جامعة مصر للمعلوماتية
EGYPT UNIVERSITY
OF INFORMATICS

Faculty of Engineering
Egypt University of Informatics – EUI

Modern Physics – PHM321
Spring 2024

Tutorial Sheets and Assisting Handouts

Prepared by

Dr. Hassan El-Shimy
Ms. Tasneem Aly

Revision Session

1 Conceptual MCQs - Relativity

Choose the best fit for the following questions

1. Which characterizes the main result of the Michelson-Morley experiment?
(i) verified the existence of ether
(ii) involved measuring the speed of sound from a moving source
(iii) detected no difference in the speed of light regardless of speed of the source relative to observer
(iv) was designed purposely to verify Einstein's theory of relativity

2. According to a postulate of Einstein, which of the following describes the nature of the laws of physics as one observes processes taking place in various inertial frames of reference?
(i) Laws are same only in inertial frames with zero velocity.
(ii) Laws are same only in inertial frames moving at low velocities.
(iii) Laws are same only in inertial frames moving at near speed of light.
(iv) Laws are same in all inertial frames.

3. I am stationary in a reference system but if my reference system is not an inertial reference system, then, relative to me, a system that is an inertial reference system must:
(i) remain at rest.
(ii) move with constant velocity.
(iii) be accelerating.
(iv) be none of the above.

4. If two observers are in relative motion (one moves relative to the other) with constant relative velocity, in which of the following measurements would they obtain identical values?
(i) The velocity of an electron.
(ii) The speed of a light beam.
(iii) The ticking rate of a clock.
(iv) The volume of a box.

5. Observer O fires a particle at velocity v in the positive y direction. Observer O', who is moving relative to O with velocity u in the x direction, measures the y component of the velocity of the same particle and obtains v'. How does the y component measured by O' compare with the y component measured by O?
(i) $v' > v$ (ii) $v' = v$ (iii) $v' < v$ (iv) $v' = 0$

6. Two clocks in the reference frame of observer 1 are exactly synchronized. For other observers in motion relative to observer 1, the clocks are:
(i) synchronized for all observers.
(ii) not synchronized, but all observers will agree which of the two clocks is ahead.
(iii) not synchronized, but different observers may not agree which of the clocks is ahead.
(iv) either synchronized or not synchronized, depending on the locations of the observers.

7. A mass is bouncing on the end of a spring with a period T when measured by a ground observer. What would the period of oscillation be (as measured by the same observer) if the mass and spring were moving past the ground observer at a speed of $0.80c$?
(i) 0.44 T (ii) 0.60 T (iii) 1.0 T (iv) 1.7 T

8. In Tom's frame of reference, two events A and B take place at different locations along the x-axis but are observed by Tom to be simultaneous. Which of the following statements is true? (Consider observer motion along the x-axis only.)
(i) No observers moving relative to Tom will find A and B to be simultaneous, but some may see A before B and others B before A.
(ii) No observers moving relative to Tom will find A and B to be simultaneous, but they all will observe events A and B in the same order.
(iii) All observers moving relative to Tom will also perceive A and B to be simultaneous.
(iv) Some observers moving relative to Tom will find A and B to be simultaneous, while others will not.

9. Which one of the following statements is true?
(i) The laws of conservation of energy and momentum are not valid in special relativity.
(ii) The laws of conservation of energy and momentum are valid in special relativity only if we use definitions of energy and momentum that differ from those of classical physics.
(iii) According to special relativity, particles have energy only if they are in motion.
(iv) mc^2 represents the energy of a particle moving at speed c.

10. Rockets A and C move with identical speeds in opposite directions relative to B, who is at rest in this frame of reference. A, B, and C all carry identical clocks. Hence, according to A:
(i) B's clock and C's clock run at identical slow rates.
(ii) B's clock runs fast and C's clock runs slow.
(iii) B's clock runs slow and C's clock runs even slower.
(iv) B's clock runs fast and C's clock runs even faster.
(v) B's clock runs slow and C's clock runs fast.

11. Three identical triplets Larry, Moe, and Curly are testing the predictions of special relativity. Larry and Moe set out on round-trip journeys from Earth to distant stars. Larry's star is 12 light-years from Earth (as measured in the Earth reference frame), and he travels the round trip at a speed of $0.6c$. Moe's star is 16 light-years from Earth (also measured in the Earth frame), and he travels the round trip at a speed of $0.8c$. Both journeys thus take a total of 40 years, as measured by Curly who stays home on Earth. When Larry and Moe return, how do the ages of the triplets compare?
(i) Larry = Moe > Curly
(ii) Moe < Larry < Curly
(iii) Larry < Moe < Curly
(iv) Larry = Moe = Curly

12. A star (assumed to be at rest relative to the Earth) is 100 light-years from Earth. (A light-year is the distance light travels in one year.) An astronaut sets out from Earth on a journey to the star at a constant speed of$0.98c$. Light takes 100 years to travel from Earth to the star, but the astronaut makes the trip in 20.4 ly. Does that mean that the astronaut travels faster than light?
(i) Yes (ii) No (iii) Maybe

13. A tuning fork has a frequency of 400 Hz and hence a period of $2.50 \times 10^{-3} s$. If the tuning fork is in an inertial frame of reference moving by the observer at speed of $0.750c$, what is the frequency of the fork as measured by the observer? (Assume that measurements are strictly by optical means and that the speed of sound waves in air is not pertinent here).
(i) 265 Hz (ii) 302 Hz (iii) 454 Hz (iv) 605 Hz

14. In a certain collision process, particles A and B collide, and after the collision particles C and D appear (C and D are different from A and B). Which quantities are conserved in this collision?
(i) only linear momentum.
(ii) only total relativistic energy.
(iii) only mass and linear momentum.
(iv) only linear momentum and kinetic energy.
(v) only linear momentum and total relativistic energy.

15. Two particles each of mass m are moving at a speed $v = 0.866c$ directly toward one another. After the head-on collision, all that remains is a new particle of mass M. What is the mass of this new particle?
(i) $M = 2m$ (ii) $M = 4m$ (iii) $M = m$ (iv) $M = 1.5m$ (v) None of the above.

16. Two electrons, each with a kinetic energy of 2.52 MeV, collide head-on to produce a new particle. What is the rest energy of this new particle?
(i) Zero (ii) 5.04 MeV (iii) 6.06 MeV (iv) 9.54 MeV

17. In Albert's frame of reference, there is a stick of length L_A at rest along the x-axis. Betty is traveling along the x-axis in either the positive or negative direction. In Betty's frame of reference, the length of the stick is:
(i) always equal to L_A
(ii) always greater than L_A
(iii) always less than L_A
(iv) either greater than L_A or less than L_A, depending on the direction of Betty's motion.

18. A particle of mass M moving with velocity v decays into two photons of energies E_1 and E_2. Is the rest energy of the original particle
(i) equal to $E_1 + E_2$ (ii) less than $E_1 + E_2$ (iii) greater than $E_1 + E_2$?

Section 2 on Next Page

2 Conceptual MCQs - Quantum Physics

Choose the best fit for the following questions

1. The Compton effect is based on:
   (i) scattering of photons by the tightly bound inner electrons of an atom.
   (ii) scattering of photons by the loosely bound, nearly free electrons of a material.
   (iii) interference of light waves scattered from electrons.
   (iv) the wave-like behavior of electrons.

2. In the Compton effect:
   (i) an electron emits an X-ray photon.
   (ii) an X-ray photon is absorbed by a metal surface and knocks loose an electron.
   (iii) an X-ray photon loses energy after colliding with an electron.
   (iv) an X-ray photon gains energy after colliding with an electron.

3. The photoelectric effect:
   (i) verifies that electrons behave like waves.
   (ii) involves the interference of light waves that reflect from the surface of a metal.
   (iii) is consistent only with the wave theory of light.
   (iv) verifies that light behaves as if it is composed of particles.

4. Which of the following processes is impossible under all circumstances?
   (i) photon → electron + positron.
   (ii) electron + positron → photons.
   (iii) electron → electron + photon.
   (iv) photon + electron → photon + electron
   (v) All of the above are possible.

5. Planck's quantum theory is compatible with the experimental data related to which of the following?
   (i) blackbody radiation
   (ii) the photoelectric effect
   (iii) line spectra emitted by hydrogen gas
   (iv) all of the above

6. The ultraviolet catastrophe predicts that:
   (i) all objects should radiate extreme amounts of ultraviolet light.
   (ii) as an object gets hotter its light will change from dull red to blue white.
   (iii) a black body can absorb an infinite amount of radiation if the radiation is in the ultraviolet region.
   (iv) the radiated energy approaches zero as the wavelength approaches zero.

7. A blackbody is an ideal system that
   (i) absorbs 100% of the light incident upon it, but cannot emit light of its own (i.e., a "black" body).
   (ii) emits 100% of the light it generates, but cannot absorb radiation of its own.
   (iii) absorbs 100% of the light incident upon it and emits 100% of the radiation it generates.
   (iv) None of the above.

8. A metal surface is illuminated with blue light and electrons are ejected at a given rate each with a certain amount of energy. If the intensity of the blue light is increased, electrons are ejected:
(i) at the same rate, but with more energy per electron.
(ii) at the same rate, but with less energy per electron.
(iii) at an increased rate with no change in energy per electron.
(iv) None of the above.

9. According to Einstein, what is true of the stopping potential for a photoelectric current as the wavelength of incident light becomes shorter?
(i) increases.
(ii) decreases.
(iii) remains constant.
(iv) stopping constant is directly proportional to the wavelength.

10. According to Einstein, as the wavelength of the incident monochromatic light beam becomes shorter the work function of a target material in a phototube:
(i) increases.
(ii) decreases.
(iii) remains constant.
(iv) stopping constant is directly proportional to the wavelength.

11. According to Einstein, increasing the brightness of a beam of light without changing its color will increase:
(i) the number of photons.
(ii) the energy of each photon.
(iii) the speed of the photons.
(iv) the frequency of the photons.

12. A photon absorbed by an electron will give up more energy to the electron if the photon:
(i) is not spread out over many electrons.
(ii) is moving faster.
(iii) is moving slower.
(iv) has a higher frequency.

13. Which change will not change the kinetic energy of the most energetic electrons emitted in the photoelectric effect?
(i) changing the brightness of the light.
(ii) changing the frequency of the light.
(iii) changing the metal the light is hitting.
(iv) All of the above.

14. A helium-neon laser emits red light having a wavelength of 632.8 nm and a power of 0.50 mW. How many photons are emitted each second?]
(i) 1.6×10^{15} (ii) 3.3×10^{16} (iii) 4.8×10^{17} (iv) 2.6×10^{18}

15. Sources of red, blue, and yellow light each emit light with a power of 50 mW. Which source emits more photons per second?
(i) the red source.
(ii) the blue source.
(iii) the yellow source.
(iv) They all emit the same number per second.

16. A beam of X-rays of frequency f is incident upon a substance that scatters the beam in various directions. If we measure the frequency of the scattered X-rays, we will find
(i) X-rays with frequency less than f.
(ii) X-rays with frequency greater than f.
(iii) only X-rays with frequency f.
(iv) None of the results above is found.

17. When a photon is scattered from an electron, there will be an increase in its
(i) energy. (ii) frequency. (iii) wavelength. (iv) None of the above.

18. X-ray production occurs in which process?
(i) photons hitting a metal, emitting electrons.
(ii) electrons hitting a metal, emitting photons.
(iii) photons hitting a metal, emitting x-rays.
(iv) electrons hitting a metal and scattering elastically.

19. When a proton passes through matter, it is possible for it to interact with the matter in such a way that an electron and a positron are produced; this interaction is referred to as
(i) photoelectric effect (ii) Compton effect (iii) pair production

20. In regard to the Compton scattering experiment with x-rays incident upon a carbon block, as the scattering angle becomes larger, what happens to the magnitude of difference between the incident and scattered wavelengths?
(i) increases
(ii) decreases
(iii) remains constant
(iv) difference is maximum at a 45° angle of scatter.

21. Electrons are accelerated through a potential difference of 2000 volts and are incident on a metal surface, resulting in the emission of photons. Which of the following photon wavelengths would NOT be observed from this surface?
(i) 0.24 nm (ii) 0.78 nm (iii) 1.25 nm (iv) 3.62 nm

22. Electrons of maximum kinetic energy K_1 are released when X-rays of wavelength λ_1 are incident on the surface of a metal. If the light source is replaced by another that emits photons at the same rate but of longer wavelength λ_2, how is the resulting maximum kinetic energy K_2 related to K_1?
(i) $K_2 < K_1$ (ii) $K_2 = K_1$ (iii) $K_2 > K_1$

23. A metal surface is illuminated with light of wavelength λ, and a resulting current i is observed in an electric circuit connected to the surface. The source is replaced with a different one in which the photon emission rate is only half as large. What should be the wavelength of this second source in order that the current have the same value i?
(i) 2λ (ii) $\lambda/2$ (iii) $> 2\lambda$ (iv) $< \lambda < 2$
(v) The experiment is impossible −− the second source can never give the same current i.

24. Photons of wavelength λ are incident on a metal target. Scattered photons are observed at an angle ϑ_1 relative to the direction of the original photons. In this geometry, it is determined that the scattered electrons have kinetic energy K_1. If the scattered photons were observed at a larger angle, would the corresponding kinetic energy of the scattered electrons be
(i) greater than K_1 (ii) less than K_1 (iii) equal to K_1?

25. A beam of ultraviolet light is incident on a metal surface. Electrons leave the surface with a range of kinetic energies from very small values up to some maximum value. If the light source is replaced by a different source that emits photons at the same rate but with smaller wavelength, does the range of electron kinetic energies become
(i) larger (ii) smaller (iii) remain the same?

26. The deBroglie wave of a particle can best be described as:
(i) a form of electromagnetic wave. (ii) a characteristic of the oscillation of the particle.
(iii) a probability wave. (iv) none of the above.

27. Which of the following is NOT true about the deBroglie wavelength?
(i) It is larger for an electron than for a baseball moving at the same speed.
(ii) It applies only to charged particles.
(iii) It describes the wave properties of particles such as electrons.
(iv) It is a property of waves of probability.

28. According to the de Broglie hypothesis, which of the following statements is applicable to the wavelength of a moving particle?
(i) directly proportional to its energy
(ii) directly proportional to its momentum
(iii) inversely proportional to its energy
(iv) inversely proportional to its momentum

29. The probability of finding an electron in a hydrogen atom is directly proportional to its
(i) energy
(ii) momentum
(iii) wave function's magnitude
(iv) square of the wave function's magnitude

30. The reason the position of a particle cannot be specified with infinite precision is the
(i) exclusion principle (ii) uncertainty principle (iii) principle of relativity

31. The uncertainty relationships:
(i) apply to all types of waves.
(ii) apply only to de Broglie waves.
(iii) apply only to classical waves.
(iv) apply only to light waves.

32. Suppose an electron is moving at speed v. In terms of v, what would be the speed of a baseball with the same deBroglie wavelength as the electron?
(i) v (ii) $10^{10}\ v$ (iii) $10^{-20}\ v$ (iv) $10^{-30}\ v$

33. Consider the following three experiments:

    (a) The x-component of the position of an electron is measured to within $\pm\delta x$, and simultaneously the x-component of its momentum is measured to within $\pm\delta p_x$.

    (b) The x-component of the position of an electron is measured to within $\pm\delta x$, and then the x-component of its momentum is measured to within $\pm\delta p_x$.

    (c) The x-component of the position of an electron is measured to within $\pm\delta x$, and simultaneously y-component of its momentum is measured to within $\pm\delta p_y$.

    In which of these cases does the uncertainty principle NOT impose a limitation on the outcome of the experiment?
    (i) (a) only. (ii) (b) only. (iii) (c) only. (iv) (a) and (b) only.
    (v) (a) and (c) only. (vi) (b) and (c) only. (vii) (a), (b) and (c).

34. An electron is represented by a wave packet of length d. The electron cannot be at rest, but must have a certain minimum kinetic energy K. If the size of the electron's wave packet is doubled to $2d$, does the minimum kinetic energy
    (i) increase (ii) decrease (iii) remain the same?

35. A proton (mass = 1.67×10^{-27} kg) has a kinetic energy of 1.00 MeV. If its momentum is measured with an uncertainty of 1.00%, what is the minimum uncertainty in its position?
    (i) 9.08×10^{-13} m
    (ii) 2.28×10^{-13} m
    (iii) 9.08×10^{-14} m
    (iv) 5.64×10^{-14} m

END