Quizzes Section 4

Relativity

1. You measure the speed of light from a source and find it to be $c = 3 \times 10^8\ m/s$. You then start moving towards the source at a very high speed. You measure the speed of light again and find it to be
(a) less than c.
(b) c (same as before).
(c) greater than c.

2. A stationary observer sees light of a certain frequency emitted from a source that moves towards him. If instead the observer moves at the same speed towards the source which is now stationary, the observed frequency will be:
(a) higher than before
(b) the same as before
(c) lower than before

3. Harry Potter and Draco Malfoy pass each other on broomsticks with relative speed v. Harry obersves that Draco's broom seems shorter according to the length contraction formula $L = L_p\sqrt{1 - v^2/c^2}$. Draco observes that Harry's broom seems shorter, by the same formula.
(a) This is truly a paradox and is the reason that Special Relativity is called a "theory."
(b) Actually, when used correctly the formula shows that Draco's broom must appear to be lengthened when observed by Harry.
(c) The issue is resolved because simultaneous events in one frame are not simultaneous in another.

4. Two rockets pass at high speed v with identical clocks on board. The crew on each ship sees a clock on the opposite ship running slow.
(a) This is truly a paradox and is the reason that Special Relativity is called a "theory."
(b) Actually, when used correctly the formula shows that one of the clocks has a low battery.
(c) The issue is resolved because simultaneous events in one frame are not simultaneous in another.

5. We see a spaceship flying past at 0.9c. The captain of the spaceship launches a missile, which she sees leaving her ship at 0.9c out the front. We see the missile traveling at
(a) a speed less than c.
(b) a speed equal to c.
(c) a speed greater than c.

6. Which is <u>not</u> true regarding special relativity:
(a) Two events (at different locations) which are simultaneous in one inertial frame are not simultaneous in other frames.
(b) The ordering (or sequence) of events is <u>always</u> the same regardless of the inertial frame.
(c) Moving objects appear to be contracted in length.
(d) Muons can survive longer before decaying if they are moving.
(e) In the lab frame, it can appear that two colliding particles approach each other with a relative velocity as high as almost 2c, but viewed in the rest frame of either particle the relative velocity is never greater than c.

7. A decade after his development of what we now call "Special Relativity", Einstein developed "General Relativity" which allows one to deal with accelerating frames of reference. He ingeniously asserted that
(a) there is energy in mass according to $E = mc^2$, which is derived from general relativity.
(b) there is no physical difference between a gravitation force and a force caused by the acceleration of a frame of reference.
(c) light from a distant star will bend as it passes near the Sun on its way to the Earth (viewed during an eclipse) because of the strong light field emitted by the Sun.

Blackbody

8. One of the earliest clues of quantum physics came when scientists tried to understand the nature of thermal radiation. The attempt failed when using traditional concepts. In 1900, Planck guessed a formula that fit the experimental data, and then noticed that he could derive the formula only if
(a) there is no light above a cutoff frequency given by the work function.
(b) he made a mistake in the algebra.
(c) the light field at a given frequency f can accommodate any amount of energy.
(d) the light field at a given frequency f takes on discrete values for energy, separated by hf, where h is an experimentally determined constant.

Rutherford

9. Why were Rutherford's alpha particle scattering results so surprising?
(a) The experiment suggested that the positive charge in an atom is spread over a large volume with embedded electrons like "seeds-in-a-water-melon."
(b) Classical physics suggests that electrons in orbit around center nucleus will radiate energy and quickly spiral into the nucleus.
(c) Bohr's model of the atom contradicts Rutherford's scattering experiment.

De Broglie

10. De Broglie's hypothesis
(a) confirmed that photons have no rest mass.
(b) gave justification for the quantization rule in the Bohr model of the atom.
(c) explained the photoelectric effect.

Uncertainty Principle

Which is true about the uncertainty principle (i.e., $\Delta x \Delta p \geq \hbar/2$)?
(a) The fact that particles have wave characteristics implies the uncertainty principle.
(b) The uncertainty principle explains why the Bohr model of the atom works.
(c) A large uncertainty in momentum requires a large uncertainty in position.
(d) All are true.
(e) None are true.

12. Young's two-slit experiment is performed with electrons and then repeated separately with protons. The same double-slit setup is used in both cases, and the particles are initially accelerated to the same initial kinetic energies (not relativistic). The fringe pattern for the electrons is very finely spaced. The fringes produced by the protons
(a) have wider spacing and are easier to see.
(b) have the same spacing as those for the electrons.
(c) have smaller spacing and are not likely to be seen.
(d) do not exist since the de Broglie wavelength of protons is zero.
(e) None of the above.

Nuclear

13. The mass of an atomic nucleus is equal to the mass of the number of protons and neutrons that are in it.
(a) True.
(b) False.

14. Iron has the most stable nucleus from the point of view that its constituents are bound with the highest energy per nucleon. Fusion, the joining of nuclei to form larger ones, *without* the net input of external energy tends to be *possible* for
(a) elements which are lighter than iron
(b) iron
(c) elements which are heavier than iron

15. Two heavy nuclei X and Y have similar masses. If X has a higher binding energy per nucleon, which one tends to be more stable against decay?
(a) X.
(b) Y.
(c) Same.

16. A sample of a radioactive isotope has a half-life of 1 year. After two years, the activity will be
(a) zero.
(b) half the initial value.
(c) a fourth the initial value.
(d) one eighth the initial value.
(e) exp{-2} the initial value.

17. Radon (^{222}Rn) is an inert noble gas, which comes up through the Earth's crust and can enter peoples' houses. Radon is dangerous to breath because it is active, with a decay life-time of about 4 days.
(a) If a home has a radon gas problem, it is only necessary to wait for a period much longer than 4 days and the problem will go away.
(b) Radon gas in people's homes is a problem because of the mining of fissionable materials.
(c) Radon gas is very corrosive chemically.
(d) None of the above.

Miscellaneous
18 A basic postulate of Special Relativity is
(a) the speed of light is the same in any inertial frame.
(b) light bends in a gravitational field.
(c) light is composed of photons.

19. Was the Michelson-Morley Experiment a <u>scientific</u> failure?
(a) Yes.
(b) No.

20. The photoelectric effect contradicts Planck's idea that light is composed of discrete packets of energy.
(a) True.
(b) False.

21. The fact that light is composed of photons means that light is not a wave phenomenon.
(a) True.
(b) False.

22. Which of the following experiments leads to the conclusion that light is composed of photons:
(a) The measurement of light spectra emitted from hot objects.
(b) The study of electrons ejected from various metal surfaces illuminated by different frequencies of light.
(c) The study of high-energy x-rays scattered when hitting electrons (Compton scattering).
(d) All of the above.

Answers

1. (b) Although the frequency is Doppler shifted, you measure the speed of light to be the same as before.
2. (b) Since there is no ether, only relative motion between the emitter and observer is important. This is different than for sound waves.
3. (c) Each measures the other's broom length by instantaneously marking the front and back and inspecting the separation. However, in the opposite frame, it does not appear that the marks are made simultaneously. Each views the other's measurement as bogus.
4. (c) To measure the ticks on the other ships clock, you will need two synchronized clocks in your frame located at positions where the moving clock ticks. Observers on the moving ship believe that your two clocks are not properly synchronized.
5. (a) The velocity addition rule divides the intuitive 1.8c by a factor that makes the result less than c.
6. (b) Suppose that two events are simultaneous in one frame (so that one cannot trigger the other). In a frame moving to the right, one event will precede the other. In a frame moving to the left, the opposite event will occur first. See the Lorentz transformations.
7. (b) In an accelerating frame of reference, a ray of light appears to bend. If we can't tell the difference between acceleration, say in a rocket, and the pull of gravity, then a light ray must bend in the same way in either situation. Gravity bends the path of light.
8. (d) The energy in a light field with frequency f cannot have arbitrary value but is restricted to discrete values separated by hf. This implies that light of a given frequency f is composed of indivisible packets of energy hf which are now called photons.
9. (b) Rutherford's results were surprising because they showed that an atom's positive charge and mass are concentrated in a tiny nucleus, not spread out to enable electrons rest in the center and not radiate.
10. (b) De Broglie hypothesised that like photons, all particles have a wavelength associated with their motion (i.e., $\lambda=h/p$). Electrons orbiting a nucleus are viewed as standing waves. Only certain orbital momenta permit standing waves (just as only certain frequencies correspond to standing waves on a guitar string).
11. (a) The uncertainty principle comes from particles behaving as waves. To localize a wave packet in position a wide range of interfering wavelengths is required. Therefore, a range of momenta are present when the position of the particle is more definite.
12. (c) Since the wavelength is $\lambda = h/p = h/\sqrt{2mK}$, the proton will have a much smaller wavelength because its mass is 1830 times larger. A smaller wavelength corresponds to a proportionally closer-spaced fringe pattern.
13. (b) Because energy is released when the constitutive particles join together, the mass is less according to $E = mc^2$.
14. (a) Elements that are lighter than iron increase in binding energy per nucleon with increasing size. Thus, fusing these elements together releases energy. In contrast, heavier elements increase in binding energy per nucleon with decreasing size. Thus, heavier elements release energy when undergoing fission, or breaking apart.
15. (a) Higher binding energy means harder to break apart.
16. (c) The sample loses half of its activity the first year, and half of the remaining activity in the second year.
17. (d) Radon gas is continuously generated as heavier elements in the Earth's crust undergo decay. This decay chain begins with $^{238}_{92}\mathrm{U}$ which has a long half-life (4.5×10^{9} yr). There is enough uranium that this slow decay process can produce a significant amount of radon, which percolates to the surface, sometimes in concentrated regions.
18. (a)
19. (b) A correct result is never a scientific failure.
20. (b)
21. (b) The wave describes where photons are likely to be found.
22. (d) All of these effects are explained using the idea that light is comprised of photons.