Case study:
Subrahmanyan Chandrasekhar
Black holes and X-ray telescopes

Physics - Key Stage 4

Space

Mr C White

Question slides from video

Independent task slide 1 - SUN-SIZED STARS

KEYWORDS: white dwarf, main sequence star, nebula, red giant, black dwarf, protostar

Matter is pulled together under gravity in a _________ to make a ____________

↓

Fusion reaction starts and self-sustains.

↓

Eventually force from radiation pressure balances gravitational force.

↓

Star is now a _________ ____________ ________.

↓ To next slide

Independent task slide 2 - SUN-SIZED STARS

KEYWORDS: white dwarf, main sequence star, nebula, red giant, black dwarf, protostar

Hydrogen fuel expires; collapse starts as star's surface cools.

↓

Star expands to become a ____ ________ with a large surface area.

↓

Star contracts to become a hot _______ ____________

↓

Star cools to become a ________ __________.

Independent task slide 1 - STAR MASS >> SUN'S MASS

Matter is pulled together under gravity in a _________ to make a ____________

↓

Fusion reaction starts and self-sustains.

↓

Eventually force from radiation pressure balances gravitational force.

↓

Star is now a _________ ____________ ________.

↓ To next slide

Independent task slide 2 - MASS >> SUN

Hydrogen fuel expires; collapse starts as star's surface cools.

↓

Star expands to become a ____ ________ with a large surface area.

↓

Star explodes in a ______________________.

High mass

__________ ___________

Very high mass

__________ ___________

Maths practice - independent task (information page)

Mass of the Sun = 1.99×10^{30} kg

Mass of the Earth = 5.97×10^{24}kg

Radius of Sun = 6.96×10^{8}m

Radius of Earth = 6.37×10^{6}m

Earth to Sun distance = 1.52×10^{11}m

Speed of light = 3.0×10^{8}m/s

Formula for the volume of a sphere = $^4/_3 \pi r^3$

Use the information above to answer the questions on the next slide.

Maths practice - independent task

Calculate, to 2 significant figures (in standard form where appropriate)

(1) how many Earth masses would equal the Sun's mass

(2) the volume of the Earth, in m^3

(3) the density, ρ, of the Earth (ρ = mass ÷ volume) in kg/m^3

(4) how many Suns would fit side-by-side in the distance between the Sun and the Earth

(5) the time taken for light to reach Earth from the Sun, in seconds

Review - independent task

(1) What is meant by the ‘Chandrasekhar limit’?

(2) What value (in solar masses) is the Chandrasekhar limit?

(3) How long did Chandra have to wait before being recognised for his discovery?

(4) Why do X-ray observatories need to be placed in orbit, whilst radio telescopes can be ground-based?

(5) The Hubble Space Telescope detects visible wavelength and is in orbit above the Earth. Suggest why it has been placed there, despite our atmosphere being transparent to visible wavelengths.

Answers

Independent task - SOLUTIONS slide 1 - SUN-SIZED STARS

Matter is pulled together under gravity in a NEBULA to make a PROTOSTAR

↓

Fusion reaction starts and self-sustains.

↓

Eventually force from radiation pressure balances gravitational force.

↓

Star is now a MAIN SEQUENCE STAR.

↓ To next slide

Independent task - SOLUTIONS slide 2 - SUN-SIZED STARS

Hydrogen fuel expires; collapse starts as star's surface cools.

↓

Star expands to become a RED GIANT with a large surface area.

↓

Star contracts to become a hot WHITE DWARF

↓

Star cools to become a BLACK DWARF.

Independent task - SOLUTIONS slide 1 - MASS >> SUN

Matter is pulled together under gravity in a **NEBULA** to make a **PROTOSTAR**

↓

Fusion reaction starts and self-sustains.

↓

Eventually force from radiation pressure balances gravitational force.

↓

Star is now a **MAIN SEQUENCE STAR**.

↓ To next slide

Independent task - SOLUTIONS slide 2 - MASS >> SUN

Hydrogen fuel expires; collapse starts as star's surface cools.

↓

Star expands to become a RED SUPERGIANT with a large surface area.

↓

Star explodes in a SUPERNOVA.

High mass → NEUTRON STAR

Very high mass → BLACK HOLE

Maths practice - independent task - SOLUTIONS (1)

(1) how many Earth masses would equal the Sun's mass

$1.99 \times 10^{30} \div 5.97 \times 10^{24}$ = <u>3.3×10^{5} Earth masses</u>

(2) the volume of the Earth, in m^3

$V = {}^{4}/_{3}\, \pi\, r^3 = {}^{4}/_{3}\, \pi \times (6.37 \times 10^{6})^3$

= <u>$1.1 \times 10^{21} m^3$</u>

(3) the density, ρ, of the Earth (ρ = mass ÷ volume) in kg/m^3

$\rho = m \div V = 5.97 \times 10^{24} \div 1.1 \times 10^{21}$ = <u>$5.5 \times 10^{3} kg/m^3$</u>

Maths practice - independent task - SOLUTIONS (2)

(4) how many Suns would fit side-by-side in the distance between the Sun and the Earth

$1.52 \times 10^{11} \div (2 \times 6.96 \times 10^{8})$ = 110 Sun diameters

(5) the time taken for light to reach Earth from the Sun in seconds

time = distance ÷ speed = $1.52 \times 10^{11} \div 3.0 \times 10^{8}$ = 510s

Review - independent task - SOLUTIONS

(1) What is meant by the ‘Chandrasekhar limit’? **The maximum mass a white dwarf can be before it collapses further (into a neutron star)**

(2) What value (in solar masses) is the Chandrasekhar limit? **1.4**

(3) How long did Chandra have to wait before being recognised for his discovery? **Almost 50 years (from 1934 to 1983)**

(4) Why do X-ray observatories need to be placed in orbit, whilst radio telescopes can be ground-based? **The Earth’s atmosphere absorbs X-rays so we would see nothing**

(5) The Hubble Space Telescope detects visible wavelength and is in orbit above the Earth. Suggest why it has been placed there, despite our atmosphere being transparent to visible wavelengths. **To make the images clearer as there is dust and particles in the atmosphere**