Chapter 7: Particle Physics and Cosmology

Short Answer Questions

1. 2076 Set B Q.No. 2f | 2072 Supp Q.No. 2a | 2070 Supp. (Set B) Q.No. 2 f **Does the universe have a centre? Explain.** [2]

Yes, the centre of universe was given by two famous theories; geocentric theory (Earth as a centre of universe) and Helio-centric theory (Sun as a centre of universe). So, we can consider our galaxy as the centre of the universe. This is because the universe looks more or less the same from all locations.

2. 2076 Set C Q.No. 2f | 2074 Supp Q.No. 2d | 2072 Set C Q.No. 2d **Write the quark composition of proton and neutron.** [2]

Proton: Proton consists of three quarks uud i.e., two u quarks & one d quark. The charge of proton is +1e and its baryon number is 1.

The total charge of uud quark (Q) $= \frac{+2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +1e$. Also, the baryon number (B) $= \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$.

Hence, it proves that a proton contains uud quarks.

Neutron: A chargeless particle with baryon number one is called a neutron. So the combination of one up (u) quark and two down (d) quarks satisfy this condition. Also, the charge of up quark is $+\frac{2}{3}e$ and that of down quark is $-\frac{1}{3}e$. Also, the baryon number for both up and down quark is $+\frac{1}{3}$.

So, the net charge for (udd) combination is

$$Q = +\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$$

And the baryon number for (udd) combination is

$$B = +\frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$$

From above information, the combination of three quarks (udd) gives a neutron particle.

3. 2075 GIE Q.No. 2f | 2074 Set A Q.No. 2e | 2072 Set D Q.No. 2e | 2071 Set D Q.No. 2 e **State Hubble's law and write the significance of Hubble's constant.** [2]

Hubble's law: The Hubble's law states that the speed of recession of a galaxy is proportional to its distance from us. i.e.

$V \propto r$, where V is velocity of a galaxy & r is its distance from earth.

or, $V = H_0 r$; where H_o is Hubble's constant. Its value is 2.3×10^{-18} sec^{-1}. The reciprocal of H_0 is measure of time and is taken to be the age of universe. Thus, age of universe is given by $\tau = \frac{1}{H_0}$. The value of τ is around 15×10^9 years.

4. 2075 Set B Q.No. 2e **Distinguish between leptons and quarks.** [2]

Differences between leptons and quarks

- Leptons have lepton number 1 and baryon no. 0 while quarks have 0 lepton number and $\frac{1}{3}$ baryon number.
- Leptons may be in isolated state but not quarks.

5. 2075 Set B Q.No. 2f **Give two evidences to show that the universe is expanding.** [2

The two evidences to show that universe is expanding are red shift and big bang theory.

Red shift: According to Doppler effect, if the source of light is moving with respect to an observer there is a change in wavelength of light received by the observer. This change in wavelength of light is called Doppler effect. If the source of light is moving away from the observer, the observe wavelength of the spectrum shifts towards red and such shift in wavelength is called red shif Experimentally, the red shift is observed in the spectra of galaxies which prove that universe is ever expanding.

Big Bang Theory: According to Big Bang theories millions of year ago, the whole universe was in th form of highly compressed matter concentrated in the form of huge compact mass of fire-ball. Th density and temperature of ball was very high. At a time, the ball was exploded and the matt thrown out in the form of galaxies which are even moving away and away and the universe is ev expanding as indicated by Hubble's constant.

6. 2074 Set B Q.No. 2e **State Hubble's law. What do you mean by dark matter?** [2]

Hubble's law: Please refer to 2075 GIE Q.No. 2f

Dark Matters: Dark matter is the term astronomers use to describe material in the universe that does not emit or reflect light and is, therefore, invisible. The principal way dark matter can be detected is by observing its gravitational effect on nearby objects. Although dark matter does not shine, it still exerts a gravitational force on the matter around it. Astronomers believe that dark matter is a "cosmic glue" holding together rapidly spinning galaxies and controlling the rate at which the universe expands. Astronomers have also considered that dark matter may be supermassive black holes at the centers of galaxies. These black holes may be contributing several hundred million or even a billion solar masses to the galaxies in which they reside.

7. 2073 Supp Q.No. 2f **What are the similarities and differences between a neutrino and a photon?** [2]

Similarities between a neutrino and a photon:-

i. Neutrino and photon are both parts of standard model of particle physics.
ii. Both of them has zero charge and rest mass
iii. Both of them has zero Baryon number.

Differences between a neutrino and a photon:-

Neutrino	Photon
1. Neutrino is a part of matter with small mass.	1. Photon is a part of force carriers with zero mass.
2. A neutrino is a fermion and obeys Fermi-Dirac Statistics.	2. A photon is a boson and obeys Bose-Einstein Statistics.
3. It has weak charge and 1/2 spin.	3. It has zero charge and spin 1.
4. Its Lepton number is 1.	4. Its Lepton number is zero.

8. 2073 Set C Q.No. 2e 2073 Set D Q.No. 2e **State and explain Hubble's law.** [2]

Please refer to 2075 GIE Q.No. 2f

9. 2073 Set C Q.No. 2f **What class of quark combination one can expect in the combination of one quark and a lepton. Explain with example.** [2]

There are three pair of quarks: up-down (u, d), charm-strange (c, s) and top-bottom (t, b). Similarly, there are three pair of leptons; electron-electron neutrino (e^-, ν_e), muon-muon neutrino (μ, ν_μ) and Tau-Tau neutrino (τ, ν_τ). Each quark has charge $+\frac{2}{3}e$ and their pair has $-\frac{1}{3}e$. Similarly, each lepton has charge $-1e$ and their pair has 0. If a quark u and lepton e is combined, then $ue = +\frac{2}{3}e - e = -\frac{1}{3}e$ i.e. down quark. Similarly, $cu = +\frac{2}{3}e - e = -\frac{1}{3}e$ i.e. strange quark.

So, a quark and an lepton is combined, then their respective pair quark is formed.

10. 2073 Set D Q.No. 2c **How many types of quark you know? Name them with their electronic charges.** [2]

Quarks are the elementary particles which have no internal structure and their combination form the particles like proton, electron, etc.

The different types of quarks with their charges are given below:

Name of quarks	Symbols	Charge
Up	u	$+\frac{2}{3}e$
Down	d	$-\frac{1}{3}e$
Strange	s	$-\frac{1}{3}e$
Charm	c	$+\frac{2}{3}e$
Bottom	b	$-\frac{1}{3}e$
Top	τ	$+\frac{2}{3}e$

11. 2072 Set E Q.No. 2c | 2066 Q.No. 1h | 2064 Q.No. 1 f | 2061 Q.No. 2 h | 2060 Q.No. 1 h **What are cosmic rays?** [2]

The high energy radiations coming towards earth surface from outer space are called cosmic rays. They are many times stronger than gamma rays. The most probable sources of cosmic rays are Sun, Supernova explosion and Galaxy. There are two types of cosmic rays: primary and secondary. The variations of the cosmic rays are due to latitude effect, altitude effect and East-West effect.

12. 2072 Set E Q.No. 2e **Show that proton contains three quarks: up, up and down.** [2]

Please refer to 2076 Set C Q.No. 2f

13. 2071 Supp Q.No. 2f **What are quarks? Write their names with charge they contained.** [2]

Please refer to 2073 Set D Q.No. 2c

14. 2070 Sup (Set A) Q.No. 2 f **What are the similarities and differences between quarks and leptons?** [2]

The similarities and differences between leptons and quarks are:

Similarities

- Both are elementary charged particles.
- Leptons have antileptons and quarks have also antiquarks.

Differences: Please refer to 2075 Set B Q.No. 2e

15. 2070 Set C Q.No. 2 f | 2069 (Set B) Q.No. 2a **Explain the significance of Hubble's constant.** [2]

Please refer to 2075 GIE Q.No. 2f

16. 2070 Set D Q.No. 2 f **Show that a proton contains three quarks: up, up and down (uud).** [2]

Please refer to 2076 Set C Q.No. 2f

17. 2069 (Set A) Q.No. 2f **What are the quark combination of proton and neutron.** [2]

Please refer to 2076 Set C Q.No. 2f

18. 2068 Can. Q.No. 2e | 2066 Supp Q.No. 2g **Write the quark combination of proton and neutron.** [2]

Please refer to 2076 Set C Q.No. 2f

19. 2068 Old Can. Q.No. 2g **What are quarks? Write quark combination of a proton.** [2]

Quarks are the elementary particles which have no internal structure and their combination form the particles like proton, neutron, etc. are called quarks. The main quarks are up, down, strange, charm, bottom, top.

Please refer to 2076 Set C Q.No. 2f

20. 2067 Sup Q.No. 2d **A particle consisting up, up and down quarks is a proton. Justify?** [2]

Please refer to 2076 Set C Q.No. 2f

21. 2067 Q.No. 2e **Write down the quark combination for proton and antineutron.** [2]

Proton: Please refer to 2076 Set C Q.No. 2f

Antineutron consists of one $\bar{u}$ and two $\bar{d}$ quarks. The charge of $\bar{u}$ is $-\frac{2}{3}e$ and $\bar{d}$ is $+\frac{1}{3}e$, then net charge for ($\bar{u}$ $\bar{d}$ $\bar{d}$) combination is

$$Q = -\frac{2}{3}e + \frac{1}{3}e + \frac{1}{3}e = 0$$

And the baryon number for ($\bar{u}$ $\bar{d}$ $\bar{d}$) combination is

$$B = -\frac{1}{3} - \frac{1}{3} - \frac{1}{3} = -1$$

From above information, the combination of three quarks ($\bar{u}$ $\bar{d}$ $\bar{d}$) gives a antineutron particle.

22. 2067 Old Q.No. 2d **What is red shift?** [2]

About earlier years of nineteenth century, an interesting observation was made by astronomer Edwin Hubble and he found that all galaxies are receding (moving away) from us and from each other at a very high speed. According to Doppler effect in light, if source of light is receding from an observer, its wavelength appears to increase $\left(\lambda_0 = \lambda_S \sqrt{\frac{C+V}{C-V}}\right)$, than when it was at rest. In this way, light show a shift towards the region of longer wavelength (i.e., the red region) called red shift.

23. 2067 Old Q.No. 2g **What particles do the $\bar{u}\,\bar{u}\,\bar{d}$ combination produces?** [2]

Since, the charge of up (u) quark has $+\frac{2}{3}e$ and down (d) quark has $-\frac{1}{3}e$ charge. Both of them have the baryon number $\frac{1}{3}$. Their anti-quark $\bar{u}$ and $\bar{d}$ have the charge $-\frac{2}{3}e$ and $+\frac{1}{3}e$ respectively and their baryon no is $-\frac{1}{3}$. So the net charge of the $(\bar{u}\,\bar{u}\,\bar{d})$ combination is

$$Q = -\frac{2}{3}e - \frac{2}{3}e + \frac{1}{3}e = +e$$

And the baryon number of this combination is

$$B = -\frac{1}{3} - \frac{1}{3} - \frac{1}{3} = -1$$

From above information, the $(\bar{u}\,\bar{u}\,\bar{d})$ combination produces an antiproton particle $(\bar{p})$.

24. 2067 Old Q.No. 2h **What are asteroids?**

Asteroids are the minor planets revolving round the sun in elliptical orbit between the orbits of Mars and Jupiter. The diameter of the asteroids varies from 1.6 km to 1000 km. There are thousands of asteroids revolving round the sun. Among them, Ceres is the largest asteroid having diameter 1000 km.

25. 2066 Supp Q.No. 1g 2066 Q.No. 2 h 2063 Q.No. 1 g 2061 Q.No. 1 h **What is a black hole?** [2]

If the initial mass of star was more than five solar mass, the red giant becomes a black hole. The massive star undergoes uncontrolled contraction because of inward pull of its own gravity. The contraction reach to a stage of its critical radius given by $R_s = \frac{2GM}{C^2}$, where M is the mass of star and C is velocity of star which becomes more than velocity of light. As a result, everything is trapped by the star and even light cannot escape out. The star becomes dark called black hole.

26. 2066 Q.No. 2 g **What are mesons? Write the names of two mesons.** [2]

Mesons are intermediate mass particles. They are heavier than leptons but lighter than baryons. These are unstable particles and have spin 0 or 1. Examples of mesons are Pions, Kaons, Eta particle etc.

27. 2063 Q.No. 2 g **Give two examples of the pairs of particle-antiparticle system.** [2]

Two examples of the pairs of particle-antiparticle system are:

i. Proton-antiproton
ii. Electron-antielectron

28. 2061 Q.No. 2 g **What is the quark combination of a proton?** [2]

Please refer to 2076 Set C Q.No. 2f

29. 2059 Q.No. 1 g **What quarks combination will give a neutron?** [2]

Please refer to 2076 Set C Q.No. 2f

30. 2059 Q.No. 2 g **How do you know that the universe is ever expending? Give reasons.** [2]

According to Doppler Effect, if the source of light is moving with respect to an observer, there is a change in wavelength of light received by the observer. The change in wavelength of light is called Doppler's shift. If the source of light is moving away from the observer, the observed wavelength of the spectrum shifts towards the red and such shift in wavelength is called red shift. Experimentally, the red shift is observed in the spectra of galaxies which are the constituents of the universe. In this way, it is known that the universe is ever expanding, i.e., galaxies are moving away from us.

31. 2057 Q.No. 2 g **What particles do the $\bar{u}\,\bar{u}\,\bar{d}$ combination produce?** [2]

Please refer to 2067 Old Q.No. 2g

Long Answer Questions

32. 2069 (Set B) Q.No. 6c **Name the quarks you know. Also present the quark combinations of baryon and meson groups of particles.** [4]

The different types of quarks are up, down, strange, charm, top & bottom. Their symbol, charges, Baryon number are given below.

Name of quarks	symbol	charge	Baryon number	Antiquarks
Up	u	$+\frac{2}{3}e$	$\frac{1}{3}$	$\bar{u}$
Down	d	$\frac{-1}{3}e$	$\frac{1}{3}$	$\bar{d}$
Strange	s	$\frac{-1}{3}e$	$\frac{1}{3}$	$\bar{s}$
Charm	c	$\frac{+2}{3}e$	$\frac{1}{3}$	$\bar{c}$
Bottom	b	$\frac{-1}{3}e$	$\frac{1}{3}$	$\bar{b}$
Top	t	$\frac{+2}{3}e$	$\frac{1}{3}$	$\bar{t}$

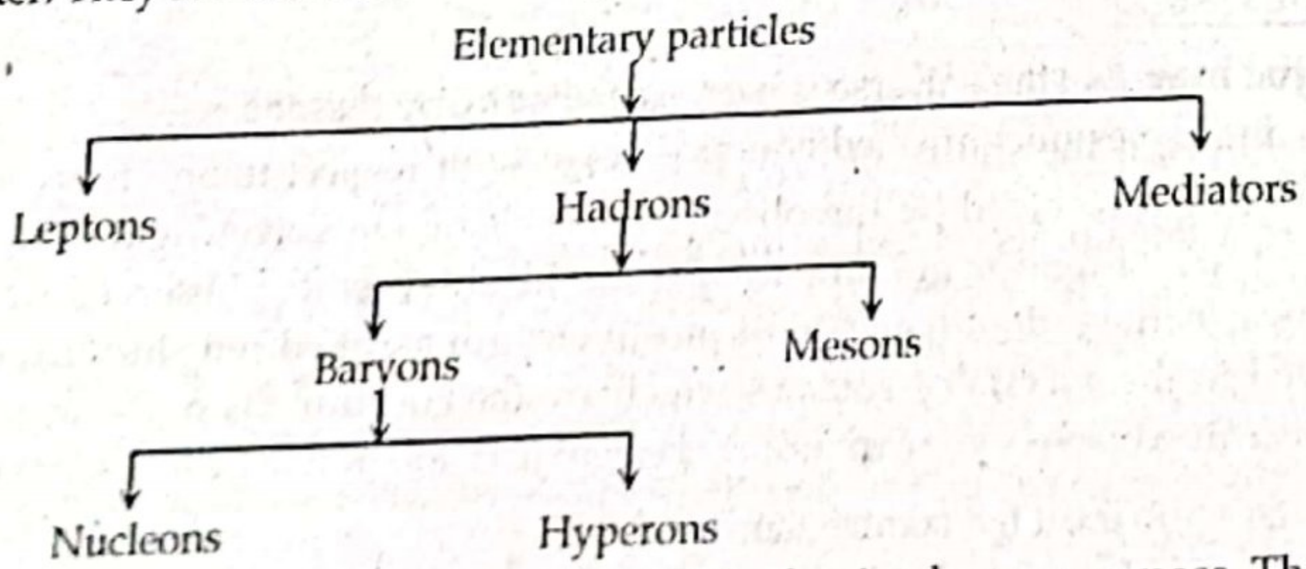
The quark combination of baryon & meson family are given below:

Baryons	Quark combination	mesons	Q. combinations
Proton (P)	uud	Pion (π^+)	$u\bar{d}$
Neutron (n)	udd	(π^-)	$\bar{u}d$
Lamlda not (λ_0)	uds	K^+	$u\bar{s}$
Sigma Plus (Σ^+)	uus	K^-	$\bar{u}s$
Sigma minus (Σ^-)	dds		
Sigma not (Σ^o)	uds	π^o	$u\bar{u}$
Chi not (Ξ^o)	uss		
Chi minus (Ξ^-)	dss		
Omega minus (Ω^-)	sss		

∴ Baryons are made up of three quarks & mesons are made up of a quark & an anti quark.

33. 2068 Old Q.No. 9 OR **Give an account of simple classification of elementary particles with examples.** [4]

Elementary particles: The particles, which are structureless and indivisible, are called elementary particles. They are regarded that they are not made up of other particles. They are the building blocks of matter. They are classified according to following charts:



Leptons: These are the light elementary particles having low or no mass. These particles are: Electron (e^-), Electron neutrino (ν_e), muon (μ^-), muon neutrino (ν_μ), taun (τ^-), taun neutrino (ν_τ). All the leptons have their corresponding antiparticles.

Hadrons: This family includes heavy particles. This group is further classified into two groups: Baryons and Mesons.

i. **Baryons:** The elementary particle having mass equal to proton or heavier than proton are called Baryons. They are also classified into two groups: Nucleon and Hyperons. The proton and neutron are called nucleon. The baryons of mass greater than the neutron and less than the deuteron are called hyperons. Lambda (λ), sigma (Σ), Xi (Ξ), etc. are hyperons.

ii. **Mesons:** These are the elementary particles of intermediate masses. These are the agents of interactions between the particles inside he nucleus. They are pions (π^+, π^-, π^-), Kaons ($K^\circ, K^\pm$), Eta (η).

c. **Mediators:** These groups contain the particles which are necessary to mediate in the interaction for the four kinds of forces: strong, electromagnetic, weak and gravitation. They are Gluon (g) for strong force, photon for electromagnetic force, zero (z°) for weak force and graviton (G) for gravitational force.

34. 2066 Q.No. 10 OR **Describe the death of a star.** [4]

Birth of star: The interstellar space is filled with clouds of dust and gases (mainly hydrogen) called **nebula**. Within the clouds, large clumps are formed which also contracts by their own gravitational interaction. Due to contraction, the temperature of core would be about 10^7K. At this temperature, the hydrogen gas at the core converts into helium gas by thermonuclear reaction producing large amount of heat and light energy as

$2_1H^2 \longrightarrow He^4$ + tremendous energy.

In this way, a star is formed in which the gravitational attraction is balanced by the outward pressure due to heat generated at the core.

Death of star: When the hydrogen gas of the central core is completely converts into helium, there is no more production of heat. There is out ward pressure to balance the inward gravitational force. So, the star contracts again and temperature increases. This causes the outer layer to expand and the star grows in size. Due to expansion, the outer layer gets cooled. This process is continued. When the outer layer is cooled to a certain limit, the star looks red and is called red giant. Due to further contraction the temperature may rise to take place, forming heavier elements producing violent explosion called nova explosion or **supernova**. This explosion throws a large portion of the star into the space. The brightness of the star increases sharply for some time and diminishes at this stage. This is called death of star.

During death of star, its initial mass plays an important role to decide its death. The death of star ends up as one of the following three ways:

1. **White dwarf:** If the initial mass of star left is comparable to the mass of sun, the red giant converts into white color which is called white dwarf.
2. **Neutron star:** When the initial mass of star is two to five times the mass sun, the red giant becomes Neutron star. During contraction of star, the specific gravity becomes so high that the electrons are collapsed into proton forming neutrons. As a result, the while star is formed by neutron called neutron star. The neutron star does not emit light but emits pulse of radiation. Therefore, the neutron star is also called pulsar.
3. **Black holes:** If the initial mass of star was more than five solar mass, the red giant becomes a black hole. The massive star undergoes uncontrolled contraction because of inward pull of its own gravity. The contraction reach to a stage of its critical radius given by $R_s = \frac{2GM}{C^2}$, where M is the mass of star and C is velocity of star which becomes more than velocity of light. As a result, everything is trapped by the star and even light cannot escape out. The star becomes dark called black hole.

35. 2062 Q.No. 9 **What are fundamental particles? How are they classified? Write the properties of quarks and lepton.** [4]

Please refer to 2068 Old Q.No. 9 OR

36. 2062 Q.No. 9 OR **Explain how Universe expands. Explain the Hubble's law.** [4]

About earlier years of nineteenth century, an interesting observation was made by astronomer Edwin Hubble an he found that all galaxies are receding (moving away) from us and from each other at a

very high speed. According to Doppler effect in light, if source of light is receding from an observer, its wavelength appears to increase $\left(\lambda_o = \lambda_s\sqrt{\frac{C+V}{C-V}}\right)$, than when it was at rest. In this way, light show a shift towards the region of longer wavelength (i.e., the red region) called red shift phenomenon. In most of the cases stars or galaxies are found to be moving away from the earth. Hence, all the galaxies are running away from each other and therefore universe is expanding.

Hubble's law: The Hubble's law states that the speed of recession of a galaxy is proportional to its distance from us. i.e.,

$V \propto r$, where V is velocity of a galaxy & r is its distance from earth.

or, $V = H_0 r$; where H_o is Hubble's constant. Its value is 2.3×10^{-18} sec^{-1}. The reciprocal of H_0 is measure of time and is taken to be the age of universe. Thus, age of universe is given by $\tau = \frac{1}{H_0}$. The value of H_0 gives the age of universe around 15×10^9 years.

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37. 2059 Q.No. 9 a OR Name the different types of galaxies you know? Describe milky way galaxy in brief. [4]

Our universe contains billions of stars. These stars are not uniformly distributed but form huge clusters or bunches. These bunch or clusters of stars are called galaxy. There are more than 10^{10} galaxies in the universe. Such galaxy, on an average contains 100 billions (10^{10}) stars. On the basis of shape, galaxies can be classified into the following three types:

i. **Elliptical galaxies:** These galaxies looks like the flat elliptical disk.
ii. **Spiral galaxies:** The spiral shaped galaxies are called spiral galaxies. The stars in these galaxies is concentrated at the centre. Two important spiral galaxies are (a) Milky way galaxy and (b) Andromeda galaxy. Most of galaxies are of this type.
iii. **Irregular galaxies:** The galaxy which has neither elliptical shape nor spiral shape is called irregular galaxies. They are smaller in size.

Milky Way galaxy: The galaxy, which contains 100 billions of stars of which our sun is a member is called Milky Way galaxy. It is spiral type. All the members of the Milky Way galaxy are revolving round the centre core called **galactic centre**. The velocity of the sun around this centre is about 250 km/s. It completes one revolution around the galactic centre in 200 millions years. This time taken by sun to complete one revolution around the galactic centre is called **cosmic year**. Our galaxy is 10^5 light years in diameter and 10^4 light year thick at the centre. The sun is about 33×10^3 light years away from galactic centre. The solar system is situated in our galaxy at about two third distances from galactic centre.

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38. 2058 Q.No. 9 OR Give a classification of elementary particles with example. [4]

Please refer to 2062 Q.No. 9

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