P100 University of Rochester NAME Soln Key - SM
S. Manly Fall 2007

Final Exam (December 17, 2007)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work where requested in order to be considered for partial credit. In problems where you are requested to show your work, no credit will be given unless your work is shown.

Problem 1 (6 pts, no need to show work):

From the presentations: put a T by statements that you think are true and an F by statements that you think are false.

F ___ The first explosion of a nuclear bomb produced by man occurred over Hiroshima, Japan. No — Trinity test in New Mexico was first

F ___ All of the large asteroids in the solar system have long since hit planets. Consequently, earth is unlikely to ever be hit by one again. Not often ... but will happen

T ___ Sound is a longitudinal wave in a medium caused by something that vibrates.

F ___ The signal from a single GPS satellite is sufficient to determine the receiver's position to within 1.5 meters. Requires more than 1 ... 3 or more best

T ___ The Planck satellite will be the next major step in mankind's investigation of the cosmic microwave background.

F ___ In the Bohr model of the atom electrons move from a high energy state to a low energy state when they absorb a photon. goes low to high

Problem 2 (4 pts, no need to show work):

The expansion of the universe seems to be accelerating. The evidence for this is based on observations of

x a) gas clouds orbiting the centers of galaxies.
4 (b) the redshift in the light from the explosions of distant supernovas.
2 (c) the cosmic microwave background.
x d) the manner in which the stars are distributed in our own galaxy.
x e) the slowing down in the pulsation rate of distant neutron stars.

Problem 3 (4 pts, no need to show work):

The amount of dark matter in the universe is

a) many times less than the amount of visible matter.
2 b) about twice as much as the amount of visible matter.
4 (c) many times more than the amount of visible matter.
d) about the same as the amount of visible matter.
e) entirely unknown at the present time.

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Scores	
1.	6/6
2.	4/4
3.	4/4
4.	4/4
5.	4/4
6.	4/4
7.	4/4
8.	4/4
9.	4/4
10.	4/4
11.	4/4
12.	4/4
13.	4/4
14.	4/4
15.	4/4
16.	4/4
17.	4/4
18.	10/10
19.	10/10
20.	10/10
Total	100/100

Wow !!

Problem 4 (4 pts, no need to show work):

A common opinion concerning the creationism versus evolution controversy is the idea the Earth was created fairly recently but that it was created with fossils and other evidence of great age already present, so that Earth has the appearance of being old even though it is really quite young. This opinion is best classified as

a) nonscientific because it contradicts common sense.
b) nonscientific because it is not testable and open to be disproved.
c) a scientific opinion that is probably incorrect.
d) a scientific opinion that is certainly correct.
e) a scientific hypothesis for which there is currently little evidence.

Problem 5 (4 pts, no need to show work):

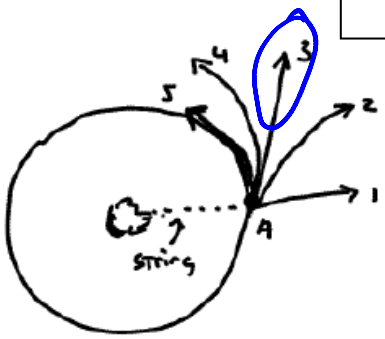
The strong force is mediated by gluons in the same way the electromagnetic force is mediated by

a) electrons.
b) neutrinos.
c) Z particles.
d) protons.
e) photons.

Problem 6 (4 pts, no need to show work):

The sketch shows the path of a ball tied to a string and swung in a horizontal circle clockwise. The string breaks when the ball is at the position shown as point A. Circle the path that best represents the initial direction of the ball in the moment after the string is cut.

counter-



Problem 7 (4 pts, no need to show work):

You are isolated and floating out in space far away from outside influences. Obviously between bouts of feeling sorry for yourself, you get bored. It turns out you have a block of wood and a block of lead, one in each hand. The blocks look and feel identical. How could you tell which one is the lead block?

a) Give each block a light tap with your finger; the one that accelerates the least is the lead block.
b) Give each one a light tap with your finger; the one that accelerates the most is the lead block.
c) Let go of the blocks; the one that falls the fastest is the lead block.
d) None of the above methods will tell you which block is which.

Problem 8 (4 pts, no need to show work):

Two electrically charged balls sit on a table. Ball A has a charge of +10q. Ball B has a charge of -1q.

a) Ball A repels ball B with a force that is 10 times that with which ball B repels ball A.
b) Ball A attracts ball B with a force that is 10 times that with which ball B attracts ball A.
c) There is no force between the balls.
d) Ball A repels ball B with the same force that ball B repels ball A.
e) Ball A attracts ball B with the same force that ball B attracts ball A..

Problem 9 (4 pts, no need to show work):

A device simultaneously shoots a beam of x-rays and a beam of visible light at passing car.

a) The visible light arrives at the car just before the x-rays.
b) The visible light arrives at the car long before the x-rays
c) The x-rays arrive at the car just before the visible light.
d) The x-rays arrive at the car long before the visible light.
e) The x-rays and the visible light arrive at the car simultaneously.

Problem 10 (4 pts, no need to show work):

According to the standard theory of big bang nucleosynthesis, the light nuclei distributed throughout our universe were formed

a) around 10^{-43} seconds after the big bang.
b) around 10^{-6} seconds after the big bang
c) around three minutes after the big bang.
d) around 400,000 years after the big bang.
e) only after the first stars in the universe were formed.

Problem 11 (4 pts, no need to show work):

A nucleus X decays into a nucleus Y and emits some form of radiation as shown by the reaction below.

$$^{50}_{21}X \rightarrow ^{50}_{20}Y + ?$$

The particle that is emitted (symbolized above as "?") is

a) an alpha particle.
b) a negative beta particle (electron)
c) a positive beta particle (positron).
d) a photon.
e) a neutron.

Any of these

Problem 12 (4 pts, no need to show work):

List one scientific problem with the big bang theory that has led many scientists to believe inflation occurred in the early universe. (There are several that we discussed and I will accept any of them as an answer.)

Horizon problem - Parts of universe out of causal connectivity in thermal equilibrium
Flatness problem - Flat space is a special case of universe geometry - yet this is what we appear to have
large-scale structure problem - We know there is large-scale structure in our universe - where does it arise in Big Bang Model?

Problem 13 (4 pts, show work):

A radio station broadcasts a signal at a frequency of 90×10^6 Hz (or s^{-1}).

What is the wavelength of this radio wave?

$v = \lambda \nu$ $\quad v = c = 3 \times 10^8$ m/s $\quad \frac{3 \times 10^8}{90 \times 10^6} = \lambda = 3.33$ m

Photons in this signal have what energy?

$E = h\nu = (6.6 \times 10^{-34}\ J \cdot s)(90 \times 10^6\ s^{-1}) = 5.9 \times 10^{-26}$ Joules

Problem 14 (4 pts, no need to show work):

A "critical mass" is needed for a chain reaction to occur in a fission bomb because

X a) if the mass is too large, the density will be too high to sustain a chain reaction.
2 b) if the mass is too small, there will not be enough uranium to start the reaction.
2 c) if the mass is too large, the temperature will get too high and the entire mass will melt away without fissioning.
X d) If the mass is too small the temperature achieved during fission will be too low to sustain the reaction.
4 (e) If the mass is too small, too many neutrons will leak out of the material without causing fission.

Problem 15 (4 pts, no need to show work):

Which of the following has the longest wavelength?

a) An alpha particle.
(b) An electron.
c) A baseball.
d) A water molecule.
e) None of these objects have a wavelength.

Problem 16 (4 pts, no need to show work):

Astronauts in orbit around the earth feel "weightless" because

a) there is no gravity in the vacuum of space.
b) they are moving at constant velocity.
c) no forces are acting on them.
d) NASA has them on a strict low carb diet.
e) they are in free fall around the earth.

Problem 17 (4 pts, show work):

Carbon-14 has a half-life of approximately 6000 years. An ancient mummified corpse is found in an archeological dig in the Andes mountains which has roughly 1/32 of the normal amount of carbon-14 found in living things. How long ago did the person who became the mummy live?

$\frac{1}{2}$ $\frac{1}{4}$ $\frac{1}{8}$ $\frac{1}{16}$ $\frac{1}{32}$
→1 →2 3,4 →5

5 half lives have passed

Person lived (5)(6000 yrs) = 30,000 yrs ago

Problem 18 (10 pts):

Briefly explain what is the cosmic microwave background and how scientists believe it originated.

The CMB is radiation coming from the early stages of the life of the universe according to big bang cosmology. Prior to ~400,000 yrs after the big bang the universe was opaque (to light). at ~400,000 yrs after the big bang, the temperature of the universe dropped low enough that neutral atoms formed. Suddenly the universe became transparent and light present in the universe at that time streamed out freely. We see this light arriving at Earth from all directions. Because it is traveling to us from some 13.2 billion light years distance, the expansion of the universe massively redshifts this light from UV to Microwave. It is a perfect blackbody spectrum at a temperature of ~ 2 degrees Kelvin.

Problem 19 (10 points):

An average person in the US lives approximately 72 years. Does this mean that it is impossible for such an average person to travel more than 72 light years from earth (in principle)? Briefly explain your reasoning. Note: assume crazy things like cryogenic sleep do not play a role here.

72 years is the traveling person's proper time. From the point of view of someone on earth, Relativistic time dilation would lead to an apparent age much greater than 72 years if person traveling with large γ. Thus they could travel much further than 72 ly.

From pt of view of traveler — They only live 72 years ... but length contraction makes what they see as 72 l.y. as a much larger distance to people on Earth. leads to SAME conclusion.

Travel of distances > 72 l.y. possible in principle.

Problem 20 (10 points):

Because of your amazing physics expertise you become a consultant on nuclear terrorism to the U.S. Department of Missles and Urban Development (MUD) after graduation. One day the Grand Pubah Ubersecretary of MUD, Samuel Thudpucker III, calls you to his office to ask for your advice on a national security matter. Samuel sits you down and says, "We have just apprehended a nasty, scumbag terrrorist type and interrogated him. He didn't give up much information at first, but after we threatened to make him watch CNN's Nancy Grace endlessly, he broke. The scumbag told us that he and his nasty friends recently acquired a special nuclear bomb that uses iron as the active bomb material. Is this credible? Should we be worried?"

Please give here a brief and appropriate response to Ubersecretary Thudpucker's questions using what you have learned in this course.

Mr. Ubersecretary, this report is NOT credible. Since the nucleons in the iron nucleus are held more tightly than the nucleons of any other nucleus, neither a fission or fusion process will lead to a release of energy. Iron is quite unsuitable as the active material for a bomb.

Some potentially useful formulas

$F = \frac{G m_1 m_2}{r^2}$

$F = \frac{k q_1 q_2}{r^2}$

$F = ma$

(distance) = (speed)(time)

$V = \frac{\Delta x}{\Delta t}$

$a = \frac{\Delta V}{\Delta t}$

Work = force × distance

Momentum = $p = mv$

$\Delta x' = \gamma \Delta x$, Δx longest in proper frame

$\Delta t' = \gamma \Delta t$, Δt shortest in proper frame

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

$c = 3 \times 10^8$ m/s

$h = 6.6 \times 10^{-34}$ J·s

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

$v = \lambda \nu$

$\nu = \frac{1}{T}$ (T = period)

$\Delta x \Delta p > h$ $\Delta E \Delta t > h$

$E = h\nu$

$\frac{\Delta N}{\Delta t} = \lambda N$

$t_{1/2} = \frac{0.693}{\lambda}$

I know this exam is taking place early in the exam period. Unfortunately, my TA's for this course have to take exams and will not grade these exams until late in the week. I hope to have the exams graded and final grades calculated by late on December 22. Once that is done and the grades are submitted, I will notify you via email that the grades are out. At that point, you can check the grades on your Access account. Please do not email me with questions/comments at that point. As soon as the grades are submitted I will try to get all the information used in calculating your grades into BlackBoard. When that is done, I will notify you via email that it is done and provide some directions. After you inspect all the input information and ponder the calculation and the curve, feel free to contact me regarding your grade and the accuracy of the spreadsheet information, if needed. If there is a mistake in the spreadsheet information, we will work together to straighten it out. If I run into technical problems with BlackBoard, the information will be put there as soon as I can do it, perhaps after Christmas if the technical experts are on vacation. Final exams will be available when you return. I urge you to pick up yours and check through it to verify that the grading was reasonable. You can submit regrade requests to me next term and I'll make a grade change if appropriate.

For now, forget it, relax, and most of all … Have a great holiday!! Thanks for being such a great class!