Section 24-1

1. Carol is in a railroad car on a train moving west along a straight stretch of track at a constant speed of 120 km/h, and Charles is in a railroad car on a train at rest on a siding along the same stretch of track. Both cars have all the blinds pulled down. As Carol's train passes Charles' train, both persons drop a pencil from shoulder height to the floor. What does each person see?

- Carol and Charles see their pencils fall exactly straight down.
- Charles sees his pencil fall straight down, but Carol sees her pencil move toward the back of the railroad car at 120 km/h the moment she lets it go.
- Charles sees his pencil fall straight down, while Carol sees her pencil fall almost straight down, but with a small backward motion due to the motion of her train.

Section 24-1

2. In which of the following "frames of reference" would matter behave exactly as it would in a stationary frame of reference?

- Accelerating downward, as in an elevator whose cable has broken.
- Moving at a constant speed in a circular path, such as in a spacecraft following a circular orbit.
- Moving in a frame of reference at a constant velocity, such as a perfectly smoothly running railway carriage on a straight track.

Section 24-1

3. Suppose you are in a spaceship traveling at 99% of the speed of light past a long, narrow space station. Your direction of travel is parallel to the length of the station. If you measure lengths on the station and how time is passing on the station, what results will you get?

- Lengths will appear shorter and time will appear to pass slower.
- Lengths will appear shorter and time will appear to pass faster.
- Lengths will appear longer and time will appear to pass faster.

Section 24-1

4. Jill is a navigator on a spaceship that is passing Mars at 99% of the speed of

light. What happens when Jill uses a ruler to measure distances on a star map inside her spaceship?

- She does not perceive any change whatsoever in the length of the ruler due to the motion of the spaceship, and does not have to make any correction for this motion.
- She has to correct her measurements because the ruler is relativistically lengthened by the motion of the spaceship.
- She has to correct her measurements because the ruler is relativistically shortened by the motion of the spaceship.

Section 24-1

5. A spaceship is moving in a straight line past the Earth at 87% the speed of light. If an observer on the spaceship can see a clock on the Earth, how much time will the observer see elapse on the Earth's clock while one second ticks by on the spaceship's clock?

- 2.8 seconds.
- 0.49 seconds.
- 2.0 seconds.

Section 24-1

6. Suppose a spaceship moves past you at 95% the speed of light, and you are able to observe a clock on this spaceship. According to Einstein's special theory of relativity, you would see that clock running slower. If a person on the spaceship looks at your clock, what would that person see?

- The person would see your clock running faster.
- The person would see your clock running slower.
- The person would see your clock running normally because you are not moving, and relativity affects only objects that are moving.

Section 24-2

7. The principle of equivalence states that

- matter and energy are equivalent.
- uniform acceleration is indistinguishable from being at rest in a uniform gravitational field.

the laws of physics are the same for all unaccelerated observers, regardless of their motion.

Section 24-2

8. The position of the perihelion of Mercury shifts by 43 arcsec more than originally expected, per century. This effect was first explained by

- the general theory of relativity.
- Newton's theory of gravity.
- the special theory of relativity.

Section 24-2

9. At which of the following locations will Newton's laws of motion be inadequate in describing precisely the behavior and motions of physical objects?

- Closer to the Sun than the radius of Mercury's orbit.
- In the Space Shuttle, moving around the Earth at a speed of about 8 km/sec.
- Inside an artillery shell as it accelerates inside the gun barrel.

Section 24-2

10. A beam of light is now known to bend as it passes a massive object such as the Sun. What is the correct explanation for this "bending"?

- Everything, including light must follow the curvature of space around a massive object.
- The gravitational field interacts with the electromagnetic waves to produce bending of the beam.
- The gravitational force from the massive object acts upon the mass of the photons to cause their paths to deviate from a straight line.

Section 24-2

11. In an observation of a group of stars adjacent to the limb of the Sun during a total solar eclipse, which way will the nearest star to the solar limb appear to move because of the curvature of space near to the Sun?

- Toward the solar limb.

- Away from the solar limb.
- In a direction parallel to the limb of the Sun.

Section 24-2

12. In what way is the light affected by the intense gravitational field as it leaves the surface of a compact but massive star such as a white dwarf?

- Its wavelength is decreased.
- Its wavelength is increased.
- It is unaffected by gravitational fields because atoms are affected only by electric and magnetic fields.

Section 24-2

13. In which of the following locations would a clock run at its fastest rate?

- In a protected spacecraft near to the Sun's surface.
- In empty space.
- In the "weightless" environment on the Space Shuttle in orbit around the Earth.

Section 24-2

14. The gravitational redshift is due to

- the inability of light or matter to escape from inside the event horizon of a black hole.
- the slowing down of time in a gravitational field.
- the Doppler shift when gravitating objects make other objects fall toward them, and thus away from the observer.

Section 24-2

15. Gravitational waves

- have never been measured, directly or indirectly.
- have been detected only indirectly using neutron stars.

☐ have been detected directly by measuring the distortions they create in metal cylinders.

Sections 24-2 and 23-9

16. What force counterbalances the gravitational attraction of matter in a neutron star of 5 solar masses?

☐ Neutron degeneracy pressure.

☐ No force is powerful enough to do so.

☐ Electron degeneracy pressure.

Section 24-2

17. Can X rays escape from inside the event horizon of a black hole?

☐ No. Nothing (not even X rays) can escape through the event horizon.

☐ Yes. Matter that has fallen into a black hole is accelerated so intensely that its X rays escape back out through the event horizon.

☐ We don't know. We believe that we see X rays from black holes, but it is not possible to decide whether they are emitted from regions inside or outside the event horizon.

Section 24-2

18. What would happen to the Earth in its orbit if the Sun were to be replaced by a black hole of 1 solar mass on the stroke of midnight tonight?

☐ Nothing.

☐ The Earth would begin to spiral inward under the gravitational force of the black hole.

☐ The Earth would begin to move in a straight line at a tangent to its previous orbit.

Section 24-3

19. Several objects believed to be black holes have been discovered in our Galaxy by

☐ observing extremely red objects in which intense gravitational fields have redshifted all the emitted light to the far red end of the spectrum.

- finding binary star systems that emit X rays, and in which one component has a mass of greater than 3 solar masses.
- finding incredibly dark regions in the Galaxy from which no radiation is being emitted, and through which no light can penetrate from behind.

Section 24-3

20. Suppose that, in a single-line binary star system, the motion of the visible star indicates that the star has an invisible companion with a mass of 7 solar masses. Satellite observations detect an X-ray source in the star system that flickers irregularly in brightness over times as short as 1/100 of a second. Which of the following statements is correct?

- The most likely explanation is that the unseen companion is a black hole.
- The most likely explanation is that the unseen companion is a neutron star, but a black hole is not ruled out.
- The rapid flickering rules out both a black hole and a neutron star, and the unseen companion is almost certainly a white dwarf.

Section 24-3

21. Because nothing, not even light, can escape from a black hole, how has the existence of such an object been established?

- By the extreme gravitational redshift of light emitted by a close companion star.
- By the existence of a very dark area in the sky, from which nothing is being emitted.
- By the observation of its gravitational effect upon a visible companion in a binary star.

Section 24-3

22. What is the source of the X rays that are seen to come from a binary star system that contains a black hole?

- Highly condensed, and hence very hot, matter in an accretion disk around a black hole, beyond its event horizon.
- The singularity inside the black hole where matter is condensed to infinite densities.

A hot spot on the surface of the companion star, produced by matter being ejected with tremendous energy from the black hole in a focused jet.

Section 24-4

23. Some scientists believe that black holes can exist with masses similar to that of the Earth, although none has yet been observed. How are these black holes believed to have formed?

During supernova explosions, when the inner planets were compressed by the expanding gas from the star.

During the Big Bang, when small pockets of the universe could have collapsed to form black holes.

During the formation of rotating black holes, when small pockets of the collapsing material was thrown off by centrifugal forces.

Section 24-4

24. Where in the universe has evidence been found for the existence of supermassive black holes with masses of at least a million solar masses?

At the center of only one galaxy, our own Milky Way Galaxy.

In the centers of many galaxies.

Nowhere in the Galaxy, though their existence has been predicted by the general theory of relativity.

Section 24-5 and Box 24-2

25. The radius of the event horizon of a black hole, the Schwarzschild radius,

will be smaller the greater the mass of the black hole because matter will then be more condensed.

will be larger the greater the mass of the black hole.

is constant, as predicted by the general theory of relativity.

Section 24-5 and Box 24-2

26. If a 5-solar-mass black hole has a radius to its event horizon of 15 km, what will be the radius of a 50-solar-mass black hole?

- 150 km, occupying much more space.
- 1.5 km because the greater mass will condense space more.
- The same radius because all black holes have the same size.

Section 24-5

27. What is "cosmic censorship"?

- The composition of a black hole is forever hidden from view.
- A singularity cannot be visible to the rest of the universe.
- Black holes of less than 3 solar masses take longer than the present age of the universe to form (so there won't be any in our universe).

Section 24-5

28. Under what circumstances can particles escape from inside the event horizon of a black hole?

- No circumstances at all—nothing can ever escape from inside the event horizon, no matter what.
- Only if matter is being accelerated inward through the event horizon by gravity— high-energy photons from the matter can escape back out, but never the matter itself.
- Only if the black hole is rotating—then the matter escapes through the ergosphere.

Section 24-6

29. What fundamental characteristic distinguishes a Kerr black hole from a Schwarzschild black hole?

- A Kerr black hole is supermassive; a Schwarzschild black hole is not.
- A Kerr black hole rotates; a Schwarzschild black hole does not.
- A Kerr black hole is part of a semi-detached binary star system; a Schwarzschild black hole is either an isolated object or a member of a detached binary star system.

Section 24-6

30. Which of the following characteristics is expected to be a fundamental property of a black hole, and is very important for distinguishing one black hole from another?

- The ratio of protons to neutrons in the innermost mass of the black hole.
- The magnetic field of the black hole.
- The rate of rotation of a black hole.

Section 24-6

31. What are the basic physical properties of a black hole?

- Mass, angular momentum (or spin), and electric charge.
- Magnetic field, electric charge, and mass.
- Electric charge, angular momentum (or spin), and temperature.

Section 24-6

32. When a massive rotating star collapses into a black hole, which of the following properties will be enhanced?

- Angular rotation speed.
- Electric charge.
- Mass.

Section 24-7

33. What would be the nature of the forces or influences on a spacecraft as it approached the event horizon of a black hole?

- Tidal forces (also called differential gravitational forces) would act with different strengths along the axis of the spacecraft, stretching it and tearing it apart.
- The intense heat emitted from highly condensed and very hot matter within the event horizon would destroy the spacecraft.
- The magnitude of the gravitational force would be sufficient to crush the spacecraft.

Section 24-7

34. If a spacecraft equipped with a regularly flashing yellow light were to be observed as it moved toward a black hole, what would be seen as it approached the event horizon (assuming that it remained intact and functional, which is questionable!)?

- The light would become more and more red and the flashing rate would appear to slow down and eventually stop at the event horizon.
- The flashing light would become more and more blue and the flashing rate would speed up as the spacecraft accelerated into the black hole.
- The color of the flashing light would remain yellow and the flashing rate would slow down but not stop. The light would disappear at the moment that the spacecraft passed through the event horizon.

Section 24-8

35. By what mechanism is it thought that the mass (and therefore the size) of a black hole can decrease?

- By the escape of radioactive particles from material that is radioactive within the black hole.
- By "evaporation," particle-antiparticle pairs forming just outside the event horizon, one of which enters the hole while the second one escapes.
- There is no known mechanism for this to occur.

Section 24-8

36. All black holes are predicted to evaporate by continually emitting one component of a particle-antiparticle pair. Which of the following situations is true?

- The lowest-mass black hole will evaporate most rapidly.
- The highest-mass black hole will evaporate most rapidly because of its higher gravitational field.
- All black holes evaporate at the same rate, independent of their masses.