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Physics 3710 – Exam III

David Peak
Utah State University, david.peak@usu.edu

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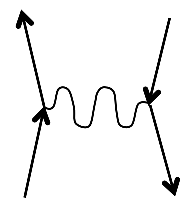
Physics 3710 – Exam III   Name:
May 3, 2013

For each question, circle the letter that represents the *best* choice.

1. Solutions to the Dirac Equation describe particles with spin equal to
(a) 0
(b) $\hbar/2$
(c) $\hbar$
(d) $2\hbar$

2. A Dirac particle has mass m and electric charge q. The Dirac antiparticle has mass and charge equal to
(a) m,q
(b) $-m,q$
(c) $m,-q$
(d) $-m,-q$

3. The QED diagram to the right (in which time runs upward) might represent
(a) an electron on the left exchanging a virtual photon with an electron on the right
(b) an electron on the left exchanging a virtual photon with a positron on the right
(c) a real photon creating an electron-positron pair
(d) an electron-positron pair annihilating to create a real photon



4. The intrinsic strength, $k_E e^2/\hbar c$, of the electric interaction between two electrons increases when the distance between the electrons is less than 10^{-5} nm because of
(a) Z^0 exchange
(b) gluon exchange
(c) reduced screening by virtual pairs
(d) nonlinear gravitational effects

5. In a good vacuum, two electrically neutral, parallel metal sheets attract one another at small separations primarily due to
(a) excluded vacuum fluctuations between the plates
(b) strong nuclear force effects
(c) gravity
(d) weak nuclear force effects

6. Theoretical calculation of the energy density associated with all allowed vacuum fluctuations
(a) exactly agrees with the "vacuum energy density" required to account for the observed accelerated expansion rate of the universe
(b) is vastly greater than the "vacuum energy density" required to account for the observed accelerated expansion rate of the universe
(c) is vastly smaller than the "vacuum energy density" required to account for the observed accelerated expansion rate of the universe
(d) shows that the Casimir Effect cannot possibly exist

7. After it is created, the rho-zero meson decays into two pions with a mean lifetime of about 10^{-24} s. This process is most likely due to the
(a) gravitational interaction
(b) weak interaction
(c) electromagnetic interaction
(d) strong interaction

8. Which *one* of the following is a fermion? A
(a) photon
(b) W^+ exchange boson
(c) ρ^0 meson
(d) Δ^- baryon

Questions 9-12 refer to: Particles observed in accelerator collisions are categorized as baryons, mesons, leptons, and exchange bosons. Identify each of the following:

9. A positively charged W , W^+
(a) baryon
(b) meson
(c) lepton
(d) exchange boson

10. A neutral pion, π^0
(a) baryon
(b) meson
(c) lepton
(d) exchange boson

11. A negatively charged muon, μ^-
(a) baryon
(b) meson
(c) lepton
(d) exchange boson

12. A proton, p
(a) baryon
(b) meson
(c) lepton
(d) exchange boson

Questions 13-16 refer to: In each of the following an incoming particle, A , transforms into an outgoing particle, B , plus an emitted boson: $A \to B + boson$. If allowed, identify the interaction responsible for each transformation.

13. $\mu^- \to e^- + boson$
(a) color interaction
(b) weak interaction
(c) electromagnetic interaction
(d) not allowed

14. $s_{red} \rightarrow s_{blue} + boson$
(a) color interaction
(b) weak interaction
(c) electromagnetic interaction
(d) not allowed

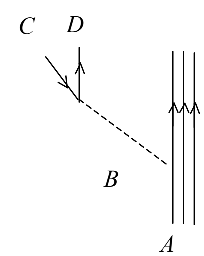
15. $d_{red} \rightarrow u_{red} + boson$
(a) color interaction
(b) weak interaction
(c) electromagnetic interaction
(d) not allowed

16. $d_{red} \rightarrow u_{blue} + boson$
(a) color interaction
(b) weak interaction
(c) electromagnetic interaction
(d) not allowed

17. The "in" state of a QCD process is a red u quark. Which one of the following could be a valid "out" state?
(a) a blue u quark and a red, anti-blue gluon
(b) a red u quark and a blue, anti-red gluon
(c) a blue d quark and a red, anti-blue gluon
(d) an anti-blue $\bar{u}$ anti-quark and a red, blue gluon

18. A pion initially consists of a red d quark and $\bar{u}$ anti-quark. The d quark emits a gluon and changes color to green. After absorbing the gluon, the color of the $\bar{u}$ anti-quark is
(a) anti-red
(b) anti-green
(c) anti-blue
(d) red

Questions 19-22 refer to: The diagram to the right depicts the beta decay of the neutron.



19. Worldline *A* corresponds to
(a) a u quark
(b) a d quark
(c) an electron
(d) an electron anti-neutrino

20. Worldline *B* corresponds to
(a) a photon
(b) a gluon
(c) a W^-
(d) a Z^0

21. Worldline *C* corresponds to
(a) a u quark
(b) a d quark
(c) an electron
(d) an electron anti-neutrino

22. Worldline *D* corresponds to
(a) a u quark
(b) a d quark
(c) an electron
(d) an electron anti-neutrino

23. A neutrino is likely to pass through many kilometers of lead without interacting because
(a) it has no mass
(b) the $W^{\pm}$ and Z^0 are so massive
(c) the intrinsic strength of the weak interaction is many orders of magnitude smaller than the electromagnetic interaction
(d) it is a fermion

24. The decay rate of a π^+ into a left-handed μ^+ and a left-handed ν_μ is the same as the decay rate of a π^- into a right-handed μ^- and a right-handed $\bar{\nu}_\mu$. These processes
(a) violate electric charge conservation
(b) are symmetric under *CP* transformation
(c) violate *CP* symmetry
(d) violate conservation of lepton number

25. A muon can change flavor to a muon neutrino by emitting a
(a) charged W
(b) gluon
(c) Z^0
(d) photon.

26. An electron-neutrino detector measures about 1/3 of the expected neutrino flux from the Sun. This is because e, μ, and τ neutrinos have
(a) zero mass
(b) nonzero equal masses
(c) unequal masses
(d) unequal electric charges

27. Collisions between ultra-relativistic heavy ions produce a state of matter called a
(a) Bose-Einstein condensate
(b) degenerate Fermi gas
(c) perfect diamagnet
(d) quark-gluon plasma

28. In the standard model of particle physics, the top quark is much more massive than the up quark because it
(a) interacts more strongly with the Higgs field than the up
(b) has more color than the up
(c) has more angular momentum than the up
(d) has more weak isospin than the up

29. Isolated quarks are not observed because an isolated quark would
(a) be surrounded by a "gluon explosion"
(b) travel faster than the speed of light
(c) violate *CPT* symmetry
(d) be a black hole

30. Changing a particle's wavefunction by $\psi'(\vec{r},t) = S(\vec{r},t)\psi(\vec{r},t)$ produces no observable consequence. S is called a
(a) continuous time translation
(b) continuous space translation
(c) continuous parity transformation
(d) local gauge transformation

Questions 31-33 refer to: As seen from Earth, a particle created at an altitude of 25 km (event A) decays just as it reaches Earth's surface (event B), 30 km after creation (in units in which c =1).

31. What is the speed of the particle as seen from Earth?
(a) 1/2
(b) 3/5
(c) 5/6
(d) 1

32. What is the distance (in km) between A and B according to the particle?
(a) 0 km
(b) 13.8 km
(c) 16.6 km
(d) 30 km

33. What is the lifetime (in km) of the particle in its own rest frame?
(a) 16.6 km
(b) 25 km
(c) 30 km
(d) 54.3 km

Questions 34-35 (next page) refer to: Two identical masses, m = 1 (in some units), collide head-on and form a composite body of mass M. According to observer O, initially each mass has a $\tilde{\gamma}$ = 5/3.

34. According to O, the total *momentum* (in mass units) of the system before and after the collision is
(a) 0
(b) 2
(c) 8/3
(d) 10/3

35. The mass of the *composite* body is
(a) 0
(b) 2
(c) 8/3
(d) 10/3

36. The Schwarzschild radius of Sun is 3 km. The Schwarzschild radius of a second star is 6 km. Which one of the following is true?
(a) The mass of the second star is 1 solar mass, and its radius is 0.5 solar radius.
(b) The mass of the second star is 1 solar mass, and its radius is 2 solar radius.
(c) The mass of the second star is 0.5 solar masses, irrespective of its radius.
(d) The mass of the second star is 2 solar masses, irrespective of its radius.

37. According to the Friedmann equation, how old would the universe be if it only ever contained slow massive particles?
(a) $1/(2H_0)$
(b) $2/(3H_0)$
(c) $1/H_0$
(d) infinite

38. Adding the correct amount of vacuum energy to that of slow massive particles in the Friedmann equation is required to make the age of the universe be the observed value
(a) $1/(2H_0)$
(b) $2/(3H_0)$
(c) $1/H_0$
(d) infinite

39. If the ratio of photons to baryons were much greater than its measured value
(a) the ratio of primordial helium to hydrogen would be much smaller
(b) the fluctuations in the CMB would be much smaller
(c) the average energy per photon in the CMB would be much lower
(d) vacuum energy would have become dominant much later

40. An early epoch of exponential growth of a has been proposed in order to explain why
(a) there are so many black holes
(b) the CMB is so smooth
(c) there is so much dark matter
(d) there is so much dark energy