Excises 2

Applications of Accelerators

WS 2022-2023

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1. [1 point] Calculate the force acting on a proton that travels at the speed of 0.45c, affecting only an electric field of 230 [V/m].

Force net= Felectric + F magnetic = q [ E + (v X B)] = q [ E + 0 ] = 230 \* 1.6\*10-19  = 3.68 \*10-17 N

1. [1 point] Calculate the force acted on a neutron that travels at the speed of 0.4c, affected only by a magnetic field of 1.5 [T].

Force net= Felectric + F magnetic = q [ E + (v X B)] = 0 N since neutrons have zero charge

1. [1 point] Identify the heaviest of the leptons and the heaviest of the quarks and find out their mass by looking up in the table/internet and writing it here with units.

* The heaviest lepton is the Tauon lepton with mass = 1.776 MeV/c2
* The heaviest quark is Top quark with mass = 173.1 MeV/c2

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| Table 1: List of hypothesized particles. |
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| Reference:  Wikipedia, List of particles, <https://en.wikipedia.org/wiki/List_of_particles>, 05/11/2022 |

1. [1 point] Give a rough estimate how much heavier is a proton compared to an electron.

A proton's mass is 938.28 MeV/c2, while an electron's mass is 0.511 MeV/c2. As a result, the proton weighs 1836 times as much as an electron.

1. [1 point] A particle has a relativistic gamma of 1.78, what is its speed in [m/s]?
2. [1 point] Write very short definitions and classify the following concepts in groups: Fermions Bosons Mesons Hadrons Baryons Leptons

* Fermions: Elementary particle with odd half-integer spin (1/2, 3/2,…etc).
* Bosons: Elementary particle with integer spin (1, 2,..etc).
* Mesons: particle that is not elementary anymore since it is consist of quark and antiquark. Its spin is 0 or 1
* Hadrons: a particle that is includes of many quarks. it experiences the strong nuclear force. Like Baryons and Meson.
* Baryons: A baryon is a type of hadron, and it contains three quarks.
* Leptons: Elementary particle. It is affected only by the electromagnetic force, weak force, and gravitational force and are not affected by the strong force.

1. [1 point] Which one of the elementary fermions is usually accelerated in an accelerator?

The electrons

1. [1 point] Up and down quarks have a mass of the order 5 [MeV/c2]. Why then is the proton so heavy?

Because of two reasons: (1) kinetic energy of the proton and (2) Quantum chromodynamics (QCD) binding energy which is carried by the gluons to hold the quarks together.

1. [1 point] Identify the coolest lepton! (Spoiler: it is the muon). What is its mean lifetime and why do we detect atmospheric muons in the lab?

The mean lifetime is 2.2 microseconds. It is typically produced at a height of 30 km above sea level and needs around 100 microseconds to arrive reaching our detectors in laboratories at sea level, even while moving at a speed of 99.999% of light. That period is far longer than their mean lifetime, and according to classical physics, laboratory detection of atmospheric muons is impossible.

Since the muon speed is almost the light speed, and according to the relativity theory, the muon experiences the time dilation and length contraction . The mean lifetime is increased by factor of gamma while the travelling length will be decreased by factor of gamma. Therefore, we can detect them in the lab.

1. [1 point] A linear accelerator can accelerate protons to 1.3 [TeV]. What is the available CoM energy if we shoot the protons on a fixed Beryllium target for an industrial application? What would be the available CoM energy if we use two such accelerators to form a collider?

* For fixed Target , the available energy in the center of momentum can be calculated as follow:
* For a collider , the available energy in the center of momentum can be calculated as follow:

1. [1 point] Assuming that after a half-life, half of the radioactive material disintegrates / decays, how many average half-lives does it approximately take, so that 14 grams of 14-C decays?

* C-14 is the only radioactive carbon isotopes. Its abundance is ~1.2\*10-12
* Number of Carbon atoms in 14 gram can be calculated as follow:
* Natom = [Mass in gram \* abundance )/ Atomic mass of c-14] [Avogadro’s number] = [14 \* 1.2 \* 10-12 /14 g per mole]\*[ 6.02 \* 1023] = 7.224 \* 1011 atom of c-14.
* The half-life is 5,700 years = 2.6 x 1011 seconds
* decay rate is the inverse of the half-life = 1 / (2.6 x 1011 seconds) = 3.8 x 10-12 decay/ second
* The number of atoms decaying per second is the number of carbon-14 atoms multiplied by the decay rate= 7.224 \* 1011 \* 3.8 x 10-12 = 2.74512 decayed atom of c-14/ second
* For the whole 7.224 \* 1011 atom of c-14, they need time = 2.63\* 1011 second to totally decay which is = 8 334.1451 years

1. [2 point]: write a python class for a particle, don't forget the init, by giving Z and A. this class should have a method which gives the number of neutrons back. Instantiate this class with an example.

GitHub repository link:

https://github.com/ShymaaAli/Applications-of-Accelerators-Exercises/tree/main/EX2