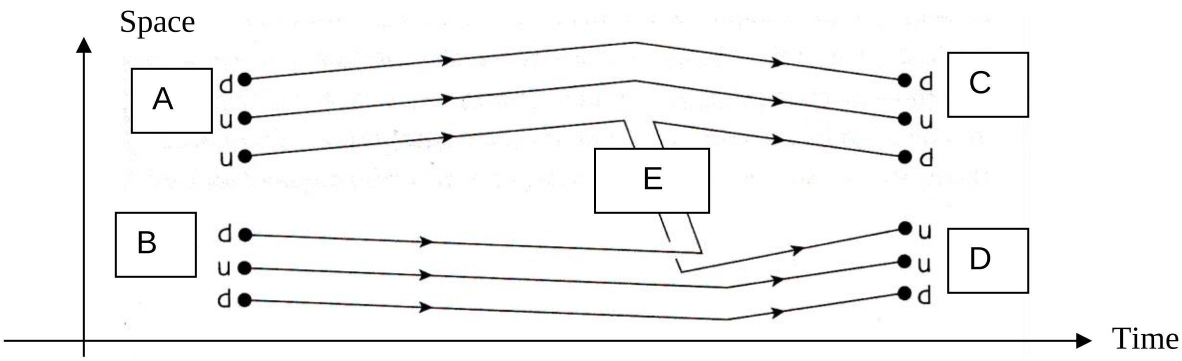
GEH1027 **2020/2021 S2**
Einstein's Universe and Quantum Weirdness **Tutorial 5**

1) Study the following space time diagram for the interaction of a proton with a neutron.



Which of the following is a correct statement for the above scenario?

a) Particle A is a proton while particle B is also a proton. But E is a fermion
b) Particle A is a proton while particle C is a meson. But E is a neutron
c) Particle B is a neutron while particle D is a proton. But E is a meson
d) Particle B is a neutron while particle D is a boson. But E is a baryon
What is the quark content for particle E?

2) Work out the quark content of the Σ^+ particle given the following properties:

a) the Σ^+ is a baryon.
b) the Σ^+ is a strange particle, with s = -1.
c) Σ^+ has a charge of +1.

3) The Periodic table has about 92 naturally occurring elements and has been extended every now and then by artificial means ~ 105. By considering the Bohr type atom (with electron moving around orbits), could you discuss the possibility of making elements with 888 atomic number? 888 seem to be auspicious Chinese number! (Hint: Equate the centripetal force to the Coulomb force) Bohr quantized the angular momentum L as

$$L = r_e m_e v_e = n\hbar$$

4) Do some research on the Web on 2 devices namely the cloud chamber and bubble chamber (it was commonly reported that the inspiration of this device came from observing bubbles in a glass of beer! Nobel Prize 1960, Donald Glaser). It seems that one can study the nature of quantum particles in such chambers by observing ***"their definite path"*** created in such devices. Discuss this "path" in relation to the uncertainty of the path of a quantum particle as in $\Delta x \Delta p \approx \hbar$. Based on what we know about the uncertainty principle, and the question in on "quantum trajectory" in Assignment 4, i**s there a contradiction?**

5) What is the significance of the famous Bell's Theorem?

6) The angular momentum of a spinning sphere is $I\omega = \frac{2}{5}mr^2\omega$ where ω denotes the angular speed. But from quantum mechanics the spin angular momentum of an electron is $s = \frac{\sqrt{3}}{2}\hbar$. Find the equatorial velocity v of an electron under the assumption that it is a little uniform **spherical particle** of radius, $r_e = 5 \times 10^{-17}m$ that is rotating about an axis through its center. **Is the result physically possible? If not, why?**

7) A particle at rest that has mass m also contains an amount of energy E given by $E = mc^2$. However, if an object is in motion, the above is modified.

a) What is this modified formula?

b) What Einstein really said, for a particle at rest was not $E = mc^2$ but $E^2 = m^2c^4$

Why the need for this distinction?