Write the following information in the first page of Answer Script before starting answer

ODD SEMESTER EXAMINATION: 2020-21

Exam ID Number_____

Course_____ Semester_____

Paper Code _____Paper Title _____

Type of Exam: _____ (Regular/Back/Improvement)

Important Instruction for students:

1. Student should write objective and descriptive answer on plain white paper.
2. Give page number in each page starting from 1st page.
3. After completion of examination, Scan all pages, convert into a single PDF, rename the file with Class Roll No. **(2019MBA15)** and upload to the Google classroom as attachment.
4. Exam timing from 10am – 1pm (for morning shift).
5. Question Paper will be uploaded before 10 mins from the schedule time.
6. Additional 20 mins time will be given for scanning and uploading the single PDF file.
7. Student will be marked as ABSENT if failed to upload the PDF answer script due to any reason.

M.Sc. PHYSICS
THIRD SEMESTER
NUCLEAR PHYSICS
MSP-303

Duration : 3 hrs. **Full Marks : 70**

(PART-A : Objective)

Time : 20 min. **Marks : 20**

Choose the correct answer from the following: ***1X20=20***

1. An atom with even number of protons
(i) is more stable
(ii) possesses higher binding energy per nucleon
(iii) is fissionable with slow neutrons.
Which of the following is/are true?
a. Only (i) **b.** (i) and (ii)
c. (i) and (iii) **d.** All of these

2. The contribution of the coulomb energy in the semi-empirical mass formula of a nucleus of mass number A and the atomic number Z is of the form (a=constant)
a. $aZA^{2/3}$ **b.** $\frac{aZ(Z-1)}{A^{1/3}}$
c. $\frac{aZ(Z+1)}{A}$ **d.** $\frac{aZ^2}{A^{2/3}}$

3. Considering the nuclear potential as an infinite 3-dimensional harmonic oscillator potential, the number of nucleons corresponding to the energy state $\frac{9}{2}\hbar\omega$ is:
a. 8 **b.** 10
c. 20 **d.** 40

4. Spin and parity of deuteron is respectively:
a. 1, -ve **b.** ½, +ve
c. ½, -ve **d.** 1, +ve

5. The total angular momentum of a nucleus with even-A nuclei is:
a. Zero **b.** Integral multiple of $\hbar$
c. Half-integral multiple of $\hbar$ **d.** None of the above

6. Which of the following nuclei is the most stable?
a. $^{17}_{8}O$ **b.** $^{48}_{20}Ca$
c. $^{44}_{20}Ca$ **d.** $^{204}_{82}Pb$

7. For an exoergic reaction, if the momentum of the projectile is zero, sum of momenta of the product particles will be:
a. Equal to the momentum of the target nucleus **b.** Greater than the momentum of the target nucleus
c. Zero **d.** None of the above

8. If the radius of Ge nucleus is measured to be twice the radius of $^{9}_{4}Be$, then the number of nucleons present in Ge nucleus is:

a. 64 **b.** 72
c. 82 **d.** 86

9. According to Fermi's theory of allowed beta decay, the energy remains conserved in the decay process, the available energy being shared among the electrons and neutrinos. At the end point i.e. $Q=T_e$, the neutrino energy:

a. Becomes equal to the total energy released in the process
b. Becomes equal to the energy of the emitted electrons
c. Becomes equal to the energy of the daughter nucleus
d. Approaches to zero

10. Double beta decay ($2\nu\beta\beta$) is a nuclear transition in which an initial nucleus (Z,A), with proton number Z and total nucleon number A decays to (Z + 2,A) emitting _____ and _____ in the process.

a. Two electrons and two antineutrinos
b. Two electrons and two neutrinos
c. Two electrons and two photons
d. Two positrons and two antineutrinos

11. Which of the following statement is true?
In radiative capture:

a. The target nucleus is bombarded with high energy gamma rays
b. The ejected particle y is the same as projectile x, but it has different energy and angular momentum
c. The projectile x is absorbed by the target nucleus X to form the daughter nucleus Y along with the emission of one or more gamma-ray quanta **1**
d. The projectile x, the target nucleus X, the ejected particle y and the daughter nucleus are all different either in Z number or A number or in both

12. Find the missing particles in the following nuclear reactions.

(i) $^{235}U + {}^{1}n \rightarrow {}^{144}Xe + {}^{90}Sr + ?$

(ii) $^{235}U + ? \rightarrow {}^{137}Cs + {}^{96}Rb + 3\,{}^{1}n$

a. (i) $2\,{}^{1}n$
(ii) high energy gamma ray
b. (i) $2\,{}^{1}p$
(ii) gamma ray
c. (i) $2\,{}^{1}n$
(ii) ${}^{1}n$
d. (i) ${}^{1}H$
(ii) neutrino

13. Which of the following statement is not correct?

a. Baryons can take part only in strong interaction whereas mesons participate in strong, electromagnetic and weak interactions
b. The eight lightest baryons of spin 1/2 form the baryon octet whereas the nine lightest set of mesons with spin 0 form the meson nonet
c. Baryons consist of a combination of three quark particles whereas mesons consist of a pair of quark-antiquark particles
d. Baryons come under fermions because they have half integer spins whereas mesons come under bosons because they have integer spins

14. The conservation of parity in a nuclear reaction requires that:
(where X: target nucleus, Y: daughter nucleus, x: projectile, y: ejected particle)

a. $\Pi_X \Pi_x (-1)^{l_X} = \Pi_Y \Pi_y (-1)^{l_Y}$

b. $\Pi_X \Pi_x (-1)^{l_x} = \Pi_Y \Pi_y (-1)^{l_y}$

c. $\Pi_X (-1)^{l_x} = \Pi_Y (-1)^{l_y}$

d. $\Pi_X \Pi_x = -\Pi_Y \Pi_y$

15. The critical energy of deformation for causing nuclear fission for light nuclei is a linear function of:

a. Z^2/A

b. Z/A

c. $Z/2$

d. Z only

16. Why is it necessary to accelerate positively charged nuclei to high kinetic energies to cause fusion?

a. To get a sustainable reaction

b. To get the isobars and isotopes

c. To result in high amount of energy in short period of time

d. To overcome electrical repulsive forces

17. Which of the following represents inverse β - decay?

a. $n^0 \rightarrow p^+ + e^- + \bar{\upsilon}$

b. $p^+ \rightarrow n^0 + e^+ + \upsilon$

c. $p^+ + {}_{-1}e^0 \rightarrow n^0 + \upsilon$

d. $\bar{\upsilon} + p \rightarrow n^0 + e^+$

18. The discovery of neutrino oscillations confirms the fact that:

a. There are three different flavors of neutrinos

b. The energy released in the process is carried away by the neutrinos only

c. The rest mass of neutrino is zero

d. Neutrinos have a small but nonzero mass

19. For application of GM counter in cosmic ray studies, the operating point must be:

a. At the starting of the plateau region

b. At the end of the plateau region

c. At the middle of the plateau region

d. Outside the plateau region

20. The strangeness (S) of the following particles are
$\Sigma^+, K^0, \Delta^-, \Omega^-$

a. -1, +1, 0, -3 respectively

b. +1, -1, 0, -2 respectively

c. +1, 0, -1, -1 respectively

d. 0, +1, -2, -3 respectively

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PART-B : Descriptive

Time : 2 hrs. 40 min. **Marks : 50**

[Answer question no.1 & any four (4) from the rest]

1. Explain in detail Fermi's theory of nuclear beta decay and hence derive the expression for the number of final state electrons in the momentum range p and $p+dp$. 10

2. **a.** Based on single particle shell model, show that the spin-orbit splitting of the two energy levels with $j = l + \frac{1}{2}$ and $j = l - \frac{1}{2}$ is given by 5+3+2=10

$$\Delta\varepsilon_{ls} = \varepsilon_{ls}(lC)\langle\phi(r)\rangle,$$

(Symbols have their usual meanings).

b. Draw the sequence of nuclear levels according to shell model considering the spin-orbit interation for the first three energy levels corresponding to $E = \frac{3}{2}\hbar\omega$, $E = \frac{5}{2}\hbar\omega$ and $E = \frac{7}{2}\hbar\omega$ respectively.

c. Calculate the spin parity of $^{14}_{7}\mathrm{N}$.

3. The Q-value of an endoergic reaction $X + a \longrightarrow Y + b$ is defined as $Q = E_Y + E_b - E_a$. 10

Show that the threshold energy of the reaction is

$$E_{th} = -Q\left(1 + \frac{M_a}{M_X}\right)$$

(Symbols have their usual meanings).

4. **a.** Explain the Bohr-Wheeler theory of nuclear fission and hence derive the expression for critical energy of deformation for lighter nuclei. 8+2=10

b. U^{238} is considered to be stable against instantaneous spontaneous fission. Justify your answer.

5. **a.** What do you mean by Townsend avalanche in a GM counter? Explain briefly. 4+2+2+2=10

b. What is the role of the quenching agent in a GM tube?

c. Draw the characteristic graph of a GM counter.

d. Mention two disadvantages of a GM counter.

6. **a.** Write down the properties of a deuteron bound state. Obtain the Potential strength of that bound system assuming a square well central potential. 8+2=10

b. Compute the binding energy per nucleon for $^{4}_{2}He$. Given mass of proton, $m_p = 1.007275\ u$, mass of neutron, $m_n = 1.008665\ u$ and $_2He^4$ = 4.00388 u..

7. **a.** What do you mean by $\tau - \theta$ puzzle? What important information does it provide about weak interaction? 5+3+2=10

b. Write a short note on double beta decay.

c. What are magic numbers? Give two examples of doubly magic nuclei.

8. **a.** List the fundamental particles (quarks and leptons) of nature along with their charge and symbols. 6+2+2=10

b. Check whether the reactions are allowed or forbidden (Using conservation laws of charge, Baryon number, Lepton number, third component of Isospin, Strangeness etc).

(i) $\pi^- + p \rightarrow K^- + K^+ + n$

(ii)) $\pi^+ \rightarrow \mu^+ + \nu_\mu$

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