Useful constants:
Planck's constant $h = 6.62\times10^{-34}$ J·s,
Speed of light $c = 3.0\times10^{8}$ m/s,
Electron's charge $e = 1.6\times10^{-19}$ C.

1. Suppose that a particle of mass m is constrained to move in a one-dimensional space between two infinitely high barriers located L apart. Using uncertainty principle find an expression for the zero-point (minimum) energy of the particle. (10%)

2. (a) Explain what is Compton scattering effect? (5%)
   (b) Derive the Compton's equation. (5%)

3. The threshold frequency of potassium is 558 nm.
   (a) What is the work function for potassium? (5%)
   (b)What is the stopping potential when light of 400 nm is incident on potassium? (5%)

4. In the early 20^{th} century, Rutherford proposed a planetary model, called Rutherford's model, to depict the atomic structure. In that model, atoms are consisted of a diffuse cloud of negatively charged electrons surrounding a small, dense, positively charged nucleus. Electrons move in an orbit about the positive nucleus just as in the case of the planets orbiting the Sun. However, the Rutherford's model has a problem to successfully describe electrons orbital motions in atoms.
   (a) What is the problem? (5%)
   (b) Later in 1913, Bohr proposed a model to fix the problem. What did Bohr propose? (5%)
   (c) Use Bohr's model to derive an equation to describe the total energy of an electron of a hydrogen atom in the n^{th} orbit. (10%)

5. The wave function $\psi(x) = A\cdot\exp(-B^2x^2/2)$, where A and B are real constants, is a normalized eigenfunction of the Schrödinger equation for a particle of mass m and energy E in a one dimensional potential $V(x)$ such that $V(x) = 0$ at $x = 0$. Find E and $V(x)$. The Schrödinger equation: $-(h^2/2m)d^2\psi(x)/dx^2+V(x)\,\psi(x)=E\,\psi(x)$. (10%)

6. (a) What is a p-n junction? What does it do? (5%)
   (b) Explain how solar cells work. (5%)

(c) Suppose an array of 30% efficient solar cells has an effective area of 100×100 m^2. The cells are tilted so as to receive maximum solar flux, an average of 680 W/m^2 for a day with 12 hours of daylight. How much energy does this array produce each day? Compare that energy with the output of a 100-MW conventional power plant. (5%)

7. (a) Explain why the transition metals have good thermal and electrical conductivities. (5%)
(b) A semiconductor has an energy gap E_g. Explain what happens when the semiconductor is bombarded with electromagnetic radiation with wavelength $\lambda < hc/E_g$. What happens if $\lambda < hc/E_g$? h and c are the Planck constant and the speed of light, respectively. (5%)
(c) Why does the electrical conductivity of a metal decrease as the temperature is increased? How would you expect the conductivity of a semiconductor to change with temperature? (5%)

8. (a) How many photons are emitted each second from a 5.0-mW helium-neon laser (λ = 632.8 nm)? (5%)
(b) If the laser contains 0.02 mole of neon gas, what fraction of the neon atoms in the tube participate in the lasing process during each second of operation? (5%)