PURDUE UNIVERSITY
PHYS221
FINAL EXAM 2002

(This exam is worth 200 points. There are 32 questions. Eight questions are worth 10 points, and 24 questions are worth 5 points. There is no penalty for guessing. Attempt all questions to maximize you score. Remember to write your name and SSN on your bubble sheet and sign the sheet. Good luck!)

1. What is the fundamental origin of magnetic fields?

   a) High voltages give rise to them
   b) Magnetic flux makes them
   c) The motion of charge
   d) Cosmic rays
   e) Light's interaction with matter

2. A rock is dropped into a swimming pool of depth 4.00 m. To someone standing outside the pool, how far below the surface of water does the rock appear to be? (The index of refraction of water is 1.33)
   a) 5.32 m
   b) 3.00 m
   c) 4.00 m
   d) you can't see the rock due to total internal reflection
   e) 1.24 m

3. The distance from earth to the center of our galaxy is about 23 000 ly (1 ly = 1 light year= 9.47×10^{15} m), as measured by an earth-based observer. A spaceship is to make this journey at a speed of 0.9992c. According to a clock on board the spaceship, how long will it take to make the trip? Express you answer in years (1 yr = 3.16×10^{7} s). [10 points]

   a) 1×10^{4} yrs
   b) 8×10^{3} yrs
   c) 4×10^{3} yrs
   d) 2×10^{3} yrs
   → e) none of the above

   On earth $\Delta t = \frac{\Delta x}{v} = \frac{23000\ ly}{0.9992c} = 23,018$ years

   The clock on board Δt_o would be

   $\Delta t = \Delta t_o / \sqrt{1 - \frac{v^2}{c^2}}$ $\quad \Delta t_o = \Delta t \sqrt{1 - \frac{v^2}{c^2}} = 920.5$ years

4. What is the force on a charge of 3C moving at 20m/s parallel to a magnetic field of magnitude 2T? [10 points]
   a) 120N
   b) 6N
   c) 0N
   d) 60N
   e) 40N

5. The potential difference across the ends of a wire is doubled in magnitude. If Ohm's law is obeyed, which one of the following statements concerning resistance of the wire is true?

a) The resistance is one half of its original value.
b) The resistance is twice its original value.
c) The resistance is not changed.
d) The resistance increases by a factor of four.
e) The resistance decreases by a factor of four.

6. Estimate the energy of K_α X-rays off of a silver (Ag) target (Z=47).

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

$E_n = -13.6\,eV\,(Z-1)^2/n^2$

$E_2 = -13.6eV\,(46)^2/2^2$ $\quad E_1 = -13.6eV(46)^2/1^2$

$E_2 = -7194.4eV$ $\quad E_1 = -28,778eV$

$\Delta E = E_2 - E_1 = 21,583\,eV = \boxed{21.6\ KeV}$

a) 10.8 KeV
b) 10.8 MeV
c) 21.6 MeV
→ d) 21.6 KeV
e) none of the above

7. Find the magnetic field inside a solenoid that is 0.5m long, has a radius r=0.05m and has 200 turns of wire. The current in the wire is 2A.

a) 1.0×10^{-3} T
b) 5.0×10^{-4} T
c) 1.25×10^{-4} T
d) 200 T
e) 0 T

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. Living organisms have a ^{14}C decay rate of about 0.24 events/gram. If an ice man is discovered and found to have a decay rate of 0.06 events/gram, how long ago did he die? (The half life of ^{14}C is about 6,000 years.)

a) not enough information has been given
b) 6,000 years ago
c) 3,000 years ago
d) 12,000 years ago ⇐
e) 24,000 years ago

$R = 0.06$ events/gram

$R_0 = 0.24$ events/gram

$R = R_0 e^{-t/\tau}$

$\ln\left(\frac{R}{R_0}\right) = -t/\tau \rightarrow t = -\tau \ln\left(\frac{R}{R_0}\right)$

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

$\tau = \frac{T_{1/2}}{\ln(2)} = \frac{6000}{\ln 2} = 8656.17$ years

$t = -(8656.17\ \text{years}) \ln\left(\frac{0.06}{0.24}\right)$

$\boxed{t = 12,000\ \text{years}}$

For 2004-fall use $\Delta x \Delta p \geq \frac{h}{2}$

or $\Delta x \Delta p \geq \frac{h}{4\pi}$

10. A proton is confined to a nucleus whose diameter is 5.5×10^{-15} m. If this distance is considered to be the uncertainty in the position of the proton, what is the minimum uncertainty in its momentum? [10 points]

(2003 text book) $\Delta x \Delta p \geq \frac{h}{2\pi}$

a) 1.9×10^{-20} kgm/s
b) 1.2×10^{-19} kgm/s
c) 5.3×10^{19} kgm/s
d) 8.3×10^{18} kgm/s
e) 9.5×10^{-19} kgm/s

$\Delta x = 5.5 \times 10^{-15}$ m

$\Delta p \geq \frac{h}{2\pi \Delta x} = \frac{6.626 \times 10^{-34}\ J \cdot s}{2\pi (5.5 \times 10^{-15}\ m)} = 1.9 \times 10^{-20}\ kg\,m/s$

11. Is the voltage in a US electrical outlet AC or DC, and roughly how many volts does it deliver?

a) AC, 240V
b) DC, 120V
c) AC, 120V
d) DC, 170V
e) AC, 170V

12. In converting electrical energy into light energy, a sixty-watt incandescent light bulb operates at about 1.07% efficiency. Assuming that all the light is green light (vacuum wavelength=555nm), determine the number of photons per second given off by the bulb. [10 points] Remember 60 W = 60 J/s

only 1.07% of this energy is light the rest is heat.

a) 5.4×10^{8} photons/sec
b) 1.8×10^{18} photons/sec
c) 7.2×10^{8} photons/sec
d) 9.0×10^{7} photons/sec
e) 3.6×10^{18} photons/sec

$60 \times 0.0107 = 0.642\ J/s = E_{total/sec}$

The energy of one photon is $= E_{photon} = \frac{hc}{\lambda} = 3.57 \times 10^{-19}\ J$

$\#\ photons/sec = \frac{E_{total/sec}}{E_{photon}} = \frac{0.642\ J/s}{3.57 \times 10^{-19}\ J} = 1.8 \times 10^{18}\ photons/sec$

13. A conducting loop starts with an area of $1m^2$. The area is decreasing at a rate of $0.1m^2$ per second. A magnetic field of strength 2T is passing through normal to the loop. What is the induced emf (voltage) in the loop?

a) 2.0 V
b) 20 V
c) 0 V
d) 0.2 V
e) 0.5 V

14. What is the focal length of an ordinary, planar mirror?

a) 0 m
b) ∞ m
c) equal to d_i
d) equal to d_o
e) m

15. If you wish to use a step down transformer on a trip to Belgium (since Belgians still drive on the proper side of the road unlike the English) to reduce the local voltage by a factor of 2 to suit your U.S. electrical gadgets, and the primary side of the transformer has 100 turns of wire, how many turns must the secondary side have?

a) 50
b) 100
c) 150
d) 200
e) none

16. Which one of the following statements is the best explanation as to why *nuclear fusion* is not at present used to generate electric power?

NOT COVERED IN 2004.

a) Fusion produces too much radiation.
b) Fusion requires isotopes that are scarce.
c) Fusion processes can result in nuclear explosions.
d) Fusion results in large amounts of radioactive waste.
e) Fusion requires very high temperatures that are difficult to contain.

17. Which one of the following is fundamentally different than the others?:

a) radio waves
b) microwaves (as in oven)
c) radar waves
d) sound waves
e) visible light

18. If someone's near point is 1.00 m, what focal length of lens is required to give them normal vision (near point 25cm)? [10 points]

a) 0.25 m
b) 0.33 m
c) 0.42 m
d) 1.25 m
e) 4.00 m

19. Which one of the following particles is not composed of quarks?

Not covered this year 2004-fall

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

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

20. A law enforcement officer in an intergalactic "police car" turns on a red flashing light and sees it generate a flash every 1.5 s. A person on earth measures that the time between flashes is 2.5 s. How fast is the "police car" moving relative to the earth? {Use: c = 3.0 x 10^8 m/s}

a) 1.4 x 10^8 m/s
→ b) 2.4 x 10^8 m/s
c) 1.33 x 10^8 m/s
d) 3.0 x 10^8 m/s
e) 1.0 x 10^8 m/s

Since the light is flashing in the car, that is the proper time.

$\Delta t_o = 1.5s$

$\Delta t = 2.5s$

$\Delta t = \frac{\Delta t_o}{\sqrt{1-\frac{v^2}{c^2}}}$

$\sqrt{1-\frac{v^2}{c^2}} = \frac{\Delta t_o}{\Delta t} = 0.6$ → square it → $1-\frac{v^2}{c^2} = 0.36$

$\frac{v^2}{c^2} = 0.64 \rightarrow v = \sqrt{0.64c^2}$

$= 2.4 \times 10^8 m/s$

21. Suppose one gallon of gasoline produces 1.1 x 10^8 J of energy, and this energy is sufficient to operate a car for twenty miles. An aspirin tablet has a mass of 325 mg. If the aspirin could be converted completely into thermal energy, how many miles could the car go on a single tablet? [10points]

a) 1.5 x 10^{16} miles
b) 2.7 x 10^9 miles
c) 2.9 x 10^{16} miles
d) 5.3 x 10^9 miles
→ e) none of the above

$325 mg = 325 \times 10^{-3} g = 325 \times 10^{-6} kg = 3.25 \times 10^{-4} kg$

$E = mc^2 = (3.25 \times 10^{-4} kg)(3 \times 10^8 m/s)^2$

$E = 2.925 \times 10^{13} J$

1 gallon of gas $\Longrightarrow 1.1 \times 10^8 J$

$\therefore$ aspirin is equivalent to $\frac{2.925 \times 10^{13} J}{1.1 \times 10^8 J} = 2.66 \times 10^5$ gallons

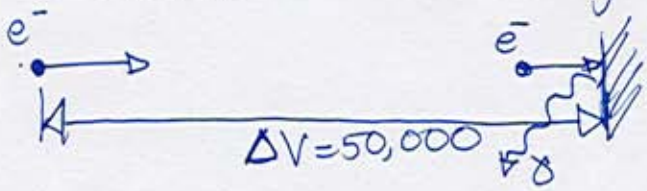
20 m.p.g. x 2.66×10^5 gallons = 5.31×10^6 miles

23. An electron is accelerated through 50,000 volts. What is the minimum wavelength photon it can produce when striking a target? [10 points]

a) 0.0124 nm
→ b) 0.0248 nm
c) 4.04 x 10^{10} m
d) 8.06 x 10^{10} m
e) none of the above

$E_{max} = 50,000$ eV — max energy of the electron

min wavelength ⟺ max energy



$\lambda = \frac{hc}{E_{max}} = \frac{1240 eV \cdot nm}{50,000 eV}$

$\lambda = 0.0248$ nm

24. Which one of the following statements is true concerning the radioisotope carbon-14 that is used in carbon dating?

a) It is produced by living cells.
b) It is produced during β- Decay.
c) It is produced by the decay of carbon-12.
d) It is produced by cells after they have died.
e) It is produced by cosmic rays striking the upper atmosphere. ←

Discussed in class in Fall 2002

26. Which one of the following types of nuclear radiation is not affected by a magnetic field?

a) Alpha particles
b) β- rays
c) gamma rays ←
d) β+ rays
e) Helium nuclei

a) Alpha particles → ${}^{4}_{2}\alpha$ charge = +2
b) β^- rays — electrons $q = -1$ (or positrons — $q = +1$)
c) gamma = γ no charge
d) β^+ rays → positrons $q = +1$ e) same as a)

28. Suppose the value of the principal quantum number is n=5. What are the possible values for the magnetic quantum number m_ℓ.

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

$n = 5$

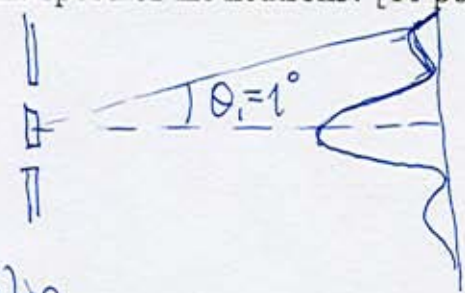
$\ell = n - 1 = 4$

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

$m_\ell = -4, -3, -2, -1, 0, +1, +2, +3, +4$

30. Neutrons are used in a Young's double slit experiment. The 1st bright fringe is found at θ=1 degree above the central bright fringe, and the separation between the slits is 1×10^{-7}m. What is the speed of the neutrons? [10 points]

→ a) 227m/s
b) 2270m/s
c) 1.75×10^{-9}m/s
d) 175m/s
e) c (the speed of light)



Bright fringes are

$d \sin\theta = m\lambda \quad m=1$

$d = \frac{\lambda}{\sin 1^\circ} = d \sin\theta_1$

$\lambda = (1 \times 10^{-7}\,m)(\sin 1^\circ)$

$\lambda = 1.745 \times 10^{-9}\,m$

according to de Broglie

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

$\therefore \quad v = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34}\,J \cdot s}{(1.675 \times 10^{-27}\,kg)(1.745 \times 10^{-9}\,m)} = 226.66\,m/s$