Solutions to Final; Phys 100

1. (5 points) Which of the following reflects the present best judgment of physicists concerning space travel?

(a) The engineering problems in making stable wormholes will take fifty years to resolve

(b) High-speed interstellar transportation of human crews is not feasible

(c) We will not need space travel if we train psychics to visualize other planets

(d) Interstellar travel depends on whether we have a large enough source of antimatter

(e) Superconducting magnets will let us overcome the speed-of-light barrier

2. (5 points) In $\Delta v \Delta x \geq h/4\pi m$, what does the quantity Δx refer to?

(a) The difference between successive measured values of a particles' position x

(b) The de Broglie wavelength of a large number of electrons making up a sample

(c) The likelihood of obtaining an exact measurement of x, if given an exact value of v

(d) A statistical measure, akin to standard deviation, describing the probability distribution for x

(e) The experimental error in x measurement introduced by the imperfections of equipment

3. (5 points) What the difference between alpha (α) radiation and infrared (IR) radiation?

(a) α is generated by gravitational force, IR is due to the weak nuclear force

(b) α is an elementary particle, IR is composed of gluons

(c) α is very low in total energy, IR particles are highly destructive

(d) α is a Helium nucleus, IR is a form of electromagnetic wave

(e) α is , IR is

4. (5 points) You lift an object that weighs 1 N by 1 m. By approximately how much does the object's mass increase?

(a) It does not increase at all

(b) wc^2/h

(c) wh/c^2

(d) $\frac{1}{2}wh^2/c$

(e) $\sqrt{w}/ch$

5. (5 points) If you built a "Dyson sphere" to completely enclose a star

(a) The star would become totally invisible to the rest of the universe

(b) The energy within would be effectively converted to "dark energy"

(c) The sphere would still radiate electromagnetically, due to its temperature

(d) The accumulation of energy within would lead to the creation of a black hole

(e) The intensity of beta radiation within the sphere would quadruple

6. (5 points) Which of the following is a good estimate for the *smallest possible* amount of time it would take to communicate a signal to the farthest point on Earth, from where you stand? (*Hint:* You don't need to remember any precise numbers. Only one option is even remotely reasonable.)

(a) 10^{-24} seconds

(b) 10^{-10} seconds

(c) 10^{-1} seconds

(d) 10^{8} seconds

(e) 10^{18} seconds

7. (5 points) Which of the following is a physics mistake in *The Algebraist*?

(a) Gravity going down to zero at the center of a large planet

(b) Spaceships that can travel faster than half the speed of light

(c) Worrying about relativistic mass increase when towing a wormhole at high speed

(d) The existence of a gas giant planet that is larger than Jupiter

(e) Being able to build a craft that dives into the high pressure areas deep in a gas giant

8. (5 points) Which of the following technologies relies on our understanding of quantum physics?

(a) Modern consumer electronics

(b) Heavier than air flight

(c) Warp drive

(d) Bridges with large spans

(e) Internal combustion engines

9. (5 points) If the total force on an object is non-zero, which of the following will change?

(a) Its distance to the center of the Earth

(b) Its electrical energy

(c) Its acceleration

(d) Its amplitude

(e) Its velocity

10. (5 points) Which of the following represents an area of physics that is not properly understood yet?

(a) The nature of temperature

(b) Line spectra

(c) Radioactive decays

(d) Quantum gravity

(e) Magnetism

11. (5 points) In our universe, which of the following measurements does *not* change relative to an observer?

(a) The speed of massive objects

(b) Mass

(c) Length

(d) Time intervals

(e) The speed of light

12. (5 points) Which is *not* true according to Aristotelian physics?

(a) The Earth is flat

(b) Earth is at the center of the universe

(c) The natural place of air is higher than that of water

(d) The Earth is subject to change and decay, but not the heavenly spheres

(e) Without a force, moving objects slow down

13. (5 points) For what phenomena that we encountered in the lab was the weak nuclear force responsible?

(a) Microwave cavities

(b) Beta decay

(c) Atomic spectra

(d) Friction

(e) Lens focusing

14. (5 points) According to Heisenberg's uncertainty principle, an object's location and speed cannot be determined simultaneously. Why do we not notice this uncertainty with a car driving down the road?

(a) We do not have a good theory of quantum gravity

(b) Our experimental equipment cannot measure such huge uncertainties

(c) The binding energies of the car's particles damp down the uncertainties

(d) Everyday automobiles move too slow compared to the speed of light

(e) A car is very massive, so the uncertainties are extremely small

15. (5 points) If you were in a spaceship far from any external gravitational influences, accelerating at "$2g$," what would you feel? (g is the acceleration due to gravity of the surface of the Earth.)

(a) As if your mass had doubled

(b) As if your weight had doubled

(c) No different, because h is always constant

(d) No different, because you're still beyond the event horizon

(e) Nothing, because you'd be immediately squashed to death

16. (5 points) As the Earth orbits the Sun, in what direction does the total force on the Earth point?

(a) Toward the Sun

(b) Away from the Sun

(c) Forward along Earth's orbit

(d) Backward along Earth's orbit

(e) The total force on earth is zero

17. (5 points) We are able to analyze the composition of distant stars because

(a) We have sent small robots to the stars and retrieved samples

(b) We can break apart the gravitational waves we detect from the stars into alpha-forms

(c) We can do spectroscopy and look for the line patterns of different elements

(d) All stars are alike, so if we know the composition of the sun, we know all others as well

(e) The spot pattern on star surfaces depend on the chemicals they are made of

18. (5 points) Most of the matter/energy in the observed universe

(a) Consists of charged neutrinos

(b) Is in the form of iron

(c) Has no gravitational effect

(d) Is "dark"—little is known about it

(e) Produces lethal muon showers throughout the universe

19. (5 points) A rocket blasts off from the surface of the Earth and heads off into space. The gravitational attraction between the rocket and the Earth will

(a) remain constant

(b) remain constant until the distance of the moon, but then abruptly become zero

(c) decrease regularly with distance, and become zero shortly beyond the moon

(d) decrease regularly with distance, but never become exactly zero

(e) increase until the distance of the moon, then gradually decrease

20. (5 points) If you were to dive deeper and deeper into a liquid moon, which of the following would you observe?

(a) Weight increases, pressure increases

(b) Weight decreases, pressure decreases

(c) Weight decreases, pressure increases

(d) Weight is constant, pressure decreases

(e) Weight increases, pressure is constant

21. (15 points) You know the following bits of physics:

- The bond energies in biological molecules are close to the energies of ultraviolet photons.
- A molecular bond is broken if a molecule absorbs a single energetic photon—not by gradually absorbing multiple photons.
- Ultraviolet photons have higher frequencies than visible photons.
- For photons, $E = hf$.

Use these facts to put together an explanation for why exposure to ultraviolet radiation increases your risk of skin cancer, while you can sit around bathed in very bright red light and it will not cause cancer. (Though it might drive you bananas.)

Answer: Since $E = hf$, and UV photons have higher frequencies, they have higher energy than visible photons. Indeed, their energy is able to break the bonds in biological molecules such as those than make up our skin. Visible photons, such as those that make up red light, cannot break these bonds because that would require the molecules to absorb multiple red photons. Therefore only UV is a cancer worry.

22. (15 points) In *The Algebraist,* The wormhole-towing E-ship *Est-taun Zhiffir* travels from Zenerre to Ulubis in 269 years as measured in the reference frame of the Ulubis system. Light from Zenerre takes 214 years to reach Ulubis. Assume that *Est-taun Zhiffir* travels at a constant speed V throughout its journey. Remember that $\gamma = 1/\sqrt{1-(v/c)^2}$, time dilation is expressed by $t = \gamma t_0$, and length contraction by $L = L_0/\gamma$.

(a) At what fraction of light speed does *Est-taun Zhiffir* travel? In other words, calculate the ratio v/c.

Answer:

$$\frac{v}{c} = \frac{214}{269} = 0.80$$

(b) What is the relativistic time-dilation factor γ for this speed s?

Answer:

$$\gamma = \frac{1}{\sqrt{1-0.80^2}} = 1.65$$

(c) How many light-years do the engineers on board the *Est-taun Zhiffir* measure the distance between Zenerre and Ulubis to be?

Answer: 214 light years is L_0, so

$$L = \frac{214}{1.65} = 130 \; c \cdot \text{years}$$

(d) How many years will the travel between Zenerre and Ulubis take for the engineers on board the *Est-taun Zhiffir*?

Answer: 269 years is t, so

$$t_0 = \frac{269}{1.65} = 161 \text{ years}$$

(e) You should find that the *Est-taun Zhiffir*'s journey takes longer than a normal human lifespan, even allowing for time dilation. Give one of the technologies imagined in *The Algebraist* that could solve the problem of the crew dying before reaching their destination.

Answer: Other than the obvious solution of achieving much larger speeds to get high γ values, the engineers can use the slow-time techniques the Slow Seers use, or use the kind of life-lengthening treatments wealthy members of the Acquisitariat have access to.

23. (15 points) Three questions about revolutionary transitions in the history of physics:

(a) Give an example of an idea from Aristotelian physics that was later superceded by Newtonian physics. Explain why the Newtonian idea works better.

Answer: Answers will vary. The conception of the universe (layered skies vs. "outer space"), the idea of force (straight line with same speed without force) etc. will work. Newtonian physics gives much more precise predictions that are much better verified by experiments.

(b) Give an example of an idea from Newtonian physics that was later superceded by relativity. Explain why the relativistic idea works better.

Answer: Again, answers will vary. The speed of light being invariant for all observers, or mass increasing with speed, or $E = mc^2$ will all do. Again, relativity fits the experimental results better, as well as reconciling electromagnetism and mechanics.

(c) Give an example of an idea from Newtonian physics that was later superceded by quantum physics. Explain why the quantum idea works better.

Answer: Again, answers will vary. The existence of atoms, line spectra, photoelectric effect, double-slit experiment, etc. etc. Quantum physics just explains the phenomena better.

24. (20 points) Two conceptual questions about quantum randomness:

(a) When each radioactive nucleus will decay is unpredictable—physicists can only give a certain probability it will decay or survive within a certain time period. Use an everyday example, such as a class of students flipping coins, to explain the concept of the *half life* of a large population of radioactive atoms.

Answer: Say you have a large number of students flip a coin every minute. If they get heads, they're out of the game, if tails, they survive to play another round. Each individual student's history will vary—we cannot exactly predict how long any individual will be in the game. But roughly half the population will survive each round. Since the population is about halved every minute, the half-life for this population is a minute. Populations of radioactive atoms are much larger, but the sam argument applies. Except that now with large numbers, statistical fluctuations will be relatively smaller. The population will be nearly exactly halved after each half-life.

(b) Say a friend tells you that the notion that the world works in a fundamentally random manner does not make sense. After all, randomness means anything could happen! But we live in an orderly universe. If physicists say quantum physics is fundamentally random and also talk about "the laws of physics" they are inconsistent. Set this friend straight—explain how there is no inconsistency here.

Answer: As the half-life example demonstrates, there is no inconsistency here. Even if individual events are unpredictable, with large populations of events, we can get some very reliable statistical predictability.

25. (15 points) Say you want to correct the misunderstanding of someone who thinks that since gravitational attraction decreases as a rocket gets farther away from Earth, weight should *increase* as we go down closer to the center of the Earth. How would you convince them that the weight at the center is zero, without resorting to "physicists say so?" For example, saying that the gravitational attraction of a spherical shell is zero if you're on the inside does not count, because you're just taking my word for that. (*Hint:* if you felt gravity at the center of the earth, in which direction would you be pulled?)

Answer: Every direction looks the same from the center of a sphere. An object at the center will be attracted *equally* by the matter surrounding it in every direction. Hence all attractions will cancel out, leaving you with no net gravitational force.

26. (20 points) Many scientists today are convinced that Artificial Intelligence (AI) is possible, that achieving machine sentience is possible within our current understanding of physics. No one has achieved anything close to a genuine AI yet, but many scientists judge the *prospects* for AI to be good in the long run. But then, there are also some who disagree. Their reasons vary; they can involve anything from a suspicion that consciousness has something to do with unsolved problems of quantum gravity to convictions that something like a "soul" as understood in spiritual belief systems is required and that the soul has to be an entity wholly beyond physics.

Answer the following. *I'm not looking for set answers, but some intelligent discussion. My ideal is that a student who succeeds in a liberal arts science course should have something sensible to say when discussing such matters.*

(a) Give some reasons you think the pro-AI people might be correct.

(b) Give some reasons you think the anti-AI people might be correct.

(c) What's your position on the AI question? Explain. (It'll have to be speculative, but that's OK.)

(d) What would it take (particularly in the way of evidence or argument) to convince you that you were *wrong* about your position?

(e) In what way did what you have learned in this course influence your answers, considering that AI is not directly a physics question? (In other words: Why is physics relevant here?)

Answer: The answers here will vary, and I'll grade them on a case-by-case basis. I'm generally looking for considerations of evidence, whether AI fits in with our current physical understanding of the world (it does, as I see it), whether AI research is slowly making progress (I think so) and so forth. Physics is relevant because the question is whether the sort of impersonal mechanisms that physics deals with can be the building blocks of what becomes a personality.