Department of Physics – Unit Test

1. An ideal gas with adiabatic exponent, undergoes a process in which its pressure P is related to its volume V by the relation = $P_0 - \alpha V$, where P_0 and α are positive constants. The volume starts from being very close to zero and increases monotonically to P_0/α. At what value of the volume during the process does the gas have maximum entropy?

   a) $\frac{P_0}{\alpha(1+\gamma)}$ b) $\frac{\gamma P_0}{\alpha(1-\gamma)}$ c) $\frac{\gamma P_0}{\alpha(1-\gamma)}$ d) $\frac{P_0}{\alpha(1-\gamma)}$

2. The H2 molecule has a reduced mass $M=8.35\times10^{-28}$ kg and an equilibrium internuclear distance $R = 0.742 \times 10^{-10}$ m. The rotational energy in terms of the rotational quantum number J is :

   a. a) $E_{rot}(J) = 7J(J-1)meV$ b) $E_{rot}(J) = \frac{5}{2}J(J+1)meV$

   b. c) $E_{rot}(J) = 7J(J+1)meV$ d) $E_{rot}(J) = \frac{5}{2}J(J-1)meV$

3. The mean value of random variable x with probability density $P(x)=\frac{1}{\sigma\sqrt{\pi}}\exp\left(-\frac{x^2+\mu x}{2\sigma^2}\right)$

   a)0 b)$\frac{\mu}{2}$ c) $-\frac{\mu}{2}$ d)σ

4. Self inductance per unit length of a long solenoid of radius R with n turns per unit length is:

   a)$\mu_0\pi R^2n^2$ 2) $2\mu_0\pi R^2n^2$ c) $\mu_0\pi R^2n$ d) $2\mu_0\pi R^2n$

5. How much force does light from a 1.8 W laser exert when it is totally absorbed by an object?

   a) 6.0×10^{-9}N b) 0.6×10^{-9}N c) 6.0×10^{-8}N d) 4.8×10^{-9}N

6. A cylindrical shell of mass m has an outer radius b and an inner radius a. The moment of inertia of the shell about the axis of the cylinder is:

   a) $\frac{1}{2}m(b^2-a^2)$ b) $\frac{1}{2}m(b^2+a^2)$ c) $m(b^2-a^2)$ d) $m(b^2+a^2)$

7. A gas contains particles of type A with fraction 0.8, and particles of type B with fraction 0.2. The probability that among 3 randomly chosen particles at least one is of type A is:

a)0.8 b)0.25 c) 0.33 d) 0.992

8. The half-life of a radioactive nuclear source is 9 days. The fraction of nuclei which are left undecayed after 3 days is:

   a) 7/8 b)1/3 c) 5/6 d) $1/2^{\frac{1}{3}}$

9. A semicircular piece of paper is folded to make a cone with the center of the semicircle as the apex. The half angle of the resulting cone would be:

   a)90^0 b) 60^0 c) 30^0 d) 45^0

10. Circular fringes are obtained with a Michelson interferometer using 600nm laser light. What minimum displacement of one mirror will make the central fringe from bright to dark?

    a) 600nm b) 300nm c) 150nm d)$120A^0$

11. In the ground state of hydrogen atom, the most probable distance of the electron from the nucleus, in units of Bohr radius a_0 is:

    a) ½ b) 1 c) 2 d) 3/2

12. The adjoint of a differential operator d/ dx acting on a wavefunction φ(x) for a quantum mechanical system is :

    A)d/dx b)$-i\hbar\frac{d}{dx}$ c) $-d/dx$ d) $i\hbar\frac{d}{dx}$

13. The number of different Bravais lattices possible in two dimension is:

    a)2 b)3 c)5 d)6

14. A transistor in common base configuration has ratio of collector current to emitter current β and ratio of collector to base current α . Which of the following is true :

    a)$\beta = \frac{\alpha}{\alpha+1}$ b) $\beta = \frac{\alpha+1}{\alpha}$ c) $\beta = \frac{\alpha}{\alpha-1}$ d) $\beta = \frac{\alpha-1}{\alpha}$

15. The central force which results in the orbit r = a(1 + cosθ) for a particle is proportional to :

    a)r b) r^2 c) r^{-2} d) None of these

16. The maximum relativistic kinetic energy of β particles from a radioactive nucleus is equal to the rest mass energy of the particle. A magnetic field is applied perpendicular to the beam of β particles, which bends it to a circle of radius R. The field is given by :

    a) $3m_0C/eR$ b) $\sqrt{2}m_0C/eR$ c) $\sqrt{3}m_0C/eR$ d) $\sqrt{3}m_0C/2eR$

17. The strength of magnetic field at the center of a regular hexagon with sides of length a

carrying a steady current I is:

a) $\mu_0 I/\sqrt{3}\pi a$ b) $\sqrt{6}\mu_0 I/\pi a$ c) $3\mu_0 I/\pi a$ d)$\sqrt{3}\ \mu_0 I/\pi a$

18. A point charge q of mass m is released from rest at a distance d from an infinite grounded conducting plane (ignore gravity). How long does it takes for the charge to hit the plane ?

a)$\frac{\sqrt{2\pi^3 m\in_0 d^3}}{q}$ b) $\frac{\sqrt{2\pi^3 m\in_0 d}}{q}$ c) $\frac{\sqrt{\pi^3 m\in_0 d^3}}{q}$ d) $\frac{\sqrt{\pi^3 m\in_0 d}}{q}$

19. Light takes approximately 8 minutes to travel from the Sun to the Earth. Suppose in the frame of the Sun an event occurs at t = 0 at the Sun and another event occurs on Earth at t = 1 minute. The velocity of the inertial frame in which both these events are simultaneous is:

a) c/8 with the velocity vector pointing from Earth to Sun

b) c/8 with the velocity vector pointing from Sun to Earth

c) The events can never be simultaneous - no such frame exists

d) $C\sqrt{(1-(1/8)^2)}$ with velocity vector pointing from sun to earth

20. A spherical shell of radius R carries a constant surface charge density ω and is rotating about one of its diameters with an angular velocity ω. The magnitude of the magnetic moment of the shell is:

a) $4\pi\sigma\omega R^4$ b) $4\pi\sigma\omega R^4/3$ c) $4\pi\sigma\omega R^4/15$ d) $4\pi\sigma\omega R^4/9$

21. Consider N non-interacting electrons ($N\sim N_A$) in a box of sides , L_x,L_y,L_z. Assume that the dispersion relation is $\varepsilon(k) = Ck^4$, where C is a constant, the ratio of the ground state energy per particle to the Fermi energy is :

a) 3/7 b)7/3 c) 3/5 d) 5/7

22. You receive on average 5 emails per day during a 365 days year. The number of days on average on which you do not receive any emails in that year are:

(a) more than 5 b) more than 2 c) 1 d) none of these

23. An ideal gas has a specific heat ratio C_p/C_v. Starting at a temperature T1 the gas under goes an isothermal compression to increase its density by a factor of two. After this an adiabatic compression increases its pressure by a factor of two. The temperature of the gas at the end of the second process would be:

a)$\sqrt{2}T_1$ b)$2T_1$ c) $T_1/2$ d) $T_1/\sqrt{2}$

24. A thin air film of thickness d is formed in a glass medium. For normal incidence, the condition for constructive interference in the reflected beam is (in terms of wavelength λ and integer m = 0, 1, 2, ...):

a) $2d=(m-1/2)\,\lambda$ b) $2d=m\,\lambda$ c) $2d=(m-1)\,\lambda$ d) $2\,\lambda = (m-1/2)d$

25. A bead of mass M slides along a parabolic wire described by $z = 2(x^2 + y^2) +$. The wire rotates with angular velocity Ω about the z-axis. At what value of Ω does the bead maintain a constant nonzero height under the action of gravity along - z ?

a) √g b) √2g c) √3g d)2√g

26. If the mean square fluctuations in energy of a system in equilibrium at temperature T is proportional to $T^{\propto}$, then the energy of the system is proportional to :

a) $T^{\propto -2}$ b) $T^{\propto}$ c) $T^{\propto /2}$ d) $T^{\propto -1}$

27. Suppose the spin degrees of freedom of a 2-particle system can be described by a 21-dimensional Hilbert subspace. Which among the following could be the spin of one of the particles ?

a) ½ b)3 c)3/2 d)2

28. Water is poured at a rate of R m3/hour from the top into a cylindrical vessel of diameter D. The vessel has a small opening of area a (√a << D)at the bottom. What should be the minimum height of the vessel so that water does not overflow ?

a) ∞ b) $R^2/2ga^2$ c) $R^2/2gaD^2$ d)$8\,R^2/\pi D^2\,g^2$

29. What is the equation of the plane which is tangent to the surface 4 xyz at the point (1, 2, 2) ?

a)x+2y+4z=12 b) 4x+2y+z=12 c)x+4y+z=0 d) 2x+y+z=6

30. Two equal positive charges of magnitude +q separated by a distance d are surrounded by a uniformly charged thin spherical shell of radius 2d bearing a total charge -2q and centred at the midpoint between the two positive charges. The net electric field at distance r from the midpoint is?

a) Zero b) proportional to d c) proportional to $\frac{1}{r^3}$ d) proportional to $\frac{1}{r^4}$

31. If the Hamiltonian of a classical particle is $H = (P_x^2 + P_y^2)/2m$, then $\langle x^2 + xy + y^2 \rangle$ at temperature T is equal to:

a) $K_B T$ b)$(1/2)\ K_B T$ c)$2K_B T$ d)$(3/2)\ K_B T$

32. After the detonation of an atom bomb, the spherical ball of gas was found to be 15 meter radius at a temperature of 3 × 10^5 K. Given the adiabatic expansion coefficient γ = 5/3, what will be the radius of the ball when its temperature reduces to 3 × 10^3 K ?

a) 156m b) 150m c) 100m d) 50m

33. The electric field $\vec{E} = E_0 \sin(\omega t - kz)\, x + 2E_0 \sin\left(\omega t - kz + \frac{\pi}{2}\right) y$ represents:

a) a linearly polarized wave b) a right hand circularly polarized wave

c) a left hand circularly polarized wave d) an elliptically polarized wave

34. A solid, insulating sphere of radius 1 cm has charge 10^{-7} C distributed uniformly over its volume. It is surrounded concentrically by a conducting thick spherical shell of inner radius 2 cm, outer radius 2.5 cm and is charged with -2×10^{-7} C. What is the electrostatic potential in Volts on the surface of the sphere?

35. The Fourier transform of the function $\frac{1}{x^4+3x^2+2}$ upto the proportionality constant is:

a) $\sqrt{2}\exp(-k^2) - \exp(-2k^2)$ b) $\sqrt{2}\exp(-k) - \exp(-\sqrt{2}|k|)$

c) $\sqrt{2}\exp\left(-\sqrt{|k|}\right) - \exp\left(-\sqrt{2|k|}\right)$ c) $\sqrt{2}\exp(-\sqrt{2}k^2) - \exp(-2k^2)$

36. A cylindrical at temperature T = 0 is separated into two compartments A and B by a free sliding piston. Compartments A and B are filled by Fermi gases made of spin 1/2 and 3/2 particles respectively, If particles in both the compartments have same mass, the ratio of equilibrium density of the gas in compartment A to that of gas in compartment B is:

a) $\frac{1}{3^{2/5}}$ b)1 c) $\frac{1}{2^{2/5}}$ d) $\frac{1}{3^{2/3}}$

37. The temperature in a rectangular plate bounded by the lines x=0,y=0, x=3 and y=5 ,$T=xy^2 - x^2y + 100$ What is the maximum temperature difference between two points on the plate?

38. A sphere of inner radius 1 cm and outer radius 2 cm, centered at origins has a volume

charge density $\rho_0 = \frac{k}{4\pi r}$, where K is a nonzero constant and r is the radial distance. A point charge of magnitude 10^{-3} C is placed at the origin. For what value of K in units of C/m2, the electric field inside the shell is constant ?

39. Suppose that the number of microstates available to a system of N particles depends on N and the combined variable UV^2, where U is the internal energy and V is the volume of the system. The system initially has volume 2m3 and energy 200 J. It undergoes an isentropic expansion to volume 4m3. What is the final pressure of the system in SI units ?

40. Let a particle of mass 1 × 10^–9 kg, constrained to have one dimensional motion, be initially at the origin(x=0m). The particle is in equilibrium with a thermal bath $K_BT = 10^{-8}$J . What is $< x^2 >$ of the particle after a time t= 5s?