1. During the in-class demo, the abundances of which two lightest elements were explained?

2. The discoveries of which two types of early galaxy proved the universe is not the same between past and present? What was the name of the theory "killed" as a result? What competing one was supported?

3. What were the three paradoxes that called the Big Bang into question until explained by inflation?

4. True or false: As far as we can tell, all the data tell us the universe is round like the earth.

5. If inflationary theory is correct, then approximately how many magnetic monopoles should be left, scattered throughout the entire visible universe?

6. How does inflation "flatten" the universe? What does this mean for parallel lines and for triangles? Relative to the so-called critical density, what does this imply for the overall mass/energy density of the universe?

7. True or false: inflation and dark energy have opposite effects upon the expansion of the universe.

8. In the Discover Magazine article, the BICEP2 collaboration was looking for evidence of gravitational _______.

9. Choose one of the ways to tell how old the universe is (or get a lower bound).

10. A full quantum mechanical theory of which force of nature should allow us to better understand the nature of the Big Bang singularity?

11. What are the three fundamental forces of nature (besides gravity)?

12. True or false: Quarks cannot exist as free particles, but only confined within baryons or mesons, or as part of a hot quark-gluon plasma like in the early universe.

13. During the epoch of "recombination" when the CMB was born, an electron could finally be bound to a nucleus in order to form a complete ______ without being knocked out again by high-energy photons.

14. About how many years did it take for stars and galaxies to start forming after the Big Bang? (Just provide the approximate order of magnitude.) True or false: the universe was completely dark before this happened.

15. In the energy budget of the universe, what is the most common component today?

16. True or false: On the largest scales, galactic structure averages out to look the same in all directions.

17. Objects outside the ______ universe are invisible because their light has not yet reached us.

18. Pick one of the types of curved space and name or list one of its features/causes/effects from lecture.

19. As far as we can tell, what is the value of the equation of state w for dark energy, and what is one of the consequences for the expansion of the universe then?

20. If the universe has positive curvature and no dark energy, it will likely end in a Big ______. If it instead expands forever (is "open"), which elements will the universe run out of for the formation of new stars?

21. According to Stephen Hawking, the prevalence of what (created by black holes) can explain dark energy?

22. True or false: Carl Sagan says if you were taken to another dimension, you could see through 3D walls.

23. If an electron took one path here, we speculate it perhaps took the other in a ______ universe.

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.
1. Hydrogen, helium (elements #1 and #2, Z=1 and Z=2, atomic mass numbers of 1 and 2, H and He) 2 points

2. Quasars and radio galaxies (also accepted: proto- or baby galaxies); Steady State; Big Bang 4 points

3. Flatness, isotropy, and missing exotic relics (just saying exotics or relics good enough, or specific example of any one of them from lecture: magnetic monopoles, cosmic strings, or rotation of universe) 3 points

4. False 1 point

5. Only 1 (see slide 7 of lecture 10) 1 point

6. Makes it really, really big really, really fast; Parallel lines stay parallel and angles of triangles add up to 180 degrees still like you learned in elementary school; Equal or close to it. 4 points

7. False, they have the same effect (accelerating expansion) 1 point

8. Waves 1 point

9. Possible answers: knowing stellar evolution, oldest stars like white dwarfs and globular clusters and oldest galaxies provide a crude lower bound, age of earth and solar system and rocks lower bound through different radioactive isotopes and elemental compositions, run expansion backwards once you know its speed (either absolute through size of whole universe or visible if you know it, or relative size from the scale factor, the average distance between galaxies) but you need Cepheid variables, Type Ia supernovae, and other standard candles to do it, Cosmic Microwave Background Radiation patterns in temperature/energy (seen with WMAP, Planck), other CMB properties, extrapolate redshift out to infinite/infinity, galaxy density over time, Hubble’s constant, etc. (And everything agrees within their uncertainties) 2 points

10. Gravity (half-credit, not answer looking for: 1 grand unified GUT force or synonym for One Force) 1 point

11. Strong (nuclear), weak (nuclear), electromagnetic (EM, electric, magnetic) 3 points

12. True 1 point

13. Atom (also accepted: H or H atom, or bound state) Half-credit (close): molecule or synonym 1 point

14. 1 billion (500 million, 2 billion, 10^9, etc. all acceptable) False: we had CMB after ~3-40,000,000 years. Trick question: Microwaves, even though technically invisible to our eyes, count as light. 2 points

15. Dark energy (OR cosmological constant OR ether OR ether OR quintessence OR vacuum energy OR vacuum fluctuations OR w=−1 material OR negative-pressure field OR quantum (mechanical) fluctuations OR particle-antiparticle pairs OR anti-gravity OR repulsive force or repulsion). Any synonym used. 1 point

16. True (clusters, voids only obvious at scales smaller than ~1-10 billion light-years or parsecs) 1 point

17. Visible 1 point

18. See slides 3,4,5,6 of Lecture 12 for all potentially correct answers 1 point

19. Slides 7 and 8 of Lecture 12. It's -1. Means universe will expand forever (accepted: Big Chill or Rip, cold dead state, heat death, stars all burn out, black holes everywhere, etc.) 2 points

20. Crunch; Hydrogen and/or helium 2 points

21. Baby universes (parallel (pocket) universe, alternate/alternative universe, bubble, similar...) 1 BONUS

22. True (unless walls 4-D instead of 3-D, but I meant ordinary walls) 1 point

23. Parallel universe (again, all synonyms accepted except bubble, which is half-credit, means something else, a different kind of multiverse member: contrast slides 7 & 8 of Lecture 13) 1 point 37+1 POINTS TOTAL

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