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ASSIGNMENT-5
ENGINEERING PHYSICS

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SECTION C-72.
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Q1. Distinguish between Fermions & Bosons.

FERMIONS	BOSONS
Half integer spin $\pm\frac{1}{2}, \pm\frac{3}{2}, \pm\frac{5}{2}, \ldots$	Integral spin $\pm 1, 2, 3, \ldots$
Obey pauli exclusion principle (one particle/quantum configuration)	Do not obey Pauli exclusion principle
Examples include Quarks (charm) Leptons (electron) etc.	Examples include Graviton Photon Gluon etc
Properties described by Fermi Dirac statistics	Properties described by Bose-Einstein statistics.
Antisymmetric wavefunc^n	Symmetric wave func^n

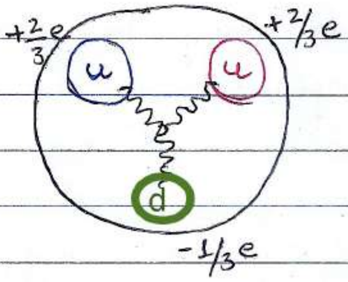
Act as particles that make up the matter	Act as a glue for matter. Holding matter together
Electron, muon, tau are electrically charged leptons	Elementary bosons do not contain any charge

Q2. What are quarks?

A quark is a type of elementary particle and a fundamental constituent of matter. Quarks combine to form composite particles called Hadrons, the most stable of which are protons & neutrons, the components of atomic nuclei. Quarks have various intrinsic properties, includic electric charge, mass, color charge and spin. They are the only elementary particles in the Standard Model of particle physics to experience all four fundamental forces (electromagnetism, gravitation, strong & weak interactions), as well the only known particles whose electric charges are not integer multiples of elementary charge.

There are six types, known as flavors, of quarks:
UP, DOWN, BOTTOM, STRANGE, CHARM & TOP.
UP & DOWN quarks have lowest masses of all quarks.
The heavier quarks rapidly change into UP & DOWN quarks through process of particle decay: The transformation from a higher mass state to a lower mass state. Hence, UP & DOWN quarks are generally stable and found most commonly in universe.

Due to a phenomenon known as color confinement, quarks are never directly observed or found in isolation; they can be found only within hadrons, which include baryons (such as protons & neutrons) and mesons (all which are unstable and short-lived). Thus much of what is known about quarks is drawn from the observations of hadrons.



A proton composed of 2 up an 1 down quark and gluons that bind them together.

Q3. Discuss different types of interactions

In physics, fundamental interactions, also known as fundamental forces, are the interactions that do not appear to be reducible to more basic interactions. There are four fundamental interactions known to exist as :

GRAVITATIONAL INTERACTION

The gravitational force is the force of mutual attraction between any two objects by the virtue of their masses. It is a universal force. Every object experiences the force due to every other object in the universe. According to Newton's Law of Gravitation, this mutual attractive force is directly proportional to the product of masses and follows inverse squarelaw for distance between them. Thus gravity acts over long distances, though with diminishing magnitude, and does not require any intervening medium. Compared to other fundamental forces, gravity is the weakest force of nature. It governs the motion of massive bodies in universe.

ELECTROMAGNETIC INTERACTION

Electromagnetic force is the force between charged particles. In the simpler case when charges are at rest, the force is given by Coulomb's law : attractive for unlike charges and repulsive for like charges, the magnitude of forces obeying the inverse square law. Charge in motion produce magnetic effects and a magnetic field gives rise to a force on moving charge. Electric and Magnetic effects, in general, are inseparable, hence the name electromagnetic force. Like gravitational force, em force acts over large distances and do not need any intervening medium. It is enormously strong compared to gravity. The electric force b/w two protons for example, is 10^{36} times the gravitational force between them, for any fixed distance. Hence thereafter, it dominates all phenomena at atomic & molecular scales. Thus, it is mainly governs the structure of atoms & molecules, the dynamics of chemical reactions and the mechanical, thermal and other macroproperties of materials like tension, friction, normal force, spring force etc.

STRONG NUCLEAR FORCE.

The strong nuclear force binds protons and neutrons in a nucleus. It is evident that without some attractive force, a nucleus will be unstable due the strong electric repulsion b/w protons. A new basic force, therefore must be invoked. The strong nuclear force is the strongest of all forces, about 100 times the em force in strength. It is charge independent and acts equally b/w all nucleons. Its range is, however, extremely small, in order of nuclear size. It is responsible for stability of nuclei and governs high-energy collision phenomena of nucleons. The electron it must be noted, (leptons) does not experience this force.

WEAK NUCLEAR FORCE.

The weak nuclear force appears only in certain nuclear processes such as β decay of a nucleus. The weak nuclear is not as weak as gravitational force but much weaker than strong nucleal & em forces. This is suggested by the fact that the decay of an elementary particle caused by the weak nuc. force (eg the decay of a pion to a muon and a nutrino) is much more slower than decays caused by strong nuc. or em forces. Neutrino (and antinutrino) experience only the weak interactions (besides gravity), so any process involving them is governed by the weak nuclear force. The range of weak nuc. force is exceedingly small, in order of 10^{-15} m.

Q4. Consider a reaction $A \to B + C$. If the rest mass of A is less than the sum of rest masses of B and C, show that the reaction cannot occur, irrespective of kinetic energy of A.

By conservation of relativestic momentum

$$\gamma_A m_A v_A = \gamma_B m_B v_B + \gamma_C m_C v_C$$

where m_A, m_B, m_C are rest masses of A, B, C respectively.
v_A, v_B, v_C are velocities of A, B, C measured from rest frame
$\gamma_A, \gamma_B, \gamma_C$ are lorentz factors of A, B, C

$$\gamma_A m_A v_A = (m_B + m_C)\left(\frac{\gamma_B v_B}{m_B + m_C} + \frac{\gamma_C v_C}{m_B + m_C}\right)$$

if $m_B + m_C > m_A$

$$\gamma_A v_A > \frac{\gamma_B v_B + \gamma_C v_C}{m_B + m_C}$$

$$(m_B + m_C)\gamma_A v_A > \gamma_B v_B + \gamma_C v_C$$

$$Q = (\gamma_A m_A - \gamma_B m_B - \gamma_C m_C)c^2$$

To establish relⁿ b/w $\gamma_A, \gamma_B, \gamma_C$

Q value for a reaction is the amount of energy absorbed or released during the nuclear reaction. ~~[scribbled out]~~ It is the kinetic energy released in the decay at rest. In the inertial frame of reference of A wrt which A is at rest independent of its velocity, Q value is (rest mass is same measured from all inertial frames)

$$Q = (m_{reactant} - m_{product})c^2$$
$$= (m_A - m_B - m_C)c^2$$

where m_A, m_B, m_C are rest masses of A, B, C.

If $m_B + m_C > m_A \rightsquigarrow$ Q is negative which means such reaction cannot happen as released kinetic energy can never be negative.

Q5. Is positron a stable particle? Explain.

A positron is a lightest super-symmetric particle (LSP) ~~can~~ and cannot decay into any standard model particle. Hence it is stable. In a reaction, total charge is conserved hence a positron cannot decay into neutral particles such as photons or neutrinos. If such reach occurs, it would violate the law of conservation of charge. The positron is the lightest charged particle and since a particle can decay only into particles lighter than itself (ie its energy must be conserved), the conservation of charge implies positron must be a stable particle. In other words an isolated positron cannot decay.

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