## Conceptual Questions

### 34.1 Cosmology and Particle Physics

1.

Explain why it only *appears* that we are at the center of expansion of the universe and why an observer in another galaxy would see the same relative motion of all but the closest galaxies away from her.

2.

If there is no observable edge to the universe, can we determine where its center of expansion is? Explain.

3.

If the universe is infinite, does it have a center? Discuss.

4.

Another known cause of red shift in light is the source being in a high gravitational field. Discuss how this can be eliminated as the source of galactic red shifts, given that the shifts are proportional to distance and not to the size of the galaxy.

5.

If some unknown cause of red shift—such as light becoming "tired" from traveling long distances through empty space—is discovered, what effect would there be on cosmology?

6.

Olbers's paradox poses an interesting question: If the universe is infinite, then any line of sight should eventually fall on a star's surface. Why then is the sky dark at night? Discuss the commonly accepted evolution of the universe as a solution to this paradox.

7.

If the cosmic microwave background radiation (CMBR) is the remnant of the Big Bang's fireball, we expect to see hot and cold regions in it. What are two causes of these wrinkles in the CMBR? Are the observed temperature variations greater or less than originally expected?

8.

The decay of one type of $K$-meson is cited as evidence that nature favors matter over antimatter. Since mesons are composed of a quark and an antiquark, is it surprising that they would preferentially decay to one type over another? Is this an asymmetry in nature? Is the predominance of matter over antimatter an asymmetry?

9.

Distances to local galaxies are determined by measuring the brightness of stars, called Cepheid variables, that can be observed individually and that have absolute brightnesses at a standard distance that are well known. Explain how the measured brightness would vary with distance as compared with the absolute brightness.

10.

Distances to very remote galaxies are estimated based on their apparent type, which indicate the number of stars in the galaxy, and their measured brightness. Explain how the measured brightness would vary with distance. Would there be any correction necessary to compensate for the red shift of the galaxy (all distant galaxies have significant red shifts)? Discuss possible causes of uncertainties in these measurements.

11.

If the smallest meaningful time interval is greater than zero, will the lines in Figure 34.9 ever meet?

### 34.2 General Relativity and Quantum Gravity

12.

Quantum gravity, if developed, would be an improvement on both general relativity and quantum mechanics, but more mathematically difficult. Under what circumstances would it be necessary to use quantum gravity? Similarly, under what circumstances could general relativity be used? When could special relativity, quantum mechanics, or classical physics be used?

13.

Does observed gravitational lensing correspond to a converging or diverging lens? Explain briefly.

14.

Suppose you measure the red shifts of all the images produced by gravitational lensing, such as in Figure 34.12.You find that the central image has a red shift less than the outer images, and those all have the same red shift. Discuss how this not only shows that the images are of the same object, but also implies that the red shift is not affected by taking different paths through space. Does it imply that cosmological red shifts are not caused by traveling through space (light getting tired, perhaps)?

15.

What are gravitational waves, and have they yet been observed either directly or indirectly?

16.

Is the event horizon of a black hole the actual physical surface of the object?

17.

Suppose black holes radiate their mass away and the lifetime of a black hole created by a supernova is about $10^{67}$ years. How does this lifetime compare with the accepted age of the universe? Is it surprising that we do not observe the predicted characteristic radiation?

### 34.4 Dark Matter and Closure

18.

Discuss the possibility that star velocities at the edges of galaxies being greater than expected is due to unknown properties of gravity rather than to the existence of dark matter. Would this mean, for example, that gravity is greater or smaller than expected at large distances? Are there other tests that could be made of gravity at large distances, such as observing the motions of neighboring galaxies?

19.

How does relativistic time dilation prohibit neutrino oscillations if they are massless?

20.

If neutrino oscillations do occur, will they violate conservation of the various lepton family numbers ($L_e$, $L_\mu$, and $L_\tau$)? Will neutrino oscillations violate conservation of the total number of leptons?

21.

Lacking direct evidence of WIMPs as dark matter, why must we eliminate all other possible explanations based on the known forms of matter before we invoke their existence?

### 34.5 Complexity and Chaos

22.

Must a complex system be adaptive to be of interest in the field of complexity? Give an example to support your answer.

23.

State a necessary condition for a system to be chaotic.

### 34.6 High-temperature Superconductors

24.

What is critical temperature $T_c$? Do all materials have a critical temperature? Explain why or why not.

25.

Explain how good thermal contact with liquid nitrogen can keep objects at a temperature of 77 K (liquid nitrogen's boiling point at atmospheric pressure).

26.

Not only is liquid nitrogen a cheaper coolant than liquid helium, its boiling point is higher (77 K vs. 4.2 K). How does higher temperature help lower the cost of cooling a material? Explain in terms of the rate of heat transfer being related to the temperature difference between the sample and its surroundings.

### 34.7 Some Questions We Know to Ask

27.

For experimental evidence, particularly of previously unobserved phenomena, to be taken seriously it must be reproducible or of sufficiently high quality that a single observation is meaningful. Supernova 1987A is not reproducible. How do we know observations of it were valid? The fifth force is not broadly accepted. Is this due to lack of reproducibility or poor-quality experiments (or both)? Discuss why forefront experiments are more subject to observational problems than those involving established phenomena.

28.

Discuss whether you think there are limits to what humans can understand about the laws of physics. Support your arguments.