Purdue University

PHYS-221

EXAM 3 – 12/15/04

(salmon)

Please use a #2 pencil to fill in data for name and student ID on the computer sheet. Mark the correct answer for each problem on the same sheet. There will be no penalty for wrong answers. Please check to see that your exam has all 16 problems. All useful basic equations and constants are provided. Note that you will not need all of the equations and constants provided to do this exam.

1 $^{226}_{88}Ra$ decays by alpha decay. What are A and Z for the daughter nuclide?

a) 226, 92
b) 222, 92
c) 226, 88
d) 222, 88
→ e) 222, 86

$$^{226}_{88}Ra \rightarrow \, ^{226-4}_{88-2}D + \, ^{4}_{2}\alpha$$

$$\boxed{^{222}_{86}D}$$

2 The energy of a photon of wavelength 400 nm is ________________.

a) 3.11×10^{-19} J
b) 3.50×10^{-19} J
c) 3.87×10^{-19} J
d) 4.25×10^{-19} J
→ e) 4.97×10^{-19} J

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

$$E = \frac{(6.626 \times 10^{-34}\ J \cdot s)(3 \times 10^{8}\ m/s)}{(400 \times 10^{-9}\ m)}$$

$$= 4.97 \times 10^{-19}\ J$$

3 What is the wavelength of a photon emitted when an electron in hydrogen goes from the n=4 state to the n=1 state?

$$E_n = -\frac{13.6 eV}{n^2}$$

a) 323 nm
b) 156 nm
c) 121 nm
d) 103 nm
→ e) 97.3 nm

$$E_4 = \frac{-13.6 eV}{4^2} \qquad E_1 = -13.6 eV$$

$$E_4 = -0.85 eV \qquad E_1 = -13.6 eV$$

$$E_\gamma = \Delta E = E_4 - E_1 = (-0.85 eV) - (-13.6 eV) = 12.75 eV$$

$$\lambda = \frac{hc}{E_\gamma} = \frac{1240 \text{ eV} \cdot \text{nm}}{12.75 \text{ eV}} = \boxed{97.25 \text{ nm}}$$

4 A conclusion from special relativity is that events that are simultaneous in one inertial frame

a) are simultaneous in all inertial reference frames.
b) are simultaneous in all inertial frames moving at the same speed.
→ c) may not be simultaneous in another inertial reference frame.
d) are simultaneous in inertial reference frames moving in the same direction.
e) are simultaneous in inertial reference frames moving in the opposite direction.

5 Light of wavelength 400 nm bombards a surface with work function 2.46 eV. What is the maximum kinetic energy of the photoelectrons from this surface?
(15 POINTS)

a) No photoelectrons are emitted.
b) 2.46 eV
c) 3.30 eV
→ d) 0.64 eV
e) 0.84 eV

$$K_{max} = hf - \phi$$

$$K_{max} = \frac{hc}{\lambda} - \phi$$

$$= \frac{1240 eV \cdot nm}{400 nm} - 2.46 eV$$

$$K_{max} = 0.64 eV$$

6 If the ground state configuration of an atom is $1s^2 2s^2 2p^4$, what is the atomic number of the atom?

a) 14
b) 10
→ c) 8
d) 4
e) 3

4 + 2 + 2 = 8 electrons

7 The half-life of ^{30}P is 2.50 minutes. If a sample of ^{30}P has 1.60×10^{10} nuclei present initially, after 10.0 minutes how many remain?

a) 0.80×10^{10} nuclei
b) 0.40×10^{10} nuclei
c) 0.20×10^{10} nuclei
→ d) 0.10×10^{10} nuclei
e) 0.05×10^{10} nuclei

$$T_{1/2} = \tau \ln 2$$

$$\tau = \frac{T_{1/2}}{\ln 2} = \frac{2.5\,\text{min}}{\ln 2} = 3.606\,\text{min}$$

$$N = N_0 e^{-t/\tau} = (1.6 \times 10^{10}) e^{-10/3.606}$$

$$= 0.1 \times 10^{10} \text{ nuclei}$$

8 A laser beam emits 2.5×10^{20} 663-nm photons per second. What is the power output of this laser?

a) 51 mW
b) 67 mW
c) 51 W
d) 75 W
e) 93 W

Each photon carries an energy

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\,\text{J}\cdot\text{s})(3 \times 10^{8}\,\text{m/s})}{(663 \times 10^{-9}\,\text{m})}$$

$$= 2.998 \times 10^{-19}\ \text{Joules}$$

Since we have 2.5×10^{20} of them emitted per second we have a total energy of

$$(2.5 \times 10^{20}\ \text{photo/sec})(2.998 \times 10^{-19}\,\text{J})$$

$$= 74.9\ \text{Joules/sec} = 74.9\,\text{W}$$

9 An electron has a speed of 300.0 m/s, accurate to 0.04%. Estimate the minimum uncertainty in the position of the electron.

$\Delta x \Delta p \geq \frac{\hbar}{2}$ $\Delta x \geq \frac{\hbar}{2\Delta p}$

→ a) 0.5 mm
b) 1.5 mm
c) 3.0 mm
d) 0.07 mm
e) None of the above

$\Delta p = m \Delta v$

$\Delta v = (0.0004)(300 \, m/s)$

$\Delta v = 0.12 \, m/s$

$\Delta p = (9.109 \times 10^{-31} \, kg)(0.12 \, m/s) = 1.09 \times 10^{-31} \, kg \cdot m/s$

$\Delta x \geq 4.82 \times 10^{-4} \, m$

$0.482 \, mm \approx 0.5 \, mm$

10 A hydrogen atom has a radius of 0.05 nm. Take this to be the uncertainty in the position of an electron in the hydrogen atom. Estimate the electron's kinetic energy (Assume that the electron is non-relativistic).

(15 POINTS)

$\Delta x = 0.05 \, nm$
$= 0.05 \times 10^{-9} \, m$

a) 0 eV
b) 1 MeV
→ c) 4 eV
d) 8 eV
e) 16 eV

$\Delta p \geq \frac{\hbar}{2\Delta x} = \frac{1.055 \times 10^{-34} \, J \cdot s}{2(0.05 \times 10^{-9} \, m)}$

$\Delta p = 1.055 \times 10^{-24} \, kg \, m/s$

if $p \approx \Delta p$ then $K = \frac{p^2}{2m} = \frac{\Delta p^2}{2m} = 6.1 \times 10^{-19} \, Joule$

$= 3.8 \, eV \approx 4.0 \, eV$

11 An electron is accelerated through 50,000 V. What is the minimum wavelength photon it can produce when striking a target?

a) 0.0496 nm
→ b) 0.0248 nm
c) 3.98×10^{-21} nm
d) 496 nm
e) 0.248 nm

$E = 50000 \text{ eV}$

$\lambda = \frac{hc}{E} = \frac{1240 \text{ eV} \cdot \text{nm}}{50000 \text{ eV}}$

$= 0.0248 \text{ nm}$

12 According to special relativity, what is the speed of light measured in a space ship traveling at 0.4 c?

a) 0.6 c
b) 1.4 c
c) 0.86 c
→ d) c
e) none of the above

The speed of light is always c in any inertial frame!

13 Tritium (^3H) decays to ^3He releasing 18.6 keV of energy. How much mass is converted into energy during this process:
(15 POINTS)

a) 2.07×10^{-13} kg
b) 3.06×10^{-13} kg
c) 2.07×10^{-29} kg
d) 3.31×10^{-29} kg
→ e) 3.31×10^{-32} kg

$E = 18.6\text{ keV} = 2.979 \times 10^{-15}\text{ J}$

$E = mc^2$

$m = \frac{E}{c^2} = \frac{2.979 \times 10^{-15}\text{ J}}{(3 \times 10^8 \text{ m/s})^2}$

$E = 3.31 \times 10^{-32}\text{ kg}$

14 If an electron is accelerated from rest through a potential difference of 100 V, what is its de Broglie wavelength?

a) 2.55×10^{-9} m
→ b) 1.23×10^{-10} m
c) 0.529×10^{-10} m
d) 8.67×10^{-9} m
e) 1.20×10^{-15} m

$KE = 100\text{ eV}$

$KE = 1.602 \times 10^{-17}\text{ J}$

$p = \sqrt{2m_e KE} = 5.4 \times 10^{-24}\text{ kg m/s}$

$\lambda = \frac{h}{p} = 1.226 \times 10^{-10}\text{ m}$

15 The most abundant isotope of helium has a $^{4}_{2}He$ nucleus with mass 6.6447×10^{-27} kg. Find the binding energy of the nucleus in MeV.

(15 POINTS)

a) 2.9×10^{-6} MeV
b) 57.6 MeV
c) 4.61×10^{-6} MeV
→ d) 28.8 MeV
e) 137.8 MeV

$2m_p + 2m_n - m_{nucleus}$

$\Delta m = 2(1.673\times10^{-27}\ kg) + 2(1.675\times10^{-27}\ kg) - 6.6447\times10^{-27}\ kg$

$E_{binding} = \Delta m c^2 = 28.8\ MeV$

16 A spaceship is 25 m wide and 100 m long. When traveling at 0.80 c (in a direction along its length), what is its observed width?

a) 42 m
→ b) 25 m
c) 16 m
d) 15 m
e) 20 m

Since the spaceship is traveling along its length The length would experience length contraction w.r.t. an observer.

The width remains the same!