- Home Work : I1. Introduction
  Answer the following questions.

Q.I1.1 Rutherford discovered nucleus in 1911 by observing scattering of alpha particle with Gold-foil. Please explain why this result shows the existence a heavy charged particle (nucleus) in gold atom? What is the essence of the Rutherford experiment?

(Answer) A small fraction of the scattered alpha particle has a large angle. It is an evidence of nucleus because there are charged particles with heavy mass similar to alpha particle. Essential part of this experiment is alpha particle energy which is enough to see the small structure.

Q.I1.2 Why can not we reach higher energy with any DC (static field) accelerator?

(Answer) To reach higher energy with a DC accelerator, the voltage between the cathode and anode has to be kept in the high voltage. The voltage is limited by breakdown.

Q.I1.3 What is the practical and fundamental limits of proton cyclotron energy?

(Answer) To reach higher energy with cyclotron, we need large size of magnet pole giving a practical limit. Another limit is the phase delay of proton circulation period by a relativistic effect. It is a fundamental limit.

Q.I1.4 LHC is constructed in LEP tunnel (27km circumference) and the designed CME is 14 TeV. As the upgrade, let us consider 28 TeV CME (double) with the same tunnel. Is it possible? If so, what is the critical issue?

(Answer) It is possible. In this energy region, synchrotron radiation loss is not significant for proton. However, we have to increase the bending magnetic field to keep the proton orbit. It will be 17 Tesla. To develop super-conducting coil material to maintain such high field is the critical issue.

Q.I1.5 LHC (proton collider) and ILC (e+ e- collider) are complementary from a scientific point of view. Please explain the reasons.

(Answer) LHC can reach higher energy than e+ e- colliders without SR energy loss. However, collision is occurred between "partons" in proton (quarks and gluons) because it is a composite particle. Initial state of each collision has different energy which we do not know. It is a disadvantage from experimental point of view, but there is some potential to reach extremely high energy. Because we have more background from residual parton fragmentation in proton collider, analysis is very complicated and several assumptions are usually required. In ILC case, the initial state (spin and energy) is well defined. In the final state, there are no background particles from fragmentations. The analysis is very simple and clear. In most cases, the data can be analysed without any theoretical assumptions. However, there is no energy reach beyond CME of the beams.

Q.I1.6 Dark-matter is a massive object which we can not see. How do we know the existence of the dark matter? What is the evidence? (Answer) By observing the spiral motion of a galaxy, the speed of the motion is not consistent to the visible matter distribution. The speed of the motion is not decreased as expected. It is consistent that the invisible matter is distributed around the galaxy.

- Home Work : I2. ILC
  Answer the following questions.

Q.I2.1 ILC is an e+ e- collider with variable CME from 240 GeV to 1 TeV. What kind of physics process can be studied in this energy region?
(Answer) At 240 GeV, Higgs property can be studied, because the cross section of Z Higgsstrahlung is maximized. From 350 GeV, top property can be studied by $t\bar{t}$ production. Up to 500 GeV and beyond, Higgs coupling with various particles including Higgs self coupling can be measure. Potentially, any new particles like SUSY particles, extra non-SM Higgs, Z' boson, could be discovered. Some BSM phenomena like extra dimension can be examined.

Q.I2.2 How do we get the polarized electrons?
(Answer) Polarized electron is obtained by photo-electron from GaAs photo-cathode. The polarization can be controlled by circular polarization of laser photon. Very high polarization up to 90% can be obtained by breaking the degeneration of the electronic state by several techniques like strain crystal, super-lattice structure.

Q.I2.3 Electron beam is generated by laser-photo-cathode, but positron is generated by e+ e- pair-creation process. Why we employ different method?
(Answer) We could not generate positron from photo-electron effect because we do not have any anti-matter photo-cathode. Positron has to be generated by the pair-creation process. Positron can be obtained from beta+ decay too.

Q.I2.4 The beam is focused down to 6 nm in vertical and 470 nm in horizontal direction. To achieve a higher luminosity, it is better to focused down in both direction. Please explain why we employ this asymmetric beam for ILC design.
(Answer) We need an asymmetric focused beam at IP to obtain an enough luminosity and suppress energy spread by Beamstrahlung and disruption, simultaneously. Otherwise, the energy spread becomes too large and the beam control becomes difficult.

Q.I2.5 One of the most important measurement in ILC is Higgs coupling. Why is this so important?

(Answer) Higgs creates mass in the standard model by spontaneous symmetry breaking. If SM is correct, Higgs coupling to particles is exactly proportional to its mass. If any deviation is observed, it strongly suggest a new physics beyond the SM.

Q.I2.6 Let us consider another option. An e+ e- collider (500GeV CME) is constructed in LEP tunnel. What is the ratio of the radiation power by this facility and LEP2 (209GeV CME)?

(Answer) Synchrotron radiation loss per turn is estimated as

$$P(GeV/turn) = 8.8575 \times 10^{-5} \frac{E[GeV]^4}{\rho[m]}. \tag{1}$$

Then, the fraction of the power at 209 GeV and 500 GeV is calculated as

$$\frac{P(500GeV)}{P(209GeV)} = \left(\frac{500}{209}\right)^4 = 32.8 \tag{2}$$

The ratio is 32.8.