1. Name one “miraculous” feat possible if an extra or higher large spatial dimension exists and you could move into it and through it.

2. What is the trick to surviving a trip through a wormhole without getting crushed?

3. True or false: According to Lisa Randall, dark matter is made of WIMPs from another dimension.

4. The ekpyrotic alternative to the Big Bang avoids the problem of the universe starting with _____ densities and temperatures and energies.

5. Another alternative to the Big Bang is that _____ annihilated with matter to create a cosmic explosion. True or false: we don’t yet know for sure whether this model is wrong or not.

6. The anthropic principle states that the _____ behave(s) a certain way since otherwise life could not exist.

7. Name one of the differences between a parallel universe and a bubble universe.

8. True or false: an ordinary rocket should be able to enter a black hole or wormhole unaided and visit a parallel universe, making it out in one piece on the other side.

9. _____ makes it more challenging for the cyclic/oscillatory model of the universe to be viable, because by definition it should prevent a Big Crunch (and thus following Big Bounce) from happening.

10. In her essay, Rubin gives the example of the _____ (plural) orbiting much faster near the Sun compared to farther away, to illustrate the galactic rotation curve problem by analogy.

11. Mysteriously perhaps, the LUX scientists were actually proud of finding _____.

12. Sam Ting’s AMS experiment is an example of what kind of dark matter detector, out of the three types?

13. The _____ is a type of dark matter particle some scientists claimed evidence of seeing coming from the Sun through the signature of what type of radiation (type of photon or light)?

14. Who found the first observational evidence for dark matter? Name one of the pieces of evidence in favor of dark matter from either lectures and/or reading assignments.

15. What is one of the properties of a WIMP that makes it “dark” matter?

16. Why was the notion of MACHOs rejected in favor of axions and WIMPs? (What was some example counter-evidence?)

17. LUX is an example of a _____ dark matter detector (one of 3 types) and uses two channels, _____ and _____ to look for WIMPs. The difference in _____ between the two provides the depth of the event.

18. True or false: Our current best explanation for dark energy is off by many orders of magnitude.

19. Before the discovery of dark energy, what did we originally imagine would eventually slow down the expansion of the universe, even if incapable of halting it completely?

20. What is the most recent CMB experiment, and what organization or group is in charge of it?

21. What is the difference between the Sachs-Wolfe and Sunyaev-Zel’dovich effects in terms of CMB changes?

22. (Optional) What concept covered so far in class do you understand least? What confuses you about 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.
1. Seeing through walls or being all-seeing/all-knowing/omniscent, moving in and out of locked rooms, removing objects from sealed containers and being able to replace them, reversing your organs by leaving our dimensional plane and then re-entering it "backwards," being able to construct a wormhole in that higher dimension so you travel long distances faster, copies of particles but at higher masses (Kaluza-Klein tower), anything else mentioned in reading assignments, Carl Sagan Cosmos video, or appropriate lecture(s) 2 points

2. Having less than zero mass (being a tachyon) so you can move faster than the speed of light, or holding mouth/throat of wormhole open with negative (less than zero) mass or energy or mass/energy density a.k.a. matter of negative mass 1 point

3. FALSE: According to Lisa Randall, WIMP theory is wrong, and dark matter is just normal matter like the kind that makes up you and me, stars, planets, and galaxies but is just embedded in the higher dimension so we can feel its gravitational pull but not see its light. 1 point

4. Infinite (accepted: indefinite, undefined, unbounded, “not finite,” synonyms that make sense in this context) 1 point

5. antimatter (or antiparticles or anti-particles). FALSE: we know it is wrong for sure now from evidence (lack of enough cosmic gamma-rays from matter/antimatter annihilation) 2 points

6. My words from lecture 13 slide 7: “The only reason our universe is the way it is (supportive of sentient life) is because if it were otherwise, then we would not be here to ask! Other universes devoid of life.” Any paraphrase even partial or summary of this statement is acceptable. See Wikipedia entry for this principle. Sample answers: laws of physics, physical laws, laws of nature, principles/rules in physics, physical principles 1 point

7. Slides 7 and 8 of lecture 13: Bubble universes (from eternal inflation model NOT basic quantum mechanics like parallel universes) are physically separate (causally distinct) and with different laws of physics (except basic) like the speed of light, and rates of expansions. Many will have no life because the conditions were not just right, expanded too fast or too slow. Parallel universes overlap our own (ghostly-like fashion), and have the same laws, being created by divergences in quantum-mechanical-level "events," and possibly containing versions of you and me (more sci-fi-like). In both cases, communication and/or travel unlikely or impossible. 2 points

8. FALSE: Hawking says your particles could survive to be ejected through a white hole or into a baby universe, but no longer in one piece as you, that’s for sure! (For wormhole, see the answer to question #2.) 1 point

9. Dark energy (or any of its other names/variants, mentioned in lecture or reading, like lambda, cosmological constant, vacuum energy, quantum fluctuations, vacuum fluctuation, phantom energy, quintessence, w<1/3) 1 point

10. Planets (synonym, like planetary bodies, accepted) 1 point

11. NOTHING! (Or synonym) 1 point

12. Indirect (as opposed to direct or collider/accelerator) 1 point

13. axion, x-rays 2 points

14. Fritz Zwicky; for second half of question see slides 3-9 and 11 of lecture 14. 3 points

15. You can spell out the acronym accurately AND/OR name a trait from slide 9 (second bullet point) of lecture 16, which is slightly different (has some extra stuff) 2 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.
Homework #6. Topics: Lectures from 02-22, 02-24, 02-26, and any/all related reading assignments
Assigned: 02-22-2016 (Monday)
Due Date: 02-29-2016 (Monday, done by BEGINNING of class). NO late accepted. In-person hand-in ONLY

16. Slide 10 upper half in lecture 14. Basically, because dark matter needs to be non-baryonic (and also not leptonic, etc.) 2 points

17. Direct (NOT indirect, collider); S1/light/scintillation/photon(s)/(V)UV/primary; S2/charge/ionization/electrons/secondary (MANY different synonyms for the correct answer); time or arrival or time of arrival or (photon) arrival time 4 points

18. TRUE \((10^{120})\) 1 point

19. Matter, gravity, gravitational force, mass, (positive) energy (density), mutual (gravitational) attraction between pieces of matter/mass in universe, like galaxies/galaxy clusters. Numerous equally correct answers 1 point

20. Planck, ESA (European Space Agency), although BICEP2 is pretty recent too it is not the answer we were looking for (no one group "in charge" of BICEP2, which is ground-based) 2 points

21. Slide 10, versus Slide 11 second bullet, respectively, of Lecture 16. Also, read the entirety of http://ifa.hawaii.edu/cosmowave/supervoids/the-integrated-sachs-wolfe-effect/ as well as http://en.wikipedia.org/wiki/Sunyaev–Zel’dovich_effect BUT notice they do have one similarity in common: both heat up the CMB (increase the energy of the photons). They just do so differently. 4 points

**Total points: 36 points**