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):

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

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.
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.
d) Four times smaller.
e) The same.

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.
e) There are no exceptions. All of the above are electromagnetic waves.

Scores
1. ___/3
2. ___/3
3. ___/3
4. ___/3
5. ___/3
6. ___/3
7. ___/3
8. ___/3
9. ___/3
10. ___/3
11. ___/3
12. ___/3
13. ___/30
14. ___/6
15. ___/6
16. ___/8
17. ___/6
18. ___/8

Total ___/100

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

The phenomenon of interference occurs for
a) sound waves.
b) light waves.
c) Both of these.
d) Neither of these.

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

The higgs particle
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.
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.
d) 14 billion years ago.
e) 14 trillion years ago.

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

The equivalence principle

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.
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.
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.
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 outser 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.
b) According Newton's laws, nothing is needed to keep them moving.
c) According to Newton's law of gravity, nothing is needed to keep them moving.
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) _____ Higher momentum particles exhibit longer wavelengths.
b) _____ The muon is the virtual particle that conveys the weak nuclear force.
c) _____ The force of gravity is only 10 times weaker than the weak nuclear force.
d) _____ Dark matter particles have mass.
e) _____ Dark energy refers to the energy carried by gluons during the early stages of the big bang.
f) _____ Inflation is necessary for the bubble multiverse to exist.
g) _____ Close inspection of the structure in the cosmic microwave background has revealed the space in the universe to be very close to flat.
h) _____ Nuclear fission is the power source for stars.
i) _____ Most of the uranium in the universe was made during the first several minutes after the big bang.
j) _____ Some scientists claim that new universes might be spawned inside black holes.
k) _____ The existence of dark matter is needed to account for the structure seen in the cosmic microwave background.
l) _____ 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) _____ The discovery of supersymmetric particles would scientifically disprove most string theories.
n) _____ Modern string theories include objects other than string-like objects.
o) _____ 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 clock-carrying-Superman perceives each minute passing on your watch to last how many minutes on his clock?

Problem 15 (6 pts, show work):

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

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

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?

Problem 16 (8 pts):

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

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.

Problem 17 (6 pts):

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

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*):

"The multiverse is not a scientific concept." -or- "The multiverse is a scientific concept."

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	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	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Some potentially useful formulas

$F = \frac{G m_1 m_2}{r^2}$ [m_1 and m_2 in kg, r in meters, F in Newtons] $\rightarrow G = 6.7 \times 10^{-11}$

$F = \frac{k q_1 q_2}{r^2}$ [q_1, q_2 in Coulombs, r in meters, F in Newtons] $\rightarrow k = 9 \times 10^9$

$F = ma$

(distance) = (speed)(time)

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

speed of sound = 330 M/s

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

$h = 6.6 \times 10^{-34}$ J·s
or
4.5×10^{-15} eV·s

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

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

work = force × distance

Momentum = $p = mv$

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

$v = \lambda \nu$

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

$E = h\nu$

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

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

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

$\Delta x \Delta p \geq h/2\pi$ $\Delta E \Delta t \geq h/2\pi$

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