Purdue University
PHYS 221
FINAL EXAM (orange)
12/17/03

Other version

All questions are worth 5 points unless otherwise stated.

1 A coin is dropped into a fountain of depth 60 cm. To someone standing outside the fountain, how far below the surface of the water does the coin appear to be when it comes to rest? (The refractive index of water is 1.33.)

a) 80 cm
b) 45 cm
c) 1.33 m
d) 41.3 cm
e) bottomless

#2

2 A high-energy proton collides with a stationary proton, and the reaction $p + p \rightarrow n + p + \pi^+$ occurs. The rest energy of the π^+ pion is 139.6 MeV. Ignore momentum conservation and find the minimum energy (in MeV) the incident proton must have. (10 points)

a) 0 MeV
b) 139.6 MeV
c) 140.9 MeV
d) 142.0 MeV
e) none of the above

use energy conservation

$m_p + m_p + E_p \Rightarrow m_n + m_p + m_\pi$

E_p: Kinetic Energy of proton

Assuming all particles are stationary in the final state $(n + p + \pi^+)$ we solve

$E_p = m_n + m_p + m_\pi - (m_p + m_p)$

$= m_n + m_\pi - m_p = (939.6 + 139.6 - 938.3)\,\text{MeV}$

$\approx 140.9\,\text{MeV}$

3 Which one of the following statements is *not* a characteristic of a plane mirror?

a) The image is real.
b) The magnification is +1
c) The image is always upright.
d) The image is reversed right to left.
e) The image and object distances are equal in magnitude.

4 A high quality picture frame contains glass coated with a thin film. The purpose of the film is to act as an anti-reflective coating for yellow/orange light of wavelength 558 nm (the color our eyes are most sensitive to). This way we will more easily see the picture behind the glass and not a reflection off the glass. If the coating has an index of refraction of 1.3, and the glass has an index of 1.52, what is the thinnest layer of film that will accomplish this? (10 points)

a) 140 nm
b) 107 nm
c) 164 nm
d) 323 nm
e) none of the above

#5

5 The sun radiates electromagnetic energy at the rate of 3.92×10^{26} W. What is the change in the sun's mass during each second that it is radiating energy? (10 points)

$E = mc^2$

The energy radiated in one second is $\Delta E = 3.92 \times 10^{26}$ J

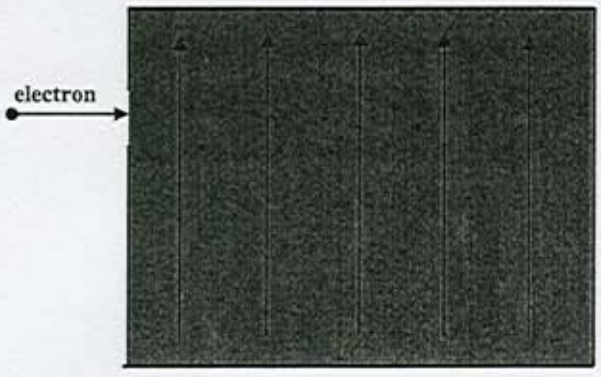
$\Delta E = (\Delta m)c^2$

$\Delta m = \frac{\Delta E}{c^2} = \frac{3.92 \times 10^{26} \text{ J}}{(3 \times 10^8 \text{ m/s})^2}$

$\Delta m = 4.36 \times 10^9$ kg

a) 2.18×10^9 kg
→ b) 4.36×10^9 kg
c) 1.31×10^{18} kg
d) 2.30×10^{-10} kg
e) none of the above

6 An electron traveling horizontally enters a region where a uniform electric field is directed upward. What is the direction of the force exerted on the electron once it has entered the field?



a) to the left
b) to the right
c) upward
d) downward
e) out of the page, toward the reader

#4

7 Which one of the following particles is not composed of quarks?

Not covered this year 2004

a) Neutron
→ b) Muon
c) Pion
d) Kaon
e) Proton

neutron (udd)
pion ($u\bar{d}$)
Kaon ($u\bar{s}$)
proton (uud)
muon (no quarks)

#19

8 Which one of the following quantities is the same for all photons in vacuum?

→ a) Speed
b) Frequency
c) Kinetic energy
d) Wavelength
e) Total energy

9 An electron travels through a region of space with no acceleration. Which one of the following statements is the best conclusion? (10 points)

a) Both **E** and **B** must be zero in that region.

b) **E** must be zero, but **B** might be non-zero in that region.

→ c) **E** and **B** might both be non-zero, but they must be mutually perpendicular.

d) **B** must be zero, but **E** might be non-zero in that region.

e) **E** and **B** might both be non-zero, but they must point in the opposite directions.

#6

10 Molybdenum has an atomic number of Z=42. Using the Bohr model, estimate the wavelength of the K_α X-ray.

K_α is a transition from $n=2$ to $n=1$

a) 6.230×10^{-10} m

b) 6.230×10^{-11} m

→ c) 7.230×10^{-11} m

d) 8.230×10^{-11} m

e) none of the above

— Remember for the Bohr model $E_n = -\frac{Z^2}{n^2} \times 13.6\,eV$

— We'll use $(Z-1)$ for larger Z

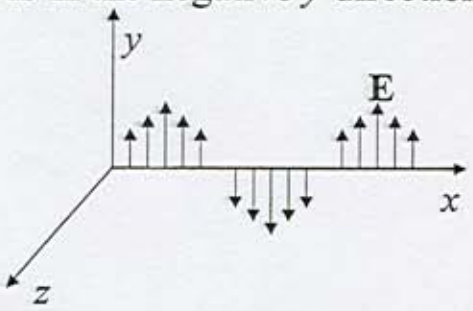
$$E_2 = -\frac{(41)^2}{2^2} \times 13.6\,eV = -5715.4\,eV$$

$$E_1 = -\frac{(41)^2}{1^2} \times 13.6\,eV = -22861.6\,eV$$

$$\Delta E = E_2 - E_1 = 17146.2\,eV = \frac{hc}{\lambda}$$ ← photon's energy

$$\lambda = \frac{hc}{\Delta E} = \frac{(4.136 \times 10^{-15}\,eV \cdot s)(3 \times 10^8\,m/s)}{17146.2\,eV} = 7.23 \times 10^{-11}\,m$$

11 The electric field **E** of an electromagnetic wave traveling the positive x direction is illustrated in the figure. This is the wave of the radiation field of an antenna. What is the direction and the phase relative to the electric field of the magnetic field at a point where the electric field is in the negative y direction?



a) $+y$ direction, in phase
b) $-z$ direction, 90° out of phase
c) $+z$ direction 90° out of phase
d) $-z$ direction, in phase
e) $+z$ direction, in phase

24

12 Suppose the straight-line distance between New York and San Francisco is 4.2×10^6 m (neglecting the curvature of the earth). A UFO is flying between these two cities at a speed of 0.70 c relative to the earth. What do the voyagers aboard the UFO measure for this distance?

a) 1×10^6 m
b) 2×10^6 m
c) 3×10^6 m
d) 4×10^6 m
e) 5×10^6 m

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

Proper length, distance as measured by observer at rest

$$L = (4.2 \times 10^6 \text{ m}) \sqrt{1 - \left(\frac{0.7c}{c}\right)^2}$$

$$L = 3.0 \times 10^6 \text{ m}$$

#2

13 Suppose the value of the principal quantum number is n=4. What are the possible values for the magnetic quantum number m_ℓ.

$\ell = n-1 = 3$

a) –2, –1, 0 +1, +2
b) –4, –3, –2, –1, 0, +1, +2, +3, +4
c) –3, –2, –1, 0, +1, +2, +3
d) –4, –2, 0, +2, +4
e) none of the above

$m_\ell = -\ell, -\ell+1, \ldots, -1, 0, 1, \ldots, \ell+1, \ell$

$m_\ell = -3, -2, -1, 0, +1, +2, +3$

14 When a light bulb is connected to a 4.5 V battery, a current of 0.16 A passes through the bulb filament. What is the resistance of the filament?

a) 440 Ω
b) 28 Ω
c) 9.3 Ω
d) 1.4 Ω
e) 0.72 Ω

15 Two positive point charges Q and $2Q$ are separated by a distance R. If the charge Q experiences a force of magnitude F when the separation is R, what is the magnitude of the force on the charge $2Q$ when the separation is $2R$?

a) $F/4$
b) $F/2$
c) F
d) $2F$
e) $4F$

#9

16 If Planck's constant were changed to 660 J•s, what would be the minimum uncertainty in the position of a 120-kg football player running at a speed of 3.5 m/s? (notice in our textbook $\Delta x \Delta p \geq \frac{h}{2}$ or $\Delta x \Delta p \geq \frac{h}{2\pi}$)

a) 0.032 m
b) 0.065 m
c) 0.13 m
→ d) 0.25 m
e) 0.50 m

In 2003 textbook

$\Delta x \Delta p \geq \frac{h}{2\pi}$ take Δp as p

$p = mv = (120\,kg)(3.5\,m/s) = 420\ kgm/s$

$\Delta x \geq \frac{660\,J \cdot s}{2\pi p} = \frac{660\,J \cdot s}{2\pi (420\ kgm/s)}$

$\boxed{\Delta x \geq 0.25m}$

#1

17 How many protons and neutrons are there in a nucleus of tin $^{120}_{50}Sn$?

nucleons = 120

protons = 50

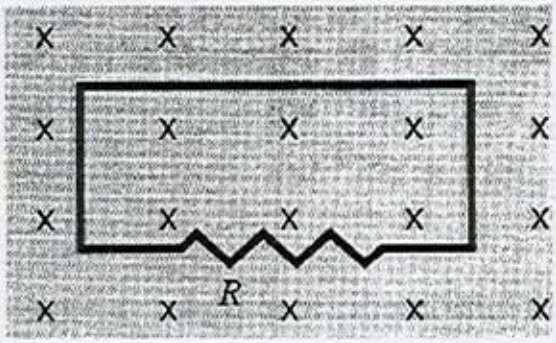
neutrons = # nucleons − # protons

= 120 − 50

neutrons = 70

a) 70 protons and 50 neutrons
b) 60 protons and 60 neutrons
c) 50 protons and 70 neutrons
d) 40 protons and 80 neutrons
e) none of the above

18 The figure shows a uniform magnetic field that is normal to the plane of a conducting loop, which has a resistance *R*. Which one of the following changes will cause an induced current to flow through the resistor?



a) decreasing the area of the loop
b) decreasing the magnitude of the magnetic field
c) increasing the magnitude of the magnetic field
d) rotation of the loop through 90° into the plane of the paper
e) all of the above

#18 19 The inter atomic spacing in a crystal of table salt is 0.282 nm. This crystal is being studied in a neutron diffraction experiment. How fast must a neutron (mass=1.67×10^{-27} kg) be moving to have a de Broglie wavelength of 0.282 nm? (10 points)

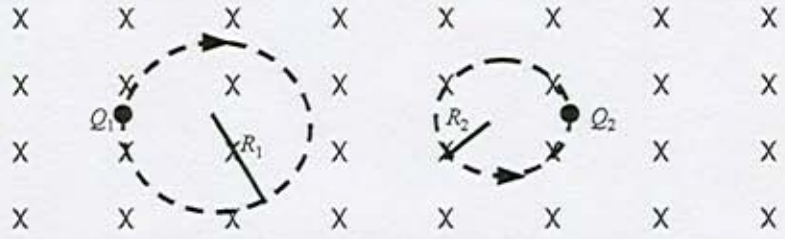
a) 2.1×10^{-2} m/s
b) 4.1×10^{-2} m/s
c) 7.1×10^{-2} m/s
d) 2.42×10^{3} m/s
→ e) 1.41×10^{3} m/s

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\therefore v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34}\ J \cdot s}{(1.67 \times 10^{-27}\ kg)(0.282 \times 10^{-9}\ m)}$$

$$v = 1.41 \times 10^{3}\ m/s$$

20 Two charges particles are traveling in circular orbits with the same speed in a region of uniform magnetic field that is directed into the page, as shown. The magnitude of the charge on each particle is identical, but the signs of the charges are unequal.



Which one of the entries in the table below is correct?

	Mass Relationship	*Sign of charge Q_1*	*Sign of charge Q_2*
a)	$m_1 = m_2$	+	−
b)	$m_1 > m_2$	−	+
c)	$m_1 < m_2$	−	+
d)	$m_1 > m_2$	+	−
e)	$m_1 < m_2$	+	−

#15 21 The approximate diameter of a proton is:

a) 10^{-9} m
b) 10^{-10} m
c) 10^{-14} m
d) 10^{-15} m ←
e) 10^{-18} m

This fact was stressed in lecture in 2003.

#5 22 Which one of the following statements concerning electromagnetic waves is false?

a) Electromagnetic waves carry energy.
b) X-rays have longer wavelengths than radio waves. ←
c) In vacuum, all electromagnetic waves travel at the same speed.
d) Lower frequency electromagnetic waves can be produced by oscillating circuits.
e) They consist of mutually perpendicular electric and magnetic fields that oscillate perpendicular to the direction of propagation.

X-rays have larger energy than radiowaves,

$E = \frac{hc}{\lambda}$ so X-rays have smaller wavelengths

#23 23 The number of radioactive nuclei present at the start of an experiment is 4.60×10^{15}. The number present twenty days later is 8.14×10^{14}. What is the half-life (in days) of the nuclei? (10 points)

$$N = N_0 e^{-\lambda t}$$

→ a) 8 days

b) 4 days

c) 2 days

d) 16 days

e) none of the above

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$\ln\left(N/N_0\right) = -\lambda t$$

$$\lambda = -\frac{\ln\left(N/N_0\right)}{t}$$

$$\lambda = -\frac{1}{20\,\text{days}} \ln\left(\frac{8.14 \times 10^{14}}{4.6 \times 10^{15}}\right) = 0.0866\ \text{days}^{-1}$$

$$T_{1/2} = \frac{0.693}{\lambda} = \frac{\ln(2)}{\lambda}$$

$$T_{1/2} = \frac{0.693}{0.0866\ \text{days}^{-1}} = 8\ \text{days}$$

24 An aluminum nail has an excess charge of +3.2 μC. How many electrons must be added to the nail to make it electrically neutral?

a) 2.0×10^{13}

b) 2.0×10^{19}

c) 3.2×10^{-6}

d) 3.2×10^{6}

e) 5.0×10^{-14}

2003 PHYS 221 Final exam answers

ORANGE

1) b
2) c
3) a
4) b
5) b
6) d
7) b
8) a
9) c
10) c
11) d
12) c
13) c
14) b
15) a
16) d
17) c
18) e
19) e
20) b
21) d
22) b
23) a
24) a