

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.

- | | |
|---|--------------------|
| ___ One type of quark found in neutrons | a. electron |
| ___ Force carrier (gauge boson) for electromagnetic interaction | b. muon neutrino |
| ___ Force carrier (gauge boson) for strong interaction | c. proton |
| ___ Only undiscovered particle predicted by the Standard Model of particle physics | d. pion |
| ___ Particle that can pass through light years of lead without interacting | e. charm (c) quark |
| ___ One of the particles mediating the weak interaction (force carrier for weak interaction) | f. W |
| ___ A particle made up of three quarks | g. gluon |
| ___ An example of a meson | h. higgs |
| ___ An example of a lepton | i. Z |
| ___ A massless particle | j. top (t) quark |
| (3 pts) List below three of the five particles listed to the right which are known to be made of other particles (have constituents). | k. muon |
| _____ | l. photon |
| | m. up (u) quark |
| | n. graviton |
| | o. hydrogen atom |
| | p. hadron |
| | q. baryon |

Scores

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

Total ___/100

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.
- 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?

- a) Yes, by pressing the brake pedal.
- 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?

- 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

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? _____

holding electrons in atoms? _____

holding nuclei together? _____

making balls fall downward when dropped? _____

nuclear fusion? _____

beta decay of a nucleus? _____

the emission of light by an atom? _____

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

List two scientific discoveries that Galileo made.

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.

Problem 18 (6 pts):

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

Problem 19 (6 pts):

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

Problem 20 (6 pts, show work):

A car has a mass of 1000 kg.

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

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?

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

Problem 21 (6 pts):

Is intergalactic space empty? Briefly defend your answer.

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.)

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?

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.

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?

Some potentially useful formulas

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

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

$$F = ma$$

$$(\text{distance}) = (\text{Speed})(\text{time})$$

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

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

Work = force \times distance

Momentum = $p = mv$

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

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

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

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

$$h = 6.6 \times 10^{-34} \text{ J}\cdot\text{s}$$

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

$$v = \lambda \nu$$

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

$$\Delta x \Delta p \approx h$$