

Final Exam (December 16, 2009)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary.

Problem 1 (2 pts, no need to show work):

incorrect value - should be 3

When you drop a ball it accelerates downward at 9.8 m/s^2 . If you instead throw it downward, then its acceleration immediately after leaving your hand, assuming no air resistance, is

- 3 - a) 9.8 m/s^2 .
- b) more than 9.8 m/s^2 .
- c) less than 9.8 m/s^2 .
- d) Cannot say, unless the speed of throw is given.

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

A moving car hits a mosquito. The evidence of the event is left on the windshield for all to appreciate.

- a) The force exerted by the car on the mosquito is greater than the force exerted by the mosquito on the car.
- b) The force exerted by the car on the mosquito is less than the force exerted by the mosquito on the car.
- 3 - c) The force exerted by the car on the mosquito is the same as the force exerted by the mosquito on the car.
- d) Nocturnal mosquitoes are made of dark matter and pass right through the windshield

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

Suppose you suddenly found yourself on a planet with the same mass as Earth but twice the radius. Relative to your weight on Earth, your weight on the new planet would be

- a) Two times larger.
- b) Two times smaller.
- c) Four times larger.
- 3 - d) Four times smaller.
- e) The same.

weight = mg

$$g = \frac{GM_E M}{R_E^2} \rightarrow \frac{GM_E M}{(2R)^2} = \frac{1}{4} mg$$

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

All of the following are electromagnetic waves EXCEPT

- a) radio waves.
- b) microwaves.
- c) light waves.
- d) X-rays.
- 3 - e) There are no exceptions. All of the above are electromagnetic waves.

3

Problem 5 (2 pts, no need to show work):

The phenomenon of interference occurs for

- 1 - a) sound waves.
- 1 - b) light waves.
- 3 - (c) Both of these.
- d) Neither of these.

Problem 6 (2 pts, no need to show work):

The higgs particle

- 3 - (a) is an as-yet-undiscovered particle that is an important component of the Standard Model of particle physics.
- b) is the virtual particle (gauge boson) that conveys the strong nuclear force.
- c) is thought to be the underlying cause of the increasing expansion rate of the universe.
- d) is a bound state of three quarks.
- e) is a form of natural radioactivity emitted by unstable heavy nuclei.

Problem 7 (2 pts, no need to show work):

The "string theory (or cosmic) landscape" refers to

- a) The set of P-branes thought to exist in M-theory.
- b) The distribution of light elements thought to be generated in the early stages of the big bang.
- c) The pattern of color (or temperature) variations in the cosmic microwave background according to a given string theories.
- 3 - (d) The vast number of ways in which the extra dimensions in string theory can be compactified leading to differing vacuum energies and differing particle spectra and force characteristics.
- e) The distribution of personalities present at theoretical physics conferences.

Problem 8 (2 pts, no need to show work):

The big bang is thought to have occurred about

- a) 5000 years ago.
- b) a million years ago.
- c) 14 million years ago.
- 3 - (d) 14 billion years ago.
- e) 14 trillion years ago.

Scores

- 1. 3/3
- 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. 30/30
- 14. 6/6
- 15. 6/6
- 16. 8/8
- 17. 6/6
- 18. 8/8

Total ___/100

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

The equivalence principle

- 3 - a) claims that accelerated reference frames and gravitational effects are indistinguishable.
- b) argues that the fact that life has evolved in our universe places strict limits on the constants of nature.
- 1 - c) is the name generally given to Einstein's discovery of $E=mc^2$.
- d) is the reason that neutrons and protons have almost the same mass.
- e) is the name given to the idea that white dwarf stars and brown dwarf stars have masses that are almost the same.

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

Our sun is expected to end its life as a

- (- a) red giant star.
- b) black hole.
- c) brown dwarf star.
- 3 - d) white dwarf star.
- e) smouldering mass of dark matter.

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

Galaxies are thought to be made mostly of dark matter. Evidence that supports this comes from observations of

- a) the redshift in the light from the explosions of distant supernovas
- b) the redshift in the light from the earliest galaxies in the universe.
- c) both of the above
- d) distant quasars.
- 3 - e) the speeds at which stars and gas clouds orbit the centers of nearby galaxies.

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

Most meteoroids – rocks moving through ^{outer} space – have been moving for billions of years. What, if anything, keeps them moving and why?

- a) According to Newton's law of gravity, the force of gravity keeps them moving.
- 3 - b) According Newton's laws, nothing is needed to keep them moving.
- 1 - c) According to Newton's law of gravity, nothing is needed to keep them moving.
- 1 - d) According to current theories about the creation of the universe, the expansion of the universe due to the big bang keeps them moving.
- e) According to Newton's law of motion, their own acceleration keeps them moving.

Problem 13 (30 pts, true or false, each part is worth 2 points):

- a) F Higher momentum particles exhibit longer wavelengths.
- b) F The muon is the virtual particle that conveys the weak nuclear force.
- c) F The force of gravity is only 10 times weaker than the weak nuclear force.
- d) T Dark matter particles have mass.
- e) F Dark energy refers to the energy carried by gluons during the early stages of the big bang.
- f) T Inflation is necessary for the bubble multiverse to exist.
- g) T Close inspection of the structure in the cosmic microwave background has revealed the space in the universe to be very close to flat.
- h) F Nuclear fission is the power source for stars.
- i) F Most of the uranium in the universe was made during the first several minutes after the big bang.
- j) T Some scientists claim that new universes might be spawned inside black holes.
- k) T The existence of dark matter is needed to account for the structure seen in the cosmic microwave background.
- l) F According to the hot big bang model, the cosmic microwave background was formed during the period in the early universe when light nuclei were formed.
- m) F The discovery of supersymmetric particles would scientifically disprove most string theories.
- n) T Modern string theories include objects other than string-like objects.
- o) F In string theory, compactification refers to the latter stage in the life cycle of massive stars when they collapse into black holes.

Problem 14 (6 pts, show work):

A clock-carrying-Superman zips past you at a speed of 90 percent the speed of light (0.9c).

You perceive each minute on the passing clock to last how many minutes according to the watch on your wrist?

The passing clock is Superman's clock → this is the proper frame. The time there is shorter than that measured in any other reference frame.

$$t_{\text{Superman}} \gamma = t_{\text{your wrist}}$$

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{0.9c}{c}\right)^2}} = 2.3$$

2.3 minutes

The clock-carrying-Superman perceives each minute passing on your watch to last how many minutes on his clock?

Same problem but in this case the proper frame is your wrist watch. Relative to that Superman would see each minute last 2.3 minutes by his clock

$$t_{\text{wrist}} \gamma = t_{\text{superman}}$$

Problem 15 (6 pts, show work):

Radon-222 ($^{222}_{86}\text{Rn}$) decays to Polonium-218 ($^{218}_{84}\text{Po}$) with a half-life of 3.8 days.

a) When Radon decays to Polonium, what form of particle is emitted?

α particle or ^4_2He

b) If a collected sample of gas initially exhibits 200 radon decays per minute, approximately how many radon decays per minute would you expect to measure 11 days later?

200 $\xrightarrow[3.8 \text{ days}]{1 \text{ half life}}$ 100 $\xrightarrow[7.6 \text{ days}]{2 \text{ half}}$ 50 $\xrightarrow[11.4 \text{ days}]{3 \text{ half}}$ 25

$\sim 25 \frac{\text{decays}}{\text{minute}}$

Problem 16 (8 pts):

Give very short descriptions of two experimental observations that provide scientific support for hot big bang cosmological models.

- 2 of 3
- Expanding universe \equiv redshift vs. distance graph for galaxies show that the further objects are away from us the higher the recession velocity
 - The relative amounts of light elements we see in the universe correspond to exactly what you might expect from Big Bang nucleosynthesis
 - The cosmic microwave background is observed with the characteristics of light from early universe when neutral atoms were formed.

Give very short descriptions of two problems with hot big bang cosmological models that are solved by the addition of inflation to the earliest stage of the big bang.

- 2 of these
- flatness of space - space could start up arbitrary geometry \rightarrow looks flat after inflation
 - Horizon problem - universe starts small before inflation - all in causal contact, which explains how very distant parts of universe are at the same temperature
 - small non-uniformities blown up to great size thru inflation explains why universe so uniform
 - quantum fluctuations during inflation led to small non-uniformities seen in early universe
 - universe starts as small quantum fluctuation that inflates avoiding a singularity

Problem 17 (6 pts):

How might an astronomer identify the atomic elements present in a distant object?

by observing the spectral lines emitted by bright sources
or absorbed from passing light for dark objects.

Problem 18 (8 pts):

Choose and briefly defend one of the two following statements (an argument for either can be made and the points are awarded for how well you make that particular argument rather than which statement you defend):

Basic points given here ...

“The multiverse is not a scientific concept.” -or- “The multiverse is a scientific concept.”

Want covered in discussion
on test.

not a scientific concept -

Science based on observation and falsifiability - not possible
with multiple universes

is a scientific concept -

Foundation of multiverse concepts spring from science with
supporting experimental evidence - [quantum mechanics]
[cosmology]

Can look at fundamental constants in our universe and
see if they are typical for different multiverse ideas.

e.g. - optimal for Blackhole production
or
Typical for string landscape

hydrogen 1 H 1.0079	beryllium 4 Be 9.0122	helium 2 He 4.0026
lithium 3 Li 6.941	magnesium 12 Mg 24.305	neon 10 Ne 20.180
sodium 11 Na 22.990	potassium 19 K 39.098	argon 18 Ar 39.948
calcium 20 Ca 40.078	scandium 21 Sc 44.956	krypton 36 Kr 83.80
strontium 38 Sr 87.62	titanium 22 Ti 47.867	xenon 54 Xe 131.29
barium 56 Ba 137.33	vanadium 23 V 50.942	radon 86 Rn 222
cesium 55 Cs 132.91	chromium 24 Cr 51.996	
francium 87 Fr [223]	manganese 25 Mn 54.938	
	iron 26 Fe 55.845	
	cobalt 27 Co 58.933	
	nickel 28 Ni 58.693	
	copper 29 Cu 63.546	
	zinc 30 Zn 65.39	
	gallium 31 Ga 69.723	
	germanium 32 Ge 72.61	
	arsenic 33 As 74.922	
	selenium 34 Se 78.96	
	cadmium 48 Cd 112.41	
	mercury 80 Hg 200.59	
	ununquadium 114 Uuq [289]	
	ununseptium 117 Uus [293]	
	ununoctium 118 Uuo [294]	
	unbinilium 120 Uub [296]	
	unbihunium 121 Uubh [297]	
	unbinilium 112 Uub [277]	
	ununnilium 110 Uun [271]	
	unundecium 111 Uuu [272]	
	unduodecimium 112 Uud [273]	
	untridecimium 113 Uud [274]	
	unquadecium 114 Uuq [275]	
	unpentdecium 115 Uup [276]	
	unhexadecium 116 Uuh [277]	
	unheptadecium 117 Uuh [278]	
	unoctadecium 118 Uuo [279]	
	unnonadecium 119 Uun [280]	
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Some potentially useful formulas

$$F = \frac{G m_1 m_2}{r^2} \left[\begin{array}{l} m_1, \text{ and } m_2 \text{ in kg} \\ r \text{ in meters} \\ F \text{ in Newtons} \end{array} \right] \rightarrow G = 6.7 \times 10^{-11}$$

$$F = \frac{k q_1 q_2}{r^2} \left[\begin{array}{l} q_1, q_2 \text{ in Coulombs} \\ r \text{ in meters} \\ F \text{ in Newtons} \end{array} \right] \rightarrow k = 9 \times 10^9$$

$$F = ma$$

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

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

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

$$\text{Work} = \text{force} \times \text{distance}$$

$$\text{Momentum} = p = mv$$

$$\Delta x' = \gamma \Delta x, \Delta x \text{ longest in proper frame}$$

$$\Delta t' = \gamma \Delta t, \Delta t \text{ shortest in proper frame}$$

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

$$1 \text{ Joule} = 1.6 \times 10^{-19} \text{ eV}$$

$$\text{speed of Sound} = 330 \text{ m/s}$$

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

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

$$\text{or } 4.5 \times 10^{-15} \text{ eV}\cdot\text{s}$$

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

$$v = \lambda \nu$$

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

$$E = h\nu$$

$$\Delta x \Delta p \geq \frac{h}{2\pi} \quad \Delta E \Delta t \geq \frac{h}{2\pi}$$

$$\frac{\Delta N}{\Delta t} = \lambda N \quad t_{1/2} = 0.693/\lambda$$