Physics 126 Fall 2008 **Name:**

Exam 5

Time Allowed: 2 hours **Total marks: 100.**

Credits are given for numerical problems only if evidence of calculations is presented.

Some Physics Constants: **Speed of light in vacuum $c=3.0\times10^{8}$ m/s**
Planck's constant $h = 6.63\times10^{-34}$ J.s
Mass of electron $m_e = 9.1\times10^{-31}$ kg
Mass of proton $m_p=1.67\times10^{-27}$ kg
Charge of electron $e = 1.6\times10^{-19}$ C
Avogadro's number $N_A = 6.02\times10^{23}$
Energy equivalence of 1 u=931 MeV

PART I Qualitative questions (2 points each)

1. Two rockets A and B in space both traveling with half the speed of light approach each other . A light beam is emitted from A and travels toward B. According to an observer in B, the speed of the light beam is

(a) $3c/2$
(b) $2c$
(c) c
(d) $2c/3$

2. Which of the following facts concerning photoelectric effect **can be explained** by classical physics?

(a) electrons are promptly released with the faintest radiation
(b) no electrons are released if the frequency of the radiation is below threshold
(c) the photoelectric-current at saturation increases with the intensity of the radiation
(d) the maximum energy of the released electrons is independent of the intensity of the radiation

3. Which of the following statements is a consequence of the uncertainty principle?

(a) the position of a particle cannot be measured with infinite accuracy
(b) the energy of a particle cannot be measured with infinite accuracy
(c) light is both particle and wave
(d) the basis of determinism in classical physics is overthrown

4.. Which of the following assumptions is the most crucial for obtaining the quantized energy levels of hydrogen atom in Bohr's theory?

(a) the path of an electron is a circle
(b) the angular momentum cannot take just any value
(c) the energy is the sum of kinetic energy and electrostatic potential energy
(d) no two electrons can have the same energy

5. Which of the following nuclei has the largest binding energy per nucleon?

(a) hydrogen
(b) helium
(c) iron
(d) uranium

PART II Quantitative questions (5 points each) $18 \times 5 = 90$

6. In the year 2098, an astronaut wears an antique, but accurate, "quartz" wristwatch on a journey at a speed of 2.0×10^8 m/s. According to mission control in Houston, the trip lasts 12 hours. How long was the trip as measured on the watch?

(a) 6.7 hr
(b) 8.9 hr
(c) 12.0 hr
(d) 16.1 hr

$$\Delta t = 12\ hr \qquad v = 2\times10^8\ m/s$$

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$\Delta t_0 = \Delta t\sqrt{1-\left(\frac{v}{c}\right)^2} = 12\sqrt{1-\left(\frac{2\times10^8}{3\times10^8}\right)^2} = 12\sqrt{1-\left(\frac{2}{3}\right)^2}$$

$$= 12\sqrt{\frac{5}{9}} = 8.9\ hr$$

7. The distance of a star is 20 light year. If a rocket travels toward it at ¾ the speed of light, what would be the distance according to the astronaut?

(a) 10 light year
(b) 13 light year
(c) 16 light year
(d) 25 light year

$$L_0 = 20\ l.y.$$

$$L = L_0\sqrt{1-\left(\frac{v}{c}\right)^2} = 20\sqrt{1-\left(\frac{3}{4}\right)^2}$$

$$= 20\sqrt{\frac{7}{16}} = 13\ l.y$$

8. Use the fact that the rest energy of a proton is 940 MeV to determine the kinetic energy of a proton traveling at 0.95*c*.

(a) 3010 MeV
(b) 2068 MeV
(c) 1230 MeV
(d) 450 MeV

$$K = mc^2\left(\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}-1\right) = 940\times\left(\frac{1}{\sqrt{1-0.95^2}}-1\right)$$

$$= 940\times2.2 = 2070\ MeV$$

9.. A laser emits a pulse of light with energy 5000 J. Determine the number of photons in the pulse if the wavelength of light is 480 nm.

(a) 5.2×10^{16}
(b) 2.5×10^{19}
(c) 1.2×10^{22}
(d) 3.1×10^{22}

$$\text{Photon energy} = \frac{hc}{\lambda} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{480\times10^{-9}} = 4.14\times10^{-19}\ \text{J}$$

$$\text{no. of photons} = \frac{5000}{4.14\times10^{-19}} = 1.2\times10^{22}$$

10. Photons of energy 5.78 eV is incident on a magnesium surface that has a work function of 3.68eV. Find the maximum kinetic energy of the ejected electrons in J.

(a) 1.24×10^{-12} J
(b) 2.85×10^{-17} J
(c) 3.36×10^{-19} J
(d) 4.75×10^{-23} J

$$K_{max} = hf - W$$
$$= 5.78 - 3.68 = 2.1\ \text{eV}$$
$$= 2.1 \times 1.6\times10^{-19}\ \text{J} = 3.36\times10^{-19}\ \text{J}$$

11. Electromagnetic radiation of wavelength 480nm is incident on a metal with work function 2.0 eV. Can electrons be ejected from the metal? (Show calculations to support your conclusion)

(a) Yes (b) No

$$\text{Photon energy} = \frac{hc}{\lambda} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{480\times10^{-9}} = 4.14\times10^{-19}\ \text{J} = 2.6\ \text{eV}$$

Since $2.6 > 2.0$, electrons can be ejected

12. Photons of energy 6 eV cause electrons to be emitted from a certain metal with a maximum kinetic energy of 4 eV. If photons of twice the wavelength are incident on this metal which one of the following statements is true?

(a) No electrons will be emitted.
(b) Electrons will be emitted with a maximum kinetic energy of 10 eV.
(c) Electrons will be emitted with a maximum kinetic energy of 8 eV.
(d) Electrons will be emitted with a maximum kinetic energy of 1 eV.

Work function $W = 6 - 4 = 2$ eV
energy of incident photon $= 6/2 = 3$ eV
$K_{max} = 3 - 2 = 1$ eV

13 Find the de Broglie wavelength of a 5-kg bowling ball traveling at 2 m/s?

Ans:

$$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{5\times2} = 6.63\times10^{-35}\ m$$

14. Determine the wavelength of the electromagnetic radiation emitted when the electron in a hydrogen atom undergoes a transition from the $n = 4$ level to the $n = 3$ level.

(a) $1.9\times10^{-6}\,m$
(b) $2.2\times10^{-7}\,m$
(c) $3.7\times10^{-8}\,m$
(d) $4.5\times10^{-9}\,m$

Energy of emitted photon

$$E = 13.6\times\left(\frac{1}{3^2}-\frac{1}{4^2}\right) = 0.66\ eV$$

From $E = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3\times10^{8}}{0.66\times1.6\times10^{-19}} = 1.9\times10^{-6}\ m$$

15. Three electrons have been removed from a beryllium atom. What is the minimum energy required to remove the remaining electron, assumed in the lowest energy level?

(a) 40.8 eV
(b) 54.4 eV
(c) 122 eV
(d) 218 eV

$$E = 13.6\frac{z^2}{n^2} = 13.6\times\frac{4^2}{1^2} = 218\ eV$$

16.Find the total number of possible states of the electron in a hydrogen atom which has the quantum number n=5.

Ans: 50

Subshell l	number
0	2
1	6
2	10
3	14
4	18
	50

17. . The maximum voltage of an X-ray tube is 20kV. Can it be used to produce X-ray of wavelength 0.02nm? (Show calculation to support your conclusion)

(a) Yes (b) No

Kinetic energy of electron, $K = 20\times10^{3}$ eV

$$K = \frac{hc}{\lambda_{min}} \qquad \lambda_{min} = \frac{hc}{K} = \frac{6.63\times10^{-34}\times3\times10^{8}}{20\times10^{3}\times1.6\times10^{-19}} = 6.2\times10^{-11}\ m$$

$$= 0.062\ nm$$

18. Write down below the electronic configuration of the ground state of chlorine (Z=17):

$$1s^2 2s^2 2p^6 3s^2 3p^5$$

19. Find the binding energy (in MeV) for lithium ${}^{7}_{3}Li$ using the following information of atomic masses:

Particle	mass in u
n	1.008665
p	1.007825
${}_3Li^7$	7.016003

mass defect $\Delta m = 3m_p + 4m_n - m({}^{7}_{3}Li)$

$= 0.042132\ u$

Binding energy $= 0.04232 \times 931$ MeV $= 39$ MeV

20. Calculate the kinetic energy of the α particle from the process

$${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + \alpha$$

using the following mass data: 226.0254u for ${}^{226}_{88}Ra$, 222.0176u for ${}^{222}_{86}Rn$, 4.0026u for α, assuming the kinetic energy of ${}^{222}_{88}Rn$ is negligible.

(a) 5.2 MeV
(b) 4.8 MeV
(c) 3.5 MeV
(d) 2.9 MeV

Loss of rest mass $= m(Ra) - m(Rn) - m_\alpha$

$= 0.0052\ u$

Energy released $= 0.0052 \times 931$ MeV

$= 4.8$ MeV

21. Which entry in the table below describes the daughter nucleus when ${}^{31}_{14}Si$ decays by β^- emission?

	number of protons	*number of neutrons*
(a)	13	18
(b)	15	31
(c)	13	17
(d)	15	16

$${}_{Z}X^{A} \rightarrow {}_{Z+1}D^{A} + {}_{-1}e^{0} + \bar{\nu}_e$$

22. A sample contains 2×10^6 nuclei of a certain radioactive isotope, which has a half life of 5.0 s. How many nuclei **have decayed** in 12.0 s?

(a) 1.62×10^6
(b) 1.28×10^6
(c) 7.5×10^5
(d) 3.8×10^5

$N_0 = 2\times10^6 \qquad \tau = 5.0\,s \qquad t = 12\,s$

$$N = N_0\, e^{-\frac{0.693\times t}{\tau}}$$

$$= 2\times10^6 \times e^{-0.693\times\frac{12}{5}} = 3.8\times10^5$$

$$N_0 - N = 1.62\times10^6$$

23. The isotope K^{40} of potassium undergoes beta decay with a half life of 1.3 billion years. Find the activity of of a 1.0 g sample of the isotope.

(a) $8.3\times10^{\cancel{8}\,5}$ Bq
(b) $5.7\times10^{\cancel{8}\,5}$ Bq
(c) $4.1\times10^{\cancel{8}\,5}$ Bq
(d) $2.5\times10^{\cancel{8}\,5}$ Bq

$$A = \lambda N$$

$$\lambda = \frac{0.693}{\tau} = \frac{0.693}{1.3\times10^9\times365\times24\times3600}$$

$$= 1.7\times10^{-17}\ s^{-1}$$

$$N = \frac{1}{40}\times6.0\times10^{23} = 1.5\times10^{22}$$

$$A = 2.5\times10^5$$