1. Describe below in brief.
   (a) optical tweezer (2%) (b) Schwarzschild radius (2%) (c) synchrotron (2%)
   (d) gravitational red shift (2%) (e) Rutherford scattering experiment (2%)

2. Calculate the probability that an allowed state is occupied if it lies above the Fermi level by $5kT$. (10%)

3. The relation for total energy (E) and momentum (p) for a relativistic particle is $E^2 = c^2 p^2 + m^2c^4$, where m is the rest mass and c is the velocity of light. Using the relativistic relations $E = \hbar\omega$ and $p = \hbar k$, where ω is the angular frequency and k is the wave number, show that the product of group velocity (v_g) and the phase velocity (v_p) is equal to c^2, that is $v_p v_g = c^2$. (20%)

4. (a) Write down the two Heisenberg uncertainty relations, one involving energy and one involving momentum. Explain the meaning of each term. (10%)
   (b) Estimate the kinetic energy (in MeV) of a neutron confined to a nucleus of diameter 12 fm. (10%)

5. Ultraviolet light of wavelength 300 nm and intensity 1.00 W/m^2 is directed at a potassium surface. The work function of potassium is 2.2 eV.
   (a) Find the maximum kinetic energy of the photoelectrons. (10%)
   (b) If one percent of the incident photons produce the photoelectrons, how many photoelectrons are emitted per second as the potassium surface has an area of 1 cm^2? (10%)

6. Consider a particle in a square potential well with infinitely high barriers at each end, which corresponds to a box with infinitely hard walls. Assume that the box is L wide.
   (a) Write down the Schrodinger's equation for the particle in a box, i.e., one dimensional Schrodinger's equation. (5%)
   (b) Derive the eigenvalues and eigenvectors, i.e. energy levels and wave functions, for a particle in a box. (5%)
   (c) Find the probabilities that a particle trapped in this box L wide can be found between $0.4L$ and $0.6L$ for the ground state and first excited state. (5%)
   (d) Estimate the expectation value of the position of a particle trapped in this box. (5%)

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