P100 University of Rochester NAME Soln key - SLM
S. Manly Spring 2007

Final Exam (May 8, 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 (13 pts, no need to show work):

By each description on the left, put the letter of the answer on the right that best fits. There may be more than one answer on the right that works, in which case any of the correct answers is sufficient.

m One type of quark found in neutrons

L Force carrier (gauge boson) for electromagnetic interaction

g Force carrier (gauge boson) for strong interaction

h Only undiscovered particle predicted by the Standard Model of particle physics

b Particle that can pass through light years of lead without interacting

f or i One of the particles mediating the weak interaction (force carrier for weak interaction)

c or q A particle made up of three quarks

d An example of a meson

k or b or a An example of a lepton

g or L or n A massless particle

(3 pts) List below three of the five particles listed to the right which are known to be made of other particles (have constituents).

c, d, o, p, q

a. electron

b. muon neutrino

c. proton

d. pion

e. charm (c) quark

f. W

g. gluon

h. higgs

i. Z

j. top (t) quark

k. muon

l. photon

m. up (u) quark

n. graviton

o. hydrogen atom

p. hadron

q. baryon

P100 University of Rochester NAME Soln key - Slm
S. Manly Spring 2007

Scores
1. 13/13
2. 3/3
3. 3/3
4. 3/3
5. 3/3
6. 3/3
7. 3/3
8. 3/3
9. 3/3
10. 3/3
11. 3/3
12. 3/3
13. 3/3
14. 7/7
15. 4/4
16. 3/3
17. 3/3
18. 6/6
19. 6/6
20. 6/6
21. 6/6
22. 7/7
23. 3/3

Total 100/100

Wow!

Problem 2 (3 pts, no need to show work):

Is it possible to prove, for certain, that a scientific theory is true?

a) Yes, by means of a single confirmed experiment that verifies the theory.
b) Yes, by carrying out a sufficient number of experimental observations.
c) Yes, by deducing it logically from other scientific theories that are known to be true.
[✓ **d)**] No, because it is always possible that a future experiment will disagree with the theory.
1 pt → **e)** No, because of the experimental error, or uncertainty, that is always present in any experimental result.

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

Is it possible for the driver of a car to accelerate the car without pressing on the accelerator pedal?

1 pt → **a)** Yes, by pressing the brake pedal.
1 pt → **b)** Yes, by turning the steering wheel.
[✓ **c)**] Yes, by both of the above methods.
d) No, because the only way to speed up a car is to press on the accelerator pedal.
e) No, because an object in motion remains in motion unless acted on by a force.

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

Suppose you are on the moon and you drop a rock and a feather at the same time. You will find that

[✓ **a)**] the two fall at the same speed, but this speed is slower than a rock would fall on Earth.
b) the two fall at the same speed, and this speed is the same as the speed of a rock falling on Earth.
c) the rock falls faster than the feather, although both of them fall slower than they would on Earth.
d) the rock falls faster than the feather, and both speeds are the same as they would be on Earth.
e) they don't fall. They remain suspended above the surface of the moon.

Problem 5 (3 pts, no need to show work):

Two sources of waves, call them A and B, send out waves across the surface of a lake. The waves from A have crests 1 cm high as measured from the normal undisturbed surface of the water. The waves from B are identical to those from A. How far is the water displaced at a point where a crest from A crosses a valley from B?

a) 2 cm above.
b) 1 cm above.
[✓ **c)**] No displacement.
d) 1 cm below
e) 2 cm below

Problem 6 (3 pts, no need to show work):

Ernest Rutherford’s experiments in which alpha particles passed through or scattered from a thin piece of gold foil demonstrated that

a) Light is a wave.
b) Light is made of particles.
[✓ **c)**] The atom contains a tiny nucleus containing most of the atom’s mass and positive charge.
d) Electrons exist.
e) Neutrons exist.
f) It is possible to generate x-rays from a heavy metal.

Problem 7 (3 pts, no need to show work):

Two electromagnetic waves have different frequencies but equal amplitudes. The one with the higher frequency has

a) Greater speed.
b) Longer wavelength.
[✓ **c)**] Greater energy.
d) All of the above.
e) None of the above.

Problem 8 (3 pts, no need to show work):

Velma’s rocket ship is moving away from Mort at a speed of 0.75c. Mort fires a laser beam toward her spaceship, observing the tip of the laser beam to move away from him at speed c. Velma observes this laser beam to move past her at a speed of

a) 1.75c.
b) 1.25c.
[✓ **c)**] c.
d) 0.75c.
e) 0.25c.
f) The light never catches up with Velma.

Problem 9 (3 pts, no need to show work):

If you were in a spaceship in outer space and accelerating at 0.5g, how heavy would you feel?

a) weightless.
[✓ **b)**] half your normal weight.
c) your normal weight.
d) 1.5 times your normal weight.
e) The answer depends on how fast the spaceship is moving.

Problem 10 (3 pts, no need to show work):

Which chemical elements were created during the first few minutes of the big bang?

a) All 92 of the naturally-occurring chemical elements.
b) Only the heaviest elements, having atomic numbers higher than that of lead.
c) Only the elements through iron in the periodic table, i.e., only elements 1 through 26.
[✓ **d)**] Only a few of the lightest elements, such as hydrogen, helium, and lithium.
e) No chemical elements were produced in the big bang. All the normal chemical elements were produced much later.

Problem 11 (3 pts, no need to show work):

One unusual aspect of dark matter is

a) it exerts no gravitational force.
b) its gravitational force pushes (repels) instead of pulling.
[✓ **c)**] it's made of a material that has not yet been observed in our laboratories.
d) it exerts a new kind of fundamental force, never observed before.
e) it moves at lightspeed.

Problem 12 (3 pts, no need to show work):

Which of the following is a consequence of Heisenberg's uncertainty principle?

1 pt for any of these

a) The overall layout of the universe.
b) The uncertainties involved in determining a person's genetic inheritance with DNA molecules are combined.
c) The range of the weak nuclear interaction.
d) The unpredictability of radioactive decay.
[✓ **e)**] All of the above.

Problem 13 (3 pts, no need to show work):

During the Manhattan project, what was the primary site for enriching uranium, i.e., separating the U-235 from U-238?

a) Los Alamos, New Mexico
b) Los Angeles, California
c) Hanford, Washington
[✓ d)] Oak Ridge, Tennessee
e) Lawrence Livermore Laboratory in Livermore, California

P100 University of Rochester NAME Soln key - SM
S. Manly Spring 2007

Problem 14 (7 pts, no need to show work):

Of the four fundamental forces of nature (strong, weak, electromagnetic, gravitational), which one is responsible for

holding atoms together to make a table? Electromagnetic

holding electrons in atoms? Electromagnetic

holding nuclei together? Strong

making balls fall downward when dropped? Gravitational

nuclear fusion? Strong

beta decay of a nucleus? Weak

the emission of light by an atom? Electromagnetic

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

List two scientific discoveries that Galileo made.

objects of Different weights fall at the same rate

Noted pendulums swing at approx. the same rate independent of amplitude

craters on moon, sunspots, Saturn was not round, Milky Way composed of stars

Moons of Jupiter, phases of Venus

Problem 16 (3 pts, no need to show work):

In football, receivers with "soft hands" are good to have on your team. Why?

a) All football players are concerned with having pretty hands and nails.
b) Having a good amount of flesh on the hands lessens the shock of the ball on the bones of the receiver's wrists, allowing them to avoid injuries.
c) If their hands are soft, it doesn't hurt as much when you give them a "high-five".
d) They are less likely to damage the ball with repeated catches.
[✓ e)] Giving a little when the ball hits the hands allows for the change in velocity of the ball to be stretched over more time generally leading to a higher probability of a good catch.

Problem 17 (3 pts, no need to show work):

List the experimental scientific evidence to date, if any, that supports string theory as a correct vision of how our universe operates.

There is no experimental evidence supporting string theory yet.

P100 University of Rochester NAME Soln key - SM
S. Manly Spring 2007

Problem 18 (6 pts):

Why is the Bohr model of the atom important historically and today?

The Bohr model is the first nuclear model of the atom that was able to explain discrete atomic spectra. This, in an of itself, was important. At its core, though, the Bohr model incorporated quantized orbits and transitions between these orbits were done by emitting and absorbing photons of energy $h\nu$. The success of the Bohr model helped solidify the idea that light exists in little quanta and helped set the scene for the emergance of quantum mechanics a decade later. Today, the Bohr model is important because it shares many of the same features of the full blown quantum mechanical solution of the Hydrogen atom and is useful for guiding one's intuition and understanding at times.

Problem 19 (6 pts):

Describe a chemical bond between atoms in a molecule? What is its essence? How does it work?

All chemical bonds are fundamentally electromagnetic in nature. In some cases, known as ionic bonds, an electron from one atom is transferred to a second atom. This leaves the former atom with a net positive electric charge and the latter atom with a net negative charge. These atoms are then attracted to one another electrostatically. In another typical type of chemical bond, known as a covalent bond, the atoms actually share a couple of electrons (usually one from each atom). The shared electrons tend to be positioned spatially between the two atomic nuclei. This means each nucleus is attracted toward the net negative charge between them and this forms the basis of the chemical bond.

P100 University of Rochester NAME Soln key - Slm
S. Manly Spring 2007

Problem 20 (6 pts, show work):

A car has a mass of 1000 kg.

$F = Ma$
$= Mg$

a) (2 pts) How much does this car weigh?

$$\underset{M}{(1000\ kg)}\ \underset{g}{(9.8\ m/s^2)} = 9800\ \text{Newtons}$$

If this car is moving along a flat, straight road at a constant 50 km/hour and it experiences wind resistance opposing its motion of 500 Newtons,

b) (2 pts) What is the net force on the car?

The net force is zero since the car is not accelerating.

c) (2 pts) What is the force exerted by the car and tires to drive the car forward?

This force must be equal and opposite to the force from wind resistance so that the net force is zero. Consequently, this force is 500 Newtons in the forward direction

I'll accept answers with no direction here.

Problem 21 (6 pts):

Is intergalactic space empty? Briefly defend your answer.

NO, intergalactic space is NOT empty.

Intergalactic space contains at least the following things:

- Some hydrogen and helium and lithium gas from the Big Bang
- Neutrinos from the big bang and stellar processes
- Virtual particle-antiparticle pairs popping in and out of the vacuum as quantum fluctuations.
- Photons streaming through space from all sources of light such as stars and the cosmic microwave background (from the big bang)
- Dark energy ... though we don't really know what this is yet.
- Some dark matter ... not yet fully understood.

The gas and dark matter interact gravitationally. So, they are mostly clumped in galaxies. But, small amounts could be found in between the galaxies,

Problem 22 (7 pts, show work):

Plutonium-239 (^{239}Pu) decays naturally emitting an alpha particle with a half-life of 24,000 years.

a) (2 pts) What is the isotope that plutonium-239 decays into? (Part of the periodic chart of the elements is reproduced below to aid in your quest for this answer.)

α decay $Z \rightarrow Z-2$
$A \rightarrow A-4$

$^{239}Pu \longrightarrow {}^{235}U + \alpha$

Answer: ^{235}U

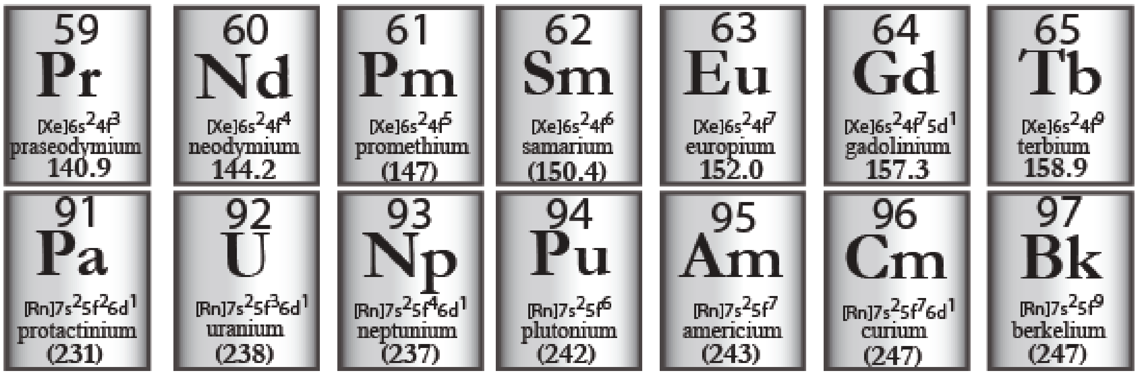
Suppose a particular nuclear bomb design requires 3.4 kg of plutonium in order to explode.

b) (2 pts) Knowing this, how much plutonium should be put in the bomb to insure that it will explode for the next 24,000 years?

6.8 kg since half of the Pu would be expected to decay in 24,000 years still leaving 3.4 kg

c) (3 pts) Do you think the strategy of putting more fissionable material in the bomb sufficient to insure the reliability of the bomb for many, many years? Briefly explain.

This isn't a great strategy. The Pu will have decayed to ^{235}U. What constitutes a critical mass of pure Plutonium might not work the same way if it is a Pu-U mixture. Also, it is necessary for other components of the bomb to function, such as the conventional explosive used to reshape the Pu into a supercritical mass. These components may not have a 24,000 "shelf life". So, it seems regular maintenance and component replacement would be necessary.



59 Pr [Xe]6s^{2}4f^3 praseodymium 140.9	60 Nd [Xe]6s^{2}4f^4 neodymium 144.2	61 Pm [Xe]6s^{2}4f^5 promethium (147)	62 Sm [Xe]6s^{2}4f^6 samarium (150.4)	63 Eu [Xe]6s^{2}4f^7 europium 152.0	64 Gd [Xe]6s^{2}4f^{7}5d^1 gadolinium 157.3	65 Tb [Xe]6s^{2}4f^9 terbium 158.9
91 Pa [Rn]7s^{2}5f^{2}6d^1 protactinium (231)	92 U [Rn]7s^{2}5f^{3}6d^1 uranium (238)	93 Np [Rn]7s^{2}5f^{4}6d^1 neptunium (237)	94 Pu [Rn]7s^{2}5f^6 plutonium (242)	95 Am [Rn]7s^{2}5f^7 americium (243)	96 Cm [Rn]7s^{2}5f^{7}6d^1 curium (247)	97 Bk [Rn]7s^{2}5f^9 berkelium (247)

Problem 23 (3 pts, answer honestly, this will help me design course in the future):

What topic (or topics) in this course did you find most confusing?

What topic (or topics) in this course did you find most interesting?

What topic (or topics) in this course did you find least interesting?

Any honest Answers here are correct

Blank → counted incorrect

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)

$$\Delta x \Delta p \simeq h$$