-This is a reference for indicating tendencies of questions and kinds/degrees of knowledges to be tested in the examination.
-There are cases in which the form of real questions in the examination is different from this.

1. Answer the following questions about the generation of X-ray from an X-ray tube.

（1） In the X-ray tube, tube voltage *E* is applied between the targe and the filament.

a) Two types of X-ray are emitted from the tube. Answer the names of types, and explain about wavelengths of them respectively.

b) Show the minimum wavelength of X-ray λmin. Here, the Plank's constant is *h*, the speed of light is *c*, and, the elementary electric charge is *e*.

（2） Consider about an atom of which binding energy of K electron shell and L electron shell is E_K and E_L respectively. The nucleus absorbs an electron, and a vacancy arises in K-shell.

a) When X-ray is emitted from the atom, show the X-ray energy.

b) When electron is emitted from the atom, provide the name of electron and show the emission energy.

2. **Answer the following questions when a photon of energy E_γ [keV] enters a detector made of a substance that is composed of a single element (atomic number: *Z*). Here, the binding energy of K electron shell and L electron shell is E_K [keV] and E_L [keV] respectively.**

(1) Find the condition in which the photoelectric effect occurs.

(2) Find the condition in which the pair production occurs.

(3) The interaction probability of the photoelectric effect is equal to that of the Compton scattering in measurement of the photon applying the detector. Answer the probability ratio of the photoelectric effect to the Compton scattering when other detector made of a different kind of substance (atomic number: 2*Z*) is applied.

(4) The mass attenuation coefficient is 7 cm^2/g when $Z=82$ and $E_\gamma=90$keV. Answer the photon interaction cross section per atom when photoelectric effect with K-shell electron only contributes to attenuation of the photon in the detector.

3. **Answer the following questions about the interaction between radiation and material.**

(1)When heavy charged particles A(mass: m_A, Atomic Number: Z_A) and B(mass: m_B, Atomic Number: Z_B) enter a material at the same velocity, the range of particle A and B are R_A and R_B respectively. Show the relation between m_A and m_B

(2) Let Sα and Sp be the stopping powers of10 MeVα particle and 1 MeV proton in a material, respectively.
Find S_α / S_p.

(3) Cherenkov light was generated when charged particles were incident on a substance with a refractive index of n. Explain the generation mechanism and of Cherenkov light and show the velocity conditions of charged particles in the material. Here, the speed of light is c.

3. **Answer the following questions about the accelerator.**

(1) When categorizing accelerators in terms of the electric field of acceleration, accelerator groups such as Cockcroft-Walton accelerators and Van de Graaff accelerators are classified into different types from linear accelerators and cyclotrons. Explain the difference between these two types.

(2) Proton and alpha particle are accelerated by the potential difference of V [MV]. After the acceleration, the velocity of the proton and the alpha particle are V_p and V_a, respectively.
Show the relation between V_p and V_a.

5. A gas-filled detector is installed in a radiation field where monochromatic alpha rays are generated. The detector is operating in pulse mode The detector is connected to a charge-sensitive preamplifier, and the current signal from the detector is converted into a voltage signal (hereinafter referred to as a pulse). Voltage E [V] was applied to the detector and the generated pulse is observed with an oscilloscope. When the operating voltage E is changed in the range of $E_1 \leq E \leq E_2$, The frequency of occurrence and the peak voltage of pulses are always constant at any voltage. Answer the following questions.

(1) When the operating voltage was gradually lowered from E_1, the observed pulse changed. Describe the details of the changes that may occur and the reasons for them.

(2) When the operating voltage was set to $E >> E_2$, the frequency of pulse generation increased significantly. Explain this possible reason.

6. Answer the following questions about the radiation measurement.

(1) Gamma rays from a gamma ray source which emits 3 MeV gamma rays are measured by a NaI(Tl) scintillation detector with an energy resolution of 15 % for 3 MeV gamma rays.

a) Show the full with at half maximum value (MeV) for the full energy peak.

b) List all the energies of the peaks that may occur the energy spectrum in addition to the full energy peaks.

(2) The measurement is performed for 10 seconds, a count of 1000 counts was obtained. After removing the source, the measurement is performed again for 100 seconds. A count of 100 counts was obtained.

a) Obtain the net count rate for the source.

b) show the statistical error of the net count rate.

7. Answer the following questions about the molecular-level effects on radiation biology.

(1) Write the reason why DNA damage caused by indirect action is dominant for irradiation of low LET radiation.

(2) Irradiate a solution with radiation and measure the inactive molecules. Complete the relationship between solute concentrations and inert molecules for irradiations of low and high LET radiation in the graph, respectively.

8. Answer the following questions about the cell-level effects on radiation biology.

(1) Survival rate S of single target single hit model is given by S = exp (-D / D0) when the dose is defined as D.

(A) Derive the survival rate S of the multi target single hit model from the survival rate S of the single target single hit model.

(B) In a multi target single hit model, answer the slope of the curve with the survival rate S on the longitudinal axis and the dose D on the horizontal axis, when the dose D is sufficiently higher than D0.

9. Answer the following questions about the effects of organs/ tissues and individual levels on radiation biology.

(1) Acute radiation disease is a series of symptoms that occur when a fairly wide area of the whole body or body is exposed to radiation of 1 Gy or more in a short time.

(a) Explain what dose LD50 (60) is.

(b) In cancer radiotherapy, patients receive fractionated irradiation of 1 Gy or more of radiation. Answer the advantages of fractionated irradiation with regard to the oxygen effect.

10. Answer the following questions about radiation exposure in body.

(1) Radioactivity of a radionuclide taken into the body decreased by exactly 1/16 in a year. The physical half-life of this radionuclide is two years.

(a) Answer a biological half-life [day].

(b) As a result of appropriate treatment immediately after taking radionuclides in the body to promote excretion, radioactivity of radionuclides decreased by 1/32 in a year. Answer how many percent the absorbed dose will be reduced by this procedure.