GRAVITATION
3. BLACK HOLES

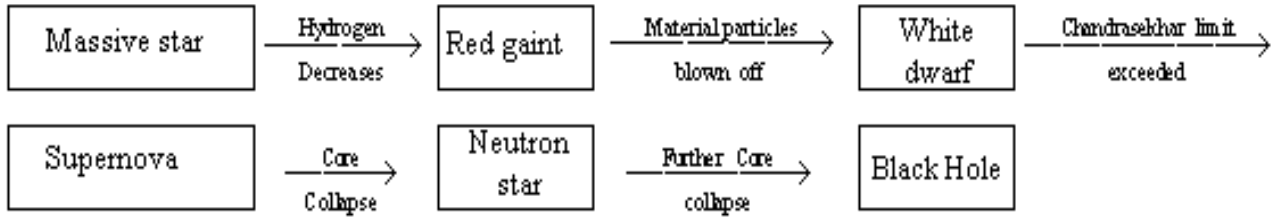
POINTS TO REMEMBER

1. The birth, life and death of star is determined by the interplay of nuclear reactions and the gravitational effects. .

2. A star may end up as a white dwarf, super nova, neutron star or a black hole depending upon the initial mass of the star.

3. The maximum mass that a white dwarf can have is called Chandra Sekhar limit. It is equal to 1.4 times the mass of the sun. Formation of black holes.

4. For an object of mass m the Schwarzschild radius is given by $R_C = \frac{2GM}{C^2}$



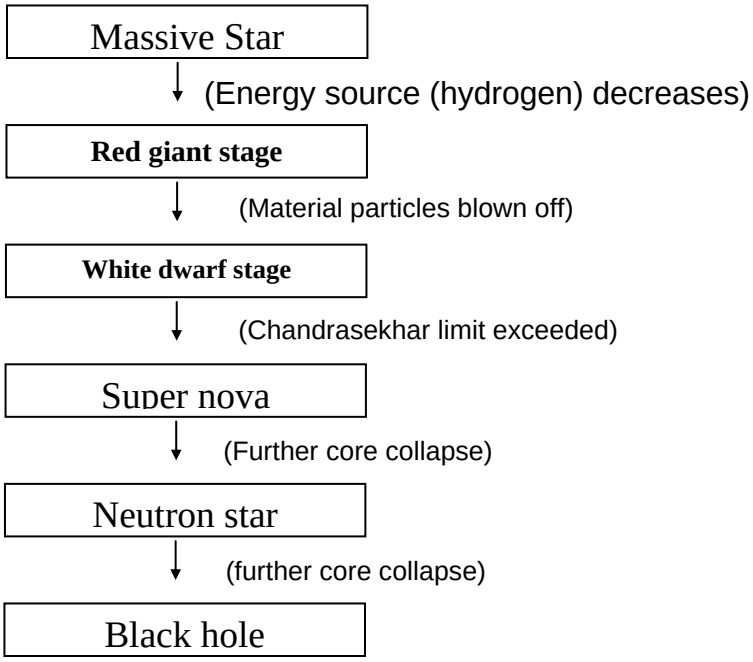
LONG ANSWER QUESTIONS

1. Describe the different stages in the formation of "Blac k holes". Can any material object escape from a black hole? If it can escape what velocity should it have?

A. All stars radiate energy by nuclear fusion of Hydrogen atoms. When Hydrogen availability is almost exhausted, the core of the star starts shrinking because of gravity. A shell of Hydrogen on the edge of Collapsing Core will be compressed and gets heated in this process. Nuclear fusion of the remaining hydrogen atoms in the shell cause expansion of its layers of the star until its diameter becomes many times more than its initial value. This is called red giant Phase of the star. After few million years, the Hydrogen in the red giant phase is completely exhausted. The red giant now blows away (or) releases the material particles present in it and forms a relatively dim star called white dwarf. In this stage, the remaining material particles will be packed in a very small volume (i.e.) about $\frac{1}{10^6}$ the size of the original star, due to the strong gravitational pulls Further the core collapse of the star is temporally stopped. This is because in extremely dense state of matter all the lower energy levels of atoms are occupied and hence the remaining electrons, though possessing high energy are forced to occupy high every level. This abnormal state creates a pressure called degenerate electron pressure which helps the core collapses to white dwarf stage. According to Subramanian Chandrasekhar the degenerate electron pressure will not be sufficient to prevent core collapse of white dwarf, If its mass becomes 1.4 time the solar mass. This is called a Chandra Sekhar's limit. This is possible in binary star system where two stars revolving around each other. The material from the star may be transferred to another, by pushing the other to cross Chandrasekhar limit. At this stage due to intense gravitational force of attraction material particles in core are crushed together and the core temperature rise over 100 billion degrees. Now the repulsive forces between nuclei overcome the force of gravity giving out an explosive shock wave, known as super nova. After supernova stage depending on the mass of the original star pressure inside the remaining core becomes very intense. Due to this pressure, electrons are forced to combine with protons reducing the whole star into a dens ball of neutron – known as Neutron star. In this neutron star normal structure of an atom is broken. If

the mass of original star is very large, say 10 times more than the mass of the sun, even neutrons will not be able to withstand the core collapse and a black hole will form.

Formation of black hole:



No material object can escape from a black hole. It should have a speed greater than the velocity of light which is impossible.

VERY SHORT ANSWER ANSWERS

1. What is a 'Wh ite dwarf'?

Ans. It is dim star having size $\frac{1}{10^6}$ of original star. When hydrogen in the red giant star is completely exhausted. It blows off the material particles and becomes a white dwarf star.

2. What is 'Chan drasekhar limit'?

Ans. If the mass of star is equal to or less than 1.4 times the solar mass then it becomes a white dwarf. A star having the mass greater than 1.4 times the solar mass can become supernova.

3. What is Neutron star?

Ans. At the stage after supernova because of high pressure electrons and protons combine and neutrons are formed. The star turns into a dense ball of neutrons known as ' neutron star'.

EXERCISE

1. What is the Schwarzschild radius for a star with a mass 10 times that of the sun?

Sol Mass of the star (M) = 10 × Solar Mass = 10 × 2×10^{30} kg.
Velocity of light (c) = 3×10^8 m/s.
Universal gravitational Constant (G) = 6.67×10^{-11} N - m^2 /kg^2
Schwarzschild radius (R) = ?

$$R = \frac{2GM}{c^2} = \frac{2X\,6.67X10^{-11}X\,20X10^{30}}{\left(3X10^8\right)^2} = 30000m = 30km$$

ASSESS YOURSELF

1. What is the principle that sets limitations on the collapse of a white dwarf?

Ans. Chandrasekhar limit.

2. Can the sun become a black hole?

Ans. No, since a star can become a black hole only when its initial mass is 10 times the mass of the sun.

3. Why does a tea spoon full of a neutron star weights almost thousand of tonnes?

Ans. As density of a neutron star is very very high of the order of10^{17} kg/m^3 .

4. What stops the collapse of a white dwarf and a Neutron Star?

Ans. Electron degeneracy pressure stops the collapse of white dwarf whereas Neutron degeneracy pressure stops the collapse of Neutron stars.

5. At what stage of the star do most of the elements originate?

Ans. Supernova Explosion.

6. What is the escape velocity from the surface of a black hole?

Ans. Equal to velocity of light