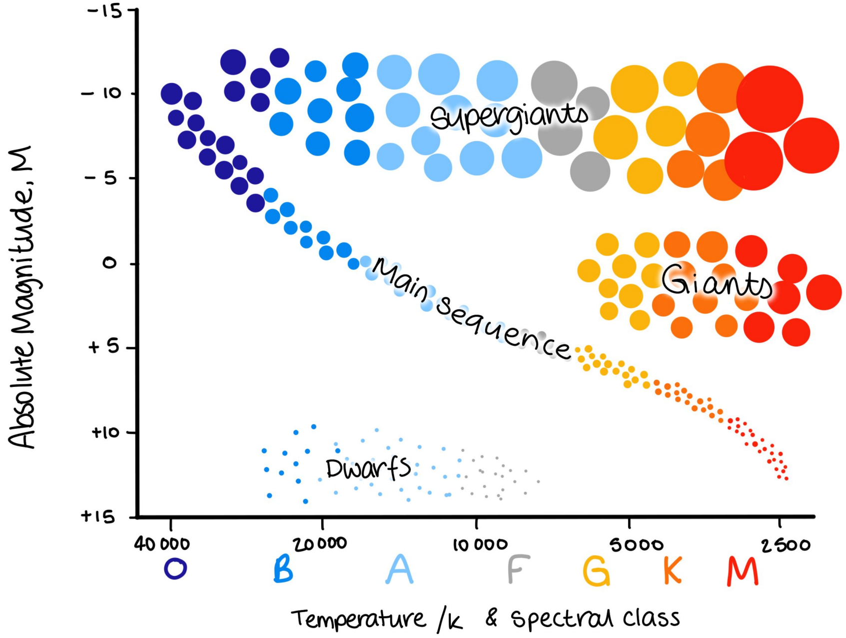

Annotate the Hertzsprung-Russell diagram to show the Sun's evolution.

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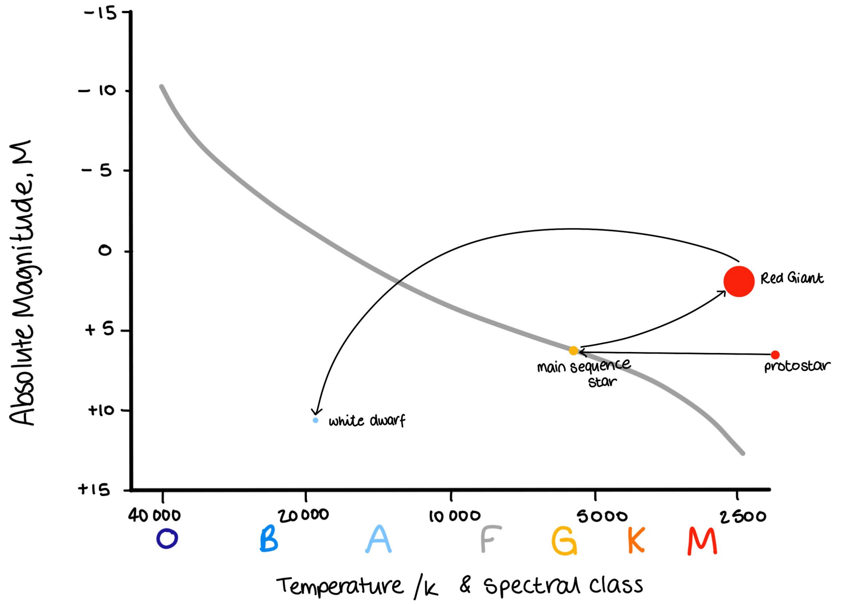

Describe the process of electrons exciting in discrete energy levels.

Describe the process of electrons exciting in discrete energy levels.

Electrons bound to an atom can only exist in certain discrete energy levels. The electrons cannot have an energy value that is between two levels. Each element has its own set of energy levels.

When an electron moves from a lower energy state to a higher energy state, it is ‘excited’. This requires the input of external energy (e.g. heating or absorbing a photon of the exact energy required).

All energy level values are negative.
True or false?

All energy level values are negative. True or false?

True.

All energy level values are negative, with the ground state being the most negative. An electron that is completely free from an atom has energy equal to 0. This negative sign is used to represent the energy required to remove the electron from the atom.

What are Emission line spectra and how are they formed?

What are emission line spectra and how are they formed?

- A series of coloured lines on a black background.
- When light passes through the outer layers of a star, the electrons in the atoms absorb photons and become excited. They then de-excite, releasing photons of specific wavelengths. These photons are detected on Earth and have wavelengths characteristic of the elements in the outer layers, shown as emission line spectra.

What are continuous line spectra?

What are continuous line spectra?

Continuous line spectra – where all visible wavelengths of light are present. They are produced by atoms of solid heated metals.

What are absorption line spectra?

What are absorption line spectra?

A series of dark spectral lines against the background of the continuous spectrum, with each line corresponding to a wavelength of light absorbed by atoms in the outer layers of a star. The dark lines are at wavelengths that are characteristic of the elements in the outer layers (as with emission spectra)

What happens when an electron is de-excited?

What happens when an electron is de-excited?

When an electron is de-excited, it releases energy as a photon with a specific wavelength. The energy released is the difference between the initial energy level of the electron, and the final energy level of the photon. This means that transitions between different energy levels produce photons with different wavelengths.

What are diffraction gratings?

What are diffraction gratings?

Components with regularly spaced slits that can diffract light. Different colours of light have different wavelengths, and so will be diffracted at different angles.

State Wien's displacement law.

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The wavelength of emitted radiation at peak intensity is inversely proportional to the temperature of the black body.

$$\lambda_{max}T = 2.9 \times 10^{-3}\ m\ K$$

State Stefan’s law.

State Stefan’s law.

The power output of a star is directly proportional to its surface area and to its (absolute temperature)^4.

$$P = \sigma A T^4$$

Define light year.

Define light year.

The distance travelled by light in a vacuum in one year. In metres this is 9.46×10^{15}m (speed of light multiplied by the number of seconds in a year).

What is the Doppler effect?

What is the Doppler effect?

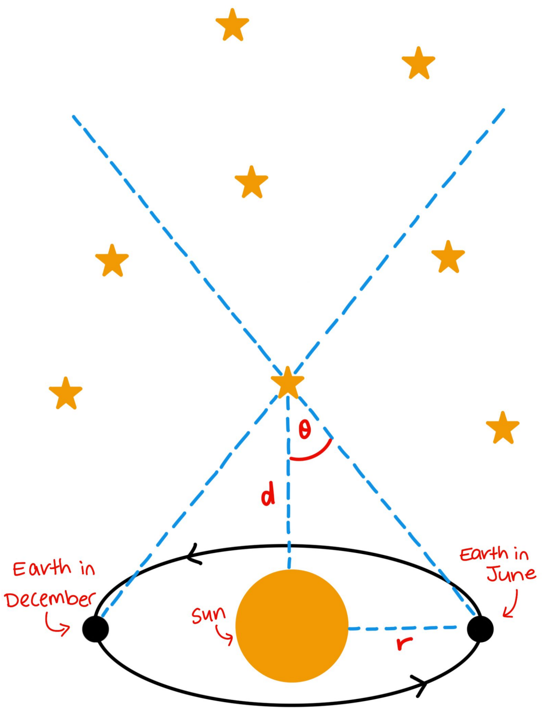
The change in wavelength and frequency of a wave as the source moves away from or towards the observer.

What is Stellar parallax?

What is Stellar parallax?

The apparent shift in position of an object against a backdrop of distant objects due to the orbit of the Earth.

It can be used to calculate distances of up to 100pc. Beyond this point, the angles involved are so small they are hard to accurately measure.

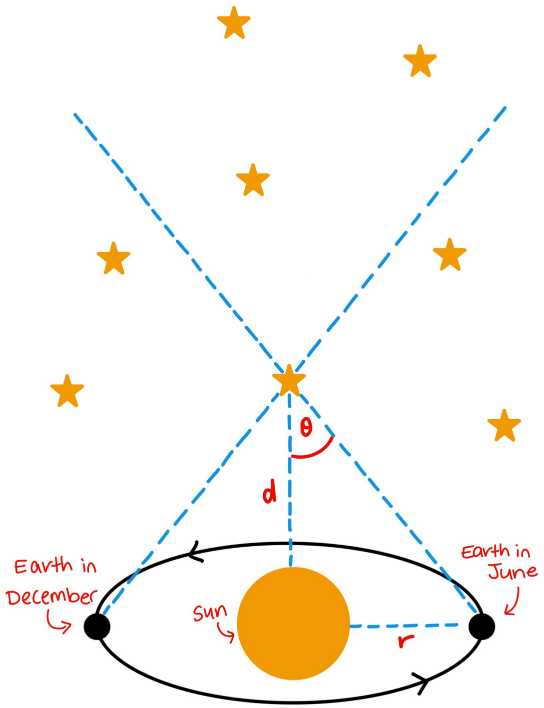


Define parsec.

Define parsec.

The distance from which 1 AU (average distance between the Earth and Sun) subtends an angle of 1 arcsecond (1/3600th of a degree).

In the diagram, if θ was 1 arcsecond, d would be 1 parsec.



What is the Cosmological principle?

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The cosmological principle states that *the universe is isotropic and homogeneous, and the laws of physics are universal.*

Isotropic means that the universe is the same in all directions to every observer, and it has no centre or edge.

Homogenous means that matter is uniformly distributed – for a large volume of the universe the density is the same.

What is red-shift?

What is red-shift?

Red shift (z) is the shift in wavelength and frequency of waves from a retreating source towards/beyond the red end of the electromagnetic spectrum. Cosmological redshift is evidence for the Big Bang.

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

Redshift (z)

Change in frequency (Δf)

original frequency (f)

velocity of object (v)

speed of light (c) $3 \times 10^8 ms^{-1}$

change in wavelength ($-\Delta \lambda$)

original wavelength (λ)

State Hubble's law

State Hubble's law

The velocity of receding objects is directly proportional to their distance from Earth.

$$v=H_0 d$$

v = recession velocity ($km\ s^{-1}$)
d = distance (Mpc)
H_0 = Hubble's Constant ≈ 65 $km\ s^{-1}\ Mpc^{-1}$

Use Hubble's law to estimate the age of the universe

Use Hubble's law to estimate the age of the universe

Time = distance / velocity = 1 / H_0 (since $v = H_0 d$)

The units of Hubble's constant must be converted to SI units

65 km s^{-1} Mpc^{-1} x10^3 gives **H_0 = 65,000 m s^{-1} Mpc^{-1}**

Divide by 1 Mpc (**3.08 x 10^{22} m**) to get the units for H_0 as s^{-1}

H_0 = 2.11 x 10^{-18} s^{-1} so **1 / H_0 = 4.74 x 10^{17} s**

Age (convert to years) = 4.74 x 10^{17} / 3600 / 24 / 365 = **1.5 x 10^{10} years (or 15 billion years).**

Draw a simplified light curve for a binary star system.

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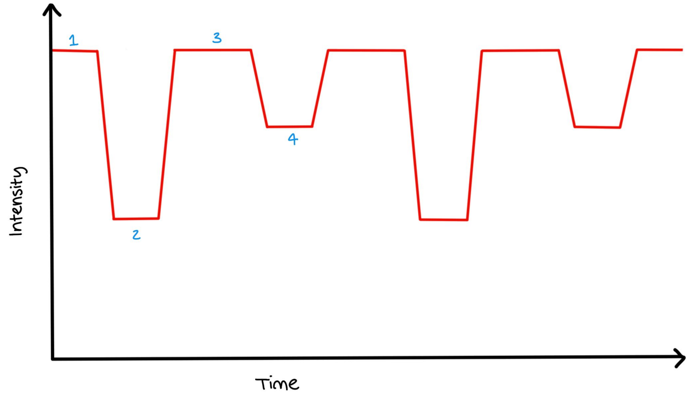
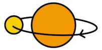
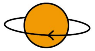
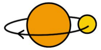
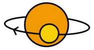


1: no eclipse, so brightness is maximum 

2: larger star is in front of smaller star, blocking all of its light – Primary minimum 

3: no eclipse, so brightness is maximum 

4: smaller star is in front of larger star, partially blocking its light – secondary minimum 

What are quasars? What suggests that they are extremely distant objects?

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A quasar is a nucleus of an active galaxy; a supermassive black hole surrounded by a disc of matter. As matter falls into the black hole, jets of radiation are emitted from the poles of the quasar.

Large optical red shift shows quasars are the most distant observable objects. From the inverse square law for intensity we know they are extremely powerful, with the same energy output as several galaxies. They were initially found to be powerful radio sources but with further telescope developments we now know they emit all wavelengths of EM radiation.

What is the Big Bang theory? State evidence that lead us to believe this is true.

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Scientists believe that, 13.8 billion years ago, the universe exploded from an extremely hot and dense point and is still expanding now.

CMBR (Cosmological Microwave Background Radiation) is the heat signature left behind from the big bang. The EM radiation released in the explosion shifted from extremely high energy waves into the microwave region as the universe expanded, stretching out the waves. CMBR has a black body distribution with a peak that corresponds to a temperature of 2.7K. There was nuclear fusion of hydrogen into helium which explains the large abundance of helium in today's universe.

What is dark energy?

What is dark energy?

- When astronomers calculated the distance to some Type Ia supernovae, they discovered them to be dimmer than expected. This suggested the expansion of the universe is accelerating, which has been attributed to dark energy.
- Dark energy is thought to be energy that has an overall repulsive effect throughout the universe.