1. The conflict between Newtonian/Galilean physics and Maxwell’s equations governing electromagnetism (electricity and magnetism) was solved by making which quantity constant, now famous among the public?

2. Give one of the reasons why exceeding the speed of light is not possible (what is “needed” to do it?) One or two words should be a sufficient answer. (Note that to the best of our knowledge today, this idea is still true.)

3. What do the three letters in $E = mc^2$ stand for?

4. Name one of the bizarre features of the theoretical tachyon particle.

5. Both the Einstein light clock demonstration in class and the ______ experiment we learned of earlier demonstrate that the speed of light being the same along different paths has some dramatic consequences.

6. True or false: When testing the “Twin Paradox” effect in real life, it was proven true.

7. What are the two kinds of reference frames as defined in relativity (in the context of the in-class demo)?

8. Which planet’s orbit did General Relativity (GR) explain/predict correctly to very high precision? What makes this planet so special that another one would not have been as effective of a test of GR?

9. True or false: Visible or not, stars will always appear in the same place regardless of the position of the sun.

10. Complete this analogy: Gravity is to “frame dragging” as electricity is to ______.

11. To prevent his universe from expanding, Einstein inserted the ______ constant into his equations.

12. Ignoring corrections at extreme distances, what shape does Hubble’s law appear to be on a normal, non-logarithmic graph?

13. True or false: a balloon interior filled with galaxies moving apart through space as the universe expands is an apt analogy for Hubble’s discovery. Regardless of whether true or false, what is a better analogy?

14. True or false: Mach’s principle as defined in lecture stands in conflict with the idea of “relative” motion and lack of a standard reference frame for all observers anywhere in outer space.

15. True or false: according to General Relativity at least, space-time can exist without matter/particles/atoms. Regardless of answer: Whose solution to Einstein’s equation demonstrated this fact?

16. According to the Big Bang theory, the universe started out as what kind of mathematical point of no size?

17. Name one of the more exotic hypotheses which people came up with in class for the birth of our Universe (NOT Big Bang or Steady State/eternity).

18. True or false: the majority of the scientific community accepted the Big Bang concept immediately. What was the name of the most prominent opposing model/theory, and who pushed for it?

19. Circle one: according to the Big Bang model the density of the universe is [increasing, decreasing, staying the same] today as it expands. What does Steady State say?

20. In *Journeys to the Ends of the Universe*, the case is made by the author that the universe [does, doesn’t] conserve energy, although we learned from the balloon example that expansion apparently [does, does not].

21. In “The Expanding Universe,” the author mentioned how astronomer ______ discovered that the Milky Way is not the only ______ in the Universe, by proving that the “______ Nebula” was actually outside of it.

Write (or type) your answers on the reverse and/or on additional pages as needed. NO MORE e-mailed HW. Watch out for multiple-part (multi-point) questions, which many of these are, as usual.
Homework #4. Topics: Lectures from 02-05 through 02-10, and any/all related reading assignments
Assigned: 02-08-2016 (Monday)
Due Date: 02-15-2016 (Monday, beginning of class). No late accepted

1. The speed of light 1 point

2. Any of the following accepted: negative (rest) mass, infinite force, infinite energy, infinite work, infinite push or kick, more energy than contained in whole universe, must be a tachyon particle, etc. Half-credit: no mass, zero mass, massless, be a photon, etc. (“no ‘weight’” not acceptable). Gets you to $c$, but not past 1 point

3. energy, mass, and the speed of light (matter accepted also instead of mass) 3 points

4. Any of following: negative mass, mass less than 0, traveling faster than the speed of light (all the time), imaginary number mass (when traveling), gains energy when slows down, loses energy when speeds up 1 point

5. Michaelson-Morley 1 point

6. True (atomic clocks on fast planes) 1 point

7. inertial (constant or zero speed), non-inertial (acceleration or gravity). In-class demo was chair moving at constant speed vs. accelerating: can’t catch ball (easily) in second case because is receding. 2 points

8. Mercury; close to Sun 2 points

9. False (because of gravitational lensing) 1 point

10. magnetism 1 point

11. cosmological 1 point

12. Line, straight line, perfectly straight (line), straight slope, linear, non-curved line, etc. sloped upwards 2 points

13. False (galaxies on surface of balloon not on the inside); raisin bread rising (this was the analogy given in class) or sugar in coffee (anything similar accepted: objects in another material, where the material substrate is itself “expanding,” pushing the objects apart, instead of them separating “on their own”) 2 points

14. True 1 point

15. True, de Sitter 2 points

16. Singularity, black hole, quantum singularity, zero-dimensional point, infinitely dense/hot point, infinitesimal point (all OK) 1 point

17. Light spreading out and forming matter 1 point

18. False, because there was an argument over it until at least 1964 with CMB discovery; Steady state theory/model; Fred Hoyle (also accepted: Hermann Bondi, Thomas Gold, though Fred was leader) 3 points

19. Decreasing, stay the same 2 points

20. does (+ and - energy cancel out to zero), doesn’t (wavelengths stretching, energy dropping) 2 points

21. (Edwin) Hubble, galaxy/Galaxy, Andromeda (which was called Nebula before being called Galaxy) (Note: not Shaply, who argued the reverse, though was first to correctly estimate the size of the Milky Way) 3 points

Total points for HW4: 34 points

Write (or type) your answers on the reverse and/or on additional pages as needed. NO MORE e-mailed HW. Watch out for multiple-part (multi-point) questions, which many of these are, as usual.