ZCT 104/3E Modern Physics
Semester II, Sessi 2004/05
Test I (17 Dec 2004)

Data
Speed of light in free space, $c = 3.00 \times 10^{8}$ ms^{-1}
Elementary charge, $e = 1.60 \times 10^{-19}$ C
The Planck constant, $h = 6.63 \times 10^{-34}$ J s
Unified atomic mass constant, $u = 1.66 \times 10^{-27}$ kg
Rest mass of electron, $m_e = 9.11 \times 10^{-31}$ kg
Rest mass of proton, $m_p = 1.67 \times 10^{-27}$ kg

1. What are the major flaws in the classical model of blackbody radiation given by Rayleigh-Jeans laws?
   I Molecular energy is quantized
   II Molecules emit or absorb energy in discrete irreducible packets
   III The intensity of short wavelength radiation emitted by a blackbody approaches infinity as the wavelength decreases.
   IV Energy is continuously divisible

   A. III, IV **B. I, II,III** **C. II, III, IV** **D. I, II**
   E. Non of the above

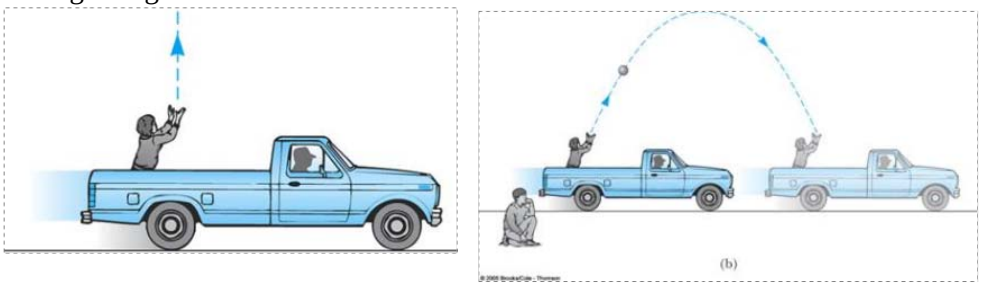
2. What are the assumptions did Planck make in dealing with the problem of radiation?
   I Molecular energy is quantized
   II Molecules emit or absorb energy in discrete irreducible packets
   III The intensity of short wavelength radiation emitted by a blackbody approaches infinity as the wavelength decreases.
   IV Energy is continuously divisible

   A. III, IV **B. I, II,III** **C. II, III, IV** **D. I, II**
   E. Non of the above

3. An unstable high-energy particle enters a detector and leaves a track of length d before it decays. Its speed relative to the detector was $v = c/2$. What is its proper lifetime? That is how long would the particle have lasted before decay had it been at rest with respect to the detector?

A. $\frac{d}{c}$ **B.** $\frac{4d}{\sqrt{3}c}$ **C.** $\frac{2d}{\sqrt{3}c}$ **D.** $\frac{\sqrt{3}d}{c}$ **E.** Non of the above

4. A ball was thrown upward by an observer in a van moving with constant speed $u << c$. He is observed by an observer in a rest frame attached to the ground, see figure below. Which of the following statement(s) is (are) true regarding the two inertial frames of reference?



   I The ball thrown follows different paths in different frames of reference
   II The kinematical laws of classical mechanics are valid only the moving frame (the van) but not to the rest frame attached to ground.
   III Classically Galilean transformation relates the trajectory of the ball in the rest frame with that in the moving frame.
   IV Since $u<<c$, Lorentz transformation will fail to relate the trajectory of the ball in the rest frame with that in the moving frame.

   A. II,III **B. I, II,III** **C. II, III, IV** **D. I Only** **E.** Non of the above

5. What measurement(s) do two observers in relative motion always agree on?
I The relativistic mass of an object
II The relativistic momentum of an object
III The relativistic energy of an object
IV $E^2 - p^2$, where p is the magnitude of relativistic momentum and E the relativistic energy the object

A. II,III **B. I, II,III** **C. II, III, IV** **D. IV Only**
E. Non of the above

6. Which of the following statement(s) is (are) true?
I The upper limit of the speed of an electron is the speed of light c.
II As more energy E is fed into an object its momentum approaches $\frac{E}{c}$.
III There is no upper limit to the relativistic momentum of an electron.
IV There is an upper limit to the relativistic momentum of an electron.

A. III **B. I, II,III** **C II, IV** **D. IV Only** **E.** Non of the above

7. The rest energy and total energy respectively, of three particles, expressed in terms of a basic amount A are (1) A, $2A$; (2) A, $3A$; (3) $3A$, $4A$. Without written calculation, rank the particles according to their kinetic energy, greatest first.

A. 2 > 1 = 3 **B.** 1 > 2 = 3 **C.** 2 > 1 > 3 **D.** 2 = 1 = 3
E. 3 > 1 = 2

8. The length of a spaceship is measured to be exactly half its rest length. By what factor do the spaceship's clocks run slow relative to clocks in the observer's frame?

A. 0.866 **B.** 0.745 **C.** 2.000 **D.** 0.366 **E.** 0.134

9. The length of a spaceship is measured to be exactly half its rest length. What is the speed parameter $\beta = v/c$ of the spaceship relative to the observer's frame?

A. 0.87 **B.** 2.00 **C.** 0.75 **D.** 2.73 **E.** 4.00

10. Consider a light pulse emitted from the origin, O, of a stationary frame S. The origin of a moving frame S', O', which overlaps with O at $t = t' = 0$ is moving with a constant speed u with respect to O. Which statement(s) correctly describe(s) the position of the wavefront of the light sphere as measured from the origins? r (r') is the distance of the wavefront from the origin O (O') at time t (t').

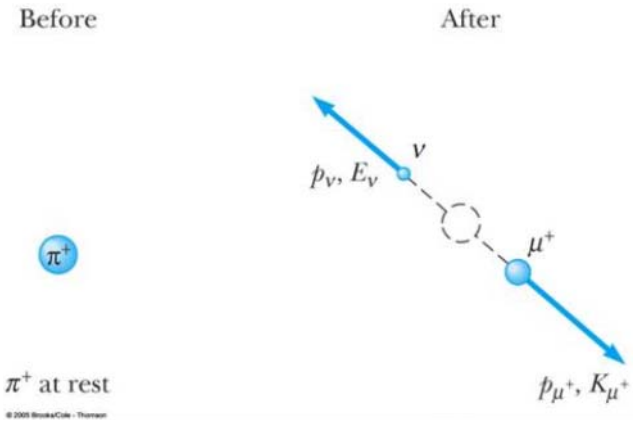
I $r = ct$ **II** $r' = ct'$ **III** $r' = r$ **IV** $r' = ut'$

A. I,II **B. I, II,III** **C. II, III, IV** **D. IV Only** **E.** Non of the above

11. Which of the following statement(s) is (are) true regarding Lorentz transformation (LT)?
I Time dilation can be recovered from LT
II Length contraction can be recovered from LT
III Absolute simultaneity is not guaranteed by LT
IV Galilean transformation is a generalisation of LT

A. II,III **B. I, II,III** **C. II, III, IV** **D. I, II** **E.** Non of the above

Question 12-13 are based on the decay of a π meson into a muon and a massless neutrino shown in figure below. The mass of the muon is known to be m_μ = 106 MeV/c^2, and the kinetic energy of the muon is measured to be K_μ = 4.6 MeV. p_μ denotes the momentum of the muon.



12. What is the momentum of the neutrino?

A. $\sqrt{\left(K_\mu + m_\mu c^2\right)^2 - m_\mu^2 c^4}$ **B.** $\left(K_\mu + m_\mu c^2\right)$

C. $\sqrt{2 m_\mu K_\mu}$ **D.** p_μ **E.** Non of the above

13. What is the total relativistic energy of the neutrino?

A. $\sqrt{\left(K_\mu + m_\mu c^2\right)^2 - m_\mu^2 c^4}$ **B.** $\left(K_\mu + m_\mu c^2\right) + \sqrt{\left(K_\mu^2 + 2K_\mu m_\mu c^2\right)}$

C. K_μ **D.** $m_\mu c^2$ **E.** Non of the above

14. What happens to the density of an object as its speed increases, as measured by an Earth observer?

A. Remain the same as it is when at rest
B. Increase by a factor of γ
C. Increase by a factor of γ^2
D. Increase by a factor of $1/\gamma$
E. Non of the above

15. What is the upper limit of the momentum of an electron?

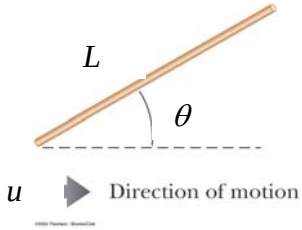
A. $m_e c$ **B.** c **C.** 0 **D.** Infinity **E.** Non of the above

16. Which of the following statement(s) is (are) true?

I Only massless particle can travel at the speed of *c*.
II Not all massless particle can travel at the speed of *c*.
III It is not necessary that a massless particle must travel at the speed of *c*.
IV All particles which are not massless must travel at the speed lower than *c*.

A. II,III **B. I, II,III** **C. I, III, IV** **D. I, IV** **E.** Non of the above

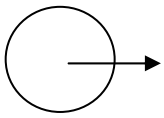
17. A moving rod is observed to have a length of *L* and to be orientated at an angle of θ = 45° with respect to the direction of motion, as shown in the figure below. The rod has a speed of $u = \frac{c}{\sqrt{2}}$.



What is the proper length of the rod?

A. $\frac{3}{2}L$ **B.** L **C.** $\sqrt{\frac{3}{2}}L$ **D.** $\frac{\sqrt{3}L}{2}$ **E.** Non of the above

18. A spaceship in the shape of a sphere moves past and observer on Earth with a speed of $v = 0.5c$ in the direction as indicated by the arrow. What shape will the observer see as the spaceship move past?



E. Non of the above

19. What is the speed of an object having relativistic momentum of magnitude p and rest mass m?

A. $\frac{p}{m}$ **B.** $\frac{c}{\sqrt{1+\left(mc/p\right)^2}}$ **C.** $\frac{mc^2}{u}$ **D.** $\frac{mu^2}{c}$ **E.** Non of the above

20. An electron with rest mass m_e moves with a speed of $\frac{\sqrt{3}}{2}c$. What is the work required to increase its speed to $\frac{2\sqrt{2}}{3}c$?

A. $m_e c^2$ **B.** $0.511 m_e c^2$ **C.** $\frac{5}{36}m_e c^2$ **D.** $\frac{\sqrt{5}}{6}m_e c^2$ **E.** Non of the above