PHYSICS 6 **FINAL EXAM** **SPRING 2003**

NAME_____

This is a closed book, closed notes exam. You may use calculators.
Make sure you show all your work! You will get partial credit for correct intermediate steps.

Useful data and equations:

1 Mole (of substance with atomic mass number [or atomic weight] A)
= A grams, which contains **No** units Avogadro's Number: **No** = 6.0×10^{23}

speed or velocity = v = distance/time or $v = d/t$

acceleration = change of velocity over time = $\Delta v / \Delta t$

acceleration due to gravity = g = 9.8 m/s^2 $d = (1/2)gt^2$

Force = mass × acceleration Work = force × distance Power = Energy/time

Classical Momentum = p = m u (m = mass, u = velocity)

Classical Kinetic Energy = 1/2 mv^2

Velocity of light: c = 3×10^8 meter/sec **Relativity relations:**

time dilation: $t = \dfrac{t_0}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ length contraction: $L = L_0\sqrt{1 - \dfrac{v^2}{c^2}}$

velocity addition $u = \dfrac{u' + V}{1 + \dfrac{Vu'}{c^2}}$

Rest Energy = m_0c^2

Binomial distribution for k identical objects out of n choices (e.g. k heads in n tosses):
$n!/((n-k)!k!) \cdot (p)^k(1-p)^{n-k}$ where *p* is the probability for a single one of the k's (e.g. head)

$c = \lambda f$ where λ is wavelength, f is frequency

Photon E = h f deBroglie: $\lambda = h / p$

Bohr model: $E_n = (-13.6 \text{ eV}) / n^2$

Heisenberg's Uncertainty $\Delta x \, \Delta p \geq h / 4\pi$

Radioactive decay $N(t) = N(0)2^{-(t/T(1/2))}$

Activity = 0.69 N / T(1/2) (N=no. of nuclei, T(1/2) is half life in seconds, Activity is in Bq)

1 Bq = 1 disintegration/sec 1 Curie = 3.7×10^{10} Bq

Constants: Avogadro's Number: $N_0 = 6.0 \times 10^{23}$

Velocity of light: c = 3×10^8 meter/sec

Planck's constant h = 6.6×10^{-34} J·s **or** h = 4.1×10^{-15} eV· s

Units: Mass: 1 Kilogram Energy: 1 J(oule) = 1 Kg m^2 / sec^2 ;
1 electron Volt (eV) = 1.6×10^{-19} J 1 MeV = 1.6×10^{-13} J
Power: 1 Watt = 1 J/s 1 MegaWatt = 10^6 Watt

NAME _____

Grades: points /possible points

I	/100	(multiple choice)
II	/50	
III	/30	
IV	/30	
V	/50	
VI_____	/40	(sentences)
Total:	/300	

I. Multiple choice -- circle the **one best answer**. 10 points each.

1) Schrödinger's equation for the Hydrogen atom determines

a. that the bound electron has a continuum of energies.
b. the exact orbit of the electron at any time, given some initial values.
c. when the electron will emit a photon.
d. a set of $\Psi(\mathbf{x},t)$ functions or states for the nucleus.
e. a set of $\Psi(\mathbf{x},t)$ functions or states for the electron.

2) Which of the following is among the consequences of Quantum Mechanics and the Copenhagen Interpretation

a. Energy conservation can not be violated, even for very short time intervals.
b. Particles can never penetrate through classically impenetrable barriers.
c. The most that can be predicted about where a system will be at a particular time is its probability to be there.
d. Where a system will be at a particular time can be known with certainty.
e. The time measurement between 2 events depends on the observer's velocity.

3) The difference between U235 and Pu239 for bombs is that

a. U uses "gun" type trigger and Pu uses implosion.
b. U uses implosion and Pu uses a "gun" type trigger.
c. U uses fusion and Pu uses fission.
d. U235 is easier to extract from ore than Pu is to extract from spent reactor fuel rods.
e. (given sufficient amounts of either material) it is technologically more difficult to initiate a complete chain reaction in U235 than in Pu.

4) Einstein's fundamental postulates that form the basis of the special theory of relativity include

a. the speed of light depends on the speed of the source.
b. the speed of light is independent of the speed of the source.
c. the speed of light depends on the speed of the observer's reference frame.
d. physical phenomena can distinguish different inertial frames of reference.
e. light is an electromagnetic wave.

5) Strontium 90 (^{90}Sr) has a half life of 28 years. In 1975 there were 80 Kg of ^{90}Sr covering the earth, as residue from atmospheric nuclear weapons testing. Today, given that there have been no significant above ground tests, the residue should be

a. 160 Kg b. 80 Kg c. 40 Kg d. 20 Kg e. 80/28 Kg

6) The Frisch and Peierls memorandum showed that

a. U238 was suitable for a nuclear bomb.
b. U235 was suitable for a nuclear bomb.
c. the critical mass of U235 was about 1 ton.
d. the critical radius of U235 was about 1 mm.
e. fission in U238 was too fast to sustain a chain reaction to the end.

The following 4 questions refer to the play Copenhagen.

7) Margrethe is

a. the maid b. the discoverer of fission c. Niels Bohr's wife
d. Werner Heisenberg's wife e. the narrator

8) Heisenberg meets with Bohr in Copenhagen particularly to talk about issues related to

a. uses for nuclear fusion b. atomic structure c. quantum theory
d. uses for nuclear fission e. German occupation of Denmark

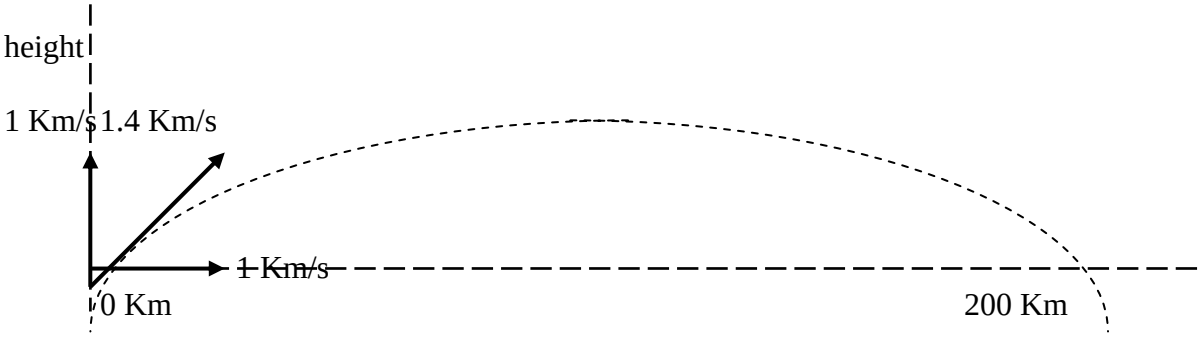
9) In some crucial calculations prior to the meeting, Heisenberg

a. used his uncertainty principle incorrectly
b. obtained the correct critical mass of U238
c. obtained the correct critical mass of U235
d. used the diffusion equation correctly
e. used the diffusion equation incorrectly

10) In the play many physics metaphors are used. One that is not used is

a. skiing and the uncertainty principle
b. skiing and the two-slit experiment
c. psychological motivation and multiple-slit experiment
d. human relations and forces between quarks
e. human relations and Schrödinger's cat

II. A tactical nuclear missile is fired from a launching tube with a speed of 1.4 Km/s. It reaches a target 200 Km away.
It is fired roughly at angle of 45 degrees to have maximum range. That means that its horizontal and vertical components of velocity are equal to 1 Km/s each **when it leaves the launching tube**.



a. Considering the horizontal motion alone, how long does it take to reach the target?

b. Considering the vertical part alone, how long does it take to reach its maximum height?

c. What is the highest point on the trajectory?

d. An alien observer is zooming by at **0.8 c** in the same horizontal direction. How long will the missile take to hit its target according to this observer?

e. How far (horizontal distance) will the missile travel according to the alien observer

III. A hydrogen atom undergoes a transition from the n=3 to the n=1 state.

a. What is the energy of the photon emitted? Use units of eV..

b. What is the frequency of that photon?

c. Suppose a light bulb is constructed that is filled with Hydrogen gas. **How many atoms** of Hydrogen would need to undergo the transition (from n=3 to n=1) **every second** if the bulb emitted 1 Watt of power at the frequency in part (b)?

IV. Group 1 found that over 53 days the Dow Jones Industrial Average increased 27 days and decreased 26 days. Assume this will be representative of the near future of the Dow. Use this information to answer the following:

a. What is the probability that the Dow will go up tomorrow?

b. What is the probability that the Dow will go up each of the next 3 days?

c. What is the probability that the Dow will go up **ONLY ONCE** in the next 3 days?

V. a. (hypothetical) nuclear power plant in Medford produces 500 MegaWatts of electrical power. Recall that power is the rate at which energy is produced:
1 Watt = 1 Joule/sec. Note also that 1 year = 3.2×10^7 sec.

a. How much electrical energy is produced by the Medford reactor in 1 year (in Joules)?

b. Express the electrical energy released in 1 year (part a.) in units of MeV.

c. Each fission reaction in the reactor core, involving U235, releases about 200 MeV. Assuming only 20% of the energy released becomes electrical, how many fission reactions are necessary to produce the requisite energy (part b.)

d. For every 3 fission reactions (on U235) about 2 nuclei of Pu239 are formed (by absorption of extra neutrons from U238). What is the mass of Pu239 produced in 1 year?

e. What is the activity (in Curies) of the Plutonium? The half life =24,400 years.

VI. State two specific ways in which Special Relativity (SR) differs from Classical Physics (CP).

a. Use 2 short, complete sentences, as in the format "In CP _____, whereas in SR _____."

b. State two ways in which Quantum Mechanics (QM) differs from Classical Physics.
Use the same format.