Quantum Mechanics

1. Calculate the energy in electron volt of a photon of wavelength 1Å.(Ans: E=12412.5eV,P= 6.62×10^{-24} kgm/sec)t
2. he energy of a photon is 5.28×10^{-19}J .Calculate the frequency and wavelength (Ans: $\nu=7.96 \times 10^{14}$Hz,λ =3768 Å)
3. Find the De Broglie wavelength of 10K eV electrons. (Ans: λ =0.1227 Å)
4. De Broglie wavelength of electron in monoenergetic beam is 7.2×10^{-11} m . Calculate the momentum and energy of electron s in the electron volts .. (Ans: P= 0.928×10^{-23} kgm/s, E=0.029 eV)
5. Determine the velocity and kinetic energy of a neutron having De Broglie wavelength 1Å. (Given mass of neutron=1.67×10^{-27}kg) (Ans: v= 3.97×10^{3} m/s E=8.225×10^{-2}eV)
6. Find the De Broglie wavelength of an electron when accelerated through a potential difference of 100V. (Ans: λ =1.227 Å)
7. What accelerating potential would be required for a proton with zero velocity to acquire velocity corresponding to De Broglie's wavelength of 10^{-14}m? Given mass of proton= 1.67×10^{-19}C. (Ans: V =8.199×10^{6}V)
8. Find the De Broglie wavelength of i) an electron accelerated through a potential of 182 V ii)1Kg object moving with a speed of 1m/sec. Comparing the results explain why the wave nature of matter is not more apparent in daily observation. (Ans: λ i) for electron =0.9087 Å ii) 1kg object= 6.63×10^{-34}m, Comment- This means that the wavelength for electron is measurable; but for the body of mass 1kg the wavelength is too small to be detected. Hence the wave nature of matter is not more apparent in daily observation.)
9. What potential difference must be applied to an electron microscope to obtain to obtain electrons of wavelength 0.3 Å. (Ans: V =1672.81V)
10. An electron has kinetic energy equal to its rest mass energy. Calculate De Broglie wavelength associated with it. Given: m= 9.1×10^{-31}kg, h=6.63×10^{-34}JS (Ans: λ =0.1715×10^{-11}m)
11. Find the lowest energy level and momentum of an electron in one dimensional potential well of width 1 Å. (Ans:E_1= 6.038×10^{-18}J P_1=33.045×10^{-25}kgm/s)
12. An electron is trapped in a rigid box of width 2 Å. Find its lowest energy level and momentum. Hence find the energy of the 3 rd energy level. (Ans:E_1= 9.44 eV,P_1=1.663×10^{-24}kgm/s, E_3= 85.5 eV)
13. Lowest energy of an electron trapped in a potential well is 38 eV. Calculate the width of the well. (Ans: L =0.996 Å ≈1 Å)
14. Compare the lowest three energy states for i) an electron confined in an infinite potential well of width 10 Å and ii) a grain of dust with mass 10^{-6}gm in an infinite potential well of width 0.1mm. What can you conclude from this comparison? (Ans:For electron E_1= 0.377 eV, E_2= 1.508 eV, E_3= 3.393 eV For grain of dust E_1= 3.433×10^{-31} eV, E_2= $13.73. \times 10^{-31}$ eV, E_3= $30.89. \times 10^{-31}$ eV comments: The energy levels are discrete for the electron. But for the grain of dust the difference between the energy levels being very small, they cannot be identified as discrete and can be

treated as almost continuous. Hence the quantization of energy is observable for the microscopic particles only)

15. Calculate first two energy eigen values of an electron in eV which is confined to a box of length 2 Å. (Ans:For electron E_1= 9.43 eV, E_2= 37.72 eV)
16. Calculate the energy difference between the ground state and the first excited state for an electron in a one dimensional rigid box of length 10^{-8}cm. (Ans: E_2- E_1=114 eV)
17. Consider a marble of mass 10 gm. In one dimensional rigid box of width 10cm. Using the expression for energy eigen values, find E_1, E_2, E_3, E_4 .Comment on the results obtained . (Ans: E_1= 5.5×10^{-64}, E_2=22×10^{-64}, E_3=4.95×10^{-63}, E_4= 8.8×10^{-63}J. Comment: The energy level values are very small and appear to be very close and so they cannot be identified as discrete hence treated as continuous)
18. Calculate the minimum uncertainty in the velocity of electron confined to a box of length 10 Å (Ans: Δv_x=7.28 $\times 10^5$ m/s)
19. If the uncertainty in the position of electron is 4×10^{-10} m. calculate the uncertainty in its momentum. (Ans: Δp_x=1.65 $\times 10^{-24}$ kg m/s)
20. The electron has a speed of 600m/s with an accuracy of 0.005%. Calculate the uncertainty with which we can locate the position of electron. (Ans: Δ_x=0.0242m)
21. The position and momentum of 1KeV electron are simultaneously measured. If the position is located to within 1 Å, find the percentage of uncertainty in its momentum.(Rest mass of electron =9.1×10^{-31}kg. (Ans: Δp_x=6.62 $\times 10^{-24}$ kg m/s, % Δp_x=38.94%)
22. Compute the minimum uncertainty in the location of 2 gm mass moving with a speed of 1.5 m/s and the minimum uncertainty in the location of an electron moving with a speed of 0.5×10^8 m/s. Given:- the uncertainty in the momentum is $\Delta p=10^{-3}p$ for both (Ans:Δ_x for the body=2.2×10^{-28}m,for electron=1.45×10^{-8}m)
23. A bullet of mass 25gms is moving with a speed of 400m/s. The speed is measured accurate upto 0.02%.Calculate the uncertainty with which the position of the bullet can be located. (Ans: Δ_x=3.315×10^{-31}m)
24. A hydrogen atom is 0.53 Å in radius. Use uncertainty principle to estimate the minimum energy an electron can have in this atom. (Ans: Δp_x=6.62 $\times 10^{-24}$ kg m/s, K.E= 13.5 eV)
25. Assume that the electron lies inside a nucleus of diameter 10^{-15}m.Using uncertainty principle, estimate the K.E. of electron in eV (Ans: ΔE=9563MeV)
26. The life time of an excited state of a nucleus is 10^{-12} sec. What is the uncertainty in energy of γ-ray photon emitted? (Ans: ΔE=6.598×10^{-4}eV)
27. The energy of an excited state of hydrogen atom is 2.11×10^{-21}J.Determine the minimum error with which the life time in this excited state can be measured? (Ans: Δt =2.5×10^{-14}sec)
28. A particle is moving in one dimensional potential box of infinite height of width 25 Å. Calculate the probability of finding the particle within an interval of 5 Å at the centers of the box when it is in its state of least energy (Ans: P =

29. Compute the de Broglie wavelength for (a) a 1000 kg automobile traveling at 100m/s (b) a 10 g bullet traveling at 500m/s (c) a smoke particle of mass 10^{-9} g moving at 1cm/s (d) an electron with a kinetic energy of 1eV (e) an electron with a kinetic energy of 100 MeV. ((a) 6.6×10^{-39} m (b) 1.3×10^{-34} m (c) 6.6×10^{-20} m (d) 1.2 nm (e) 12 fm)
30. The phase velocity of ripples on a liquid surface is , where S is the surface tension and ρ is the density of liquid. Find the group velocity of ripples. (Ans: 3/2 v_p)
31. The phase velocity of ocean waves is . Find the group velocity of ocean waves. (Ans: $v_p/2$)
32. A proton and deuteron ($m_d=2m_p$) have the same kinetic energy. Which has a longer wavelength? (Ans: $\lambda_p>\lambda_d$)
33. Find the phase and group velocities of an electron whose de Broglie wavelength is 1.2 A^0. (Ans: $v_g=6.06\times10^6$ m/s, $v_p=3.03\times10^6$ m/s)
34. Calculate the ratio of de Broglie wavelengths associated with the electrons with kinetic energies of 0.1 eV and 510 eV. (Ans: 71.4)
35. Calculate the ratio of de Broglie wavelengths of a hydrogen atom and helium atom at room temperature when they move with thermal velocities. ($M_H=1.67\times10^{-27}$Kg, $M_{He}=6.6\times10^{-27}$ Kg) (Ans: 2)
36. An electron moves in the x direction with a speed of 3.6×10^6 m/s. We can measure its speed to a precision of 1 %. (a) With what precision can we simultaneously measure its position? What can we say about its motion in the y direction? (Ans: (a)3.2 nm (b) nothing can be known about the y coordinate)
37. An electron has de Broglie wavelength of 2.00×10^{-12}m. Find its kinetic energy and the phase and group velocities of de Broglie waves. (Ans: 292 KeV, $v_g=0.771$ c $v_p=1.30$c)
38. A hydrogen atom is 5.3×10^{-11} m in radius. Use uncertainty principle to estimate the minimum energy an electron can have in this atom. (Ans: 3.4 eV)
39. Show that the phase velocity and group velocity are related by $v_g=v_p-\lambda(dv_p/d\lambda)$
40. The lowest energy possible for a certain particle trapped in a certain box is 1.00 eV. (a)What are the next two higher energies the particle can have? (b) If the particle is an electron, how wide is the box? (Ans: (a) 4 eV, 9 eV (b) 0.613 nm)
41. The ground state of a particle in an infinite one dimensional well is 4.4 eV. If the width of the well is doubled, what is the new ground state energy? (Ans: 1.2 eV)
42. Compute the lowest three energies of an electron confined to the box which is 3 A^0 wide. (Ans:4.18 eV, 16.72 eV, 37.62 eV)
43. Wavelengths can be determined with accuracies of one part in 10^6. What is the uncertainty in the position of a 1 A^0 X-ray photon when its wavelength is simultaneously measured? (Ans: 7.96 μm)
44. An electron is trapped in an infinitely deep one-dimensional well of width 0.251 nm. Initially the electron occupies n=4 state. (a) Suppose the electron jumps to the ground state with the accompanying emission of photon. What is the energy of the photon? (b) Find the energies of

other photons if electron takes other paths between n=4 state and the ground state. (Ans: (a) 89.5 (b) (1) 41.8 eV, 29.8 eV, 17.9 eV (2) 41.8 eV, 47.7 eV (3) 71.6 eV, 17.9 eV)

45. A particle is trapped in an infinitely deep one-dimensional well of width L in the n^{th} state. Calculate the probability of finding the particle in the box between x=0 and x=L/n. (Ans: 1/n)
46. A particle is trapped in an infinite one-dimensional well of width L. If the particle is in the ground state, evaluate the probability of finding the particle between x=0 and x=L/3. (Ans: 0.196)
47. An electron is trapped in a one-dimensional region of length 1.0×10^{-10} m (a) How much energy must be supplied to excite the electron from the ground state to the first excited state? (b) In the ground state, what is the probability of finding the electron in the region from $x=0.090\times10^{-10}$ m to 0.110×10^{-10} m (c) In the first excited state, what is the probability of finding the electron between x=0 and $x=0.250\times10^{-10}$ m (Ans: (a) 111eV (b) 0.38 % (c) 0.25)

48. The Fermi energy of Lithium is 4.72 eV. (a) Calculate the Fermi velocity. (b) Calculate the de Broglie wavelength of an electron moving at the Fermi velocity. (Ans: 1.29×10^6 m/s, 0.56 nm)
49. Find the probability for an electronic state to be occupied at room temperature ($k_BT=0.025$eV) if the energy of this state lies 0.1 eV above the Fermi level. Do the same for a state which lies 0.1 eV below the Fermi level. (Ans: 0.018, 0.98)
50. Fermi energy level in Silver is at 5.5 eV. What are the energies for which the probabilities of occupancy at a temperature of 300 K are 0.99, 0.01 and 0.5? (Ans: 5.38 eV, 5.619 eV, 5.5 eV)

Semiconductor

1. Calculate the conductivity of pure silicon at room temperature when the concentration of carrier is $1.5 \times 10^{16}/m^3$ and the mobilities of the electrons and holes are 0.12 and 0.05 m^2/V-sec respectively at room temperature.
2. Calculate the conductivity of Germanium specimen if a donor impurity is added to the extent of one part in 10^8 Germanium atoms at room temperature.
3. The resistivity of n type semiconductor is 10^{-6} Ω - cm. Calculate the number of donor atoms which must have been added to obtain the resistivity.
4. Calculate the conductivity of extrinsic silicon at room temperature if the donor impurity added is 1 in 10^8 silicon atoms.

5. In Germanium the energy gap is 0.75eV. What is the wavelength at which the Germanium starts to absorb the light?
6. The mobilities of charge carriers in intrinsic germanium sample at room temperature are μ_n = 3600 cm^2/V-s and μ_p = 1700 cm^2/V-s. If the density of electrons is same as holes and is equal to 2.5 x 10^{13} per cm^3, calculate the conductivity.
7. Calculate the number of acceptors to be added to a germanium sample to obtain the resistivity ρ = 10 ohm-cm. given μ = 1700 cm^2/V-s.
8. At room temperature the conductivity of a silicon crystal is 5 x 10^{-4} mho/cm. If the electron and hole mobilities are 0.14m^2/V-s and 0.05 m^2/V-s respectively, determine the density of carriers.
9. The specific density of tungsten is 18.8 g/cm^3 and its atomic weight is 184.0. Assume that there are two free electrons per atom. Calculate the concentration of free electrons. Avogadro's Number = 6.025 x 10^{23} /gm-mole.
10. Compute the conductivity of copper for which μ = 34.8 cm^2/V-s and d = 8.9 gm/cm^3. Assume that there is one free electron per atom. Avogadro's Number = 6.025 x 10^{23} /gm-mole, atomic weight of Cu = 63.5. If an electric field is applied across such a copper bar with an intensity of 10 V/cm, find the drift velocity of free electrons.
11. The resistance of copper wire of diameter 1.03 mm is 6.51 ohm per 300m. The concentration of free electrons in copper is 8.4 x x10^{28} /m3. If the current is 2 A, find the (a) mobility, (b) drift velocity (c) conductivity.
12. Calculate the energy gap in silicon if it is given that it is transparent to the radiation of wavelength greater than 11000Å
13. N type semiconductor is to have a resistivity of 10 ohm-cm. Calculate the number of donor atoms which must be added to achieve this. Given: μ = 500 cm^2/V-s.
14. Determine the mobility of electrons in copper assuming that each atom contributes one free electron for conduction. For copper : resistivity =1.7x10^{-6} ohm.cm ,density =8.96 gm/cc At.Wt. of copper A= 63.5, Avogadro number =6.02x 10 23 atoms per gram mole.
15. Find the resistivity of copper if each atom of copper contributes one free electron for conduction. (Given: density of Cu =8.96 gm/cc At.Wt. 63.5, Avogadro number =6.02x 10^{23} μ_e= 43.28 cm^2/volt.sec) density =8.96 gm/cc At.Wt. of copper A= 63.5, Avogadro number =6.02x10^{23} atoms per gram mole)
16. Calculate the conductivity of specimen if a donor impurity is added to an extent of one part in 10^8 Ge atoms at room temperature? (Given: For Ge: density =5.32 gm/cc At.Wt. 72.6, Avogadro number =6.02x 10^{23} atoms per gram mole μ= 3800 cm^2/volt.sec)
17. A Ge semiconductor contains 10^{-6} % Boron and has resistivity of 0.42 ohm.cm. Calculate the concentration and mobility of holes in the semiconductor (Given: For Ge: density =5.36 gm/cc At.Wt. 72.59, Avogadro number =6.02x 10 23 atoms per gram mole μ= 3800 cm^2/volt.sec)

18. A Ge crystal ids doped with pentavalent impurity of concentration 1ppm .If the resistivity of dopped Ge is $0.3623X10^{-3}$ ohm.m, find the conductivity and mobility of electrons Ge. Assume all the impurity atoms are ionized. (Given:density of Ge atoms $=4.42x10^{28}$ atoms/m^3 $\rho_e= 0.3623x10^{-3}$ ohm.m $\mu= 3800\ cm^2$/volt.sec)
19. A specimen of pure Ge at 300K has a density of charge carriers (intrinsic) of $2.5x10^{19}/m^3$.It is doped with donor impurity atoms at the rate of one impurity atom for envery 10^6 atoms of Ge .All impurity atoms are supposed to be ionized .The density of Ge atoms is 4.2 x10 ^{28} atoms/m^3 .Find donor concentration, conductivity and resistivity of doped Ge if $\mu_e= 0.36m^2$/volt.sec.
20. Acopper wire 0.1m long and 1.7 mm^2 cross section has a resistance 0.1 ohm when subjected to 1 volt potential difference between its ends. Calculate the density of electrons in the metal and the mobility of these electrons and the resistivity of copper. (Density of copper 8.96 gm/cc, atomic weight of Cu 63.5 Avogadro number =6.02x 10^{23} atoms per gram mole)
21. The resistance of Cu wire of diameter 1.03mm is 6.51 ohm per 300m.The concentration of free electron in copper is $8.4x10^{28}$ /m^3. If the current is 2A, find the a) drift velocity, b) conductivity c) Mobility.
22. In Ge the energy gap is 0.75eV. What is the wavelength at which Ge starts to absorb the light?
23. Calculate the energy gap of Si, given that it is transparent to radiation of wavelength greater than 11,000 Å
24. Find the drift velovity for an electron in silver wire of radius 1mm and carrying a current of 2A Density of silver is 10.5 gm/cc and its atomic weight is 108.(Hint: find n,A and then V).
25. Calculate the conductivity and current produced in a small Ge plate of area $1cm^2$ and of thickness 0.3mm when a potential difference of 2V is applied across the faces. Given that the concentration of free electrons is Ge is $2x10^{19}/m^3$ and Mobilities of electrons and holes are $0.36m^2$/v.s and $0.17m^2$/v.s respectively.
26. Calculate the conductivity and current produced in Ge sample of area 2 sq. cm and thickness 0.1mm when a potential difference of 4 V is applied across it.
27. A copper specimen having length 1m, width 1cm and thickness 1mm is conducting 1 amp current along its length and is applied with a magnetic field of 1T along its thickness. It experiences Hall Effect and Hall voltage of 0.074µV appears along its width. Calculate the Hall coefficient and the mobility of electrons in copper.(Given for copper $\sigma=5.8x10^7$ mho m)
28. The resistivity of doped silicon material is $9x10^{-3}$ ohm m .The Hall coefficient is $3.6x10^{-4}$ m^3 $coulomb^{-1}$.Assuming single carrier conduction ,find mobility and density of charge carriers ,e = $1.6x10^{-19}$C.

29. A slab of copper 2mm in length and 1.5 cm wide is placed in a uniform magnetic field with magnitude 0.40 T .When a current of 75 amp flows along the length .the voltage measured across the width is 0.81 μV determine Hall coefficient the concentration of mobile electrons in copper.
30. A copper strip 4cm wide and o.55mm thick carries a current of 100A along its length .If placed in the Magnetic field of strength of 2 w/m^2 acting along the width of the strip. A Hall voltage $29.7x10^{-6}$ volts appears across thickness. Find i) Hall electric field ii) Carrier concentration in copper strip.
31. A silver wire is in the form of ribbon 0.50cm wide and 0.10mm thick .When a current of 2 amp passes through the ribbon, perpendicular to 0.80Tesla magnetic field .Calculate the Hall voltage produced. The density of silver 10.5gm/cc and atomic weight of Ag =108.
32. Determine the conc. Of holes in Si crystal having donor concentration of $1.4x10^{24}/m^3$,when the intrinsic carrier is 1.4 $x10^{18}/m^3$. Find the ratio of electron to hole concentration.
33. Estimate the fraction of electrons in the conduction band at 300K of i) Ge (Eg=0.72 eV) ii) Si (Eg=1.1 eV) iii) Diamond (Eg=5.6 eV). What is the significance of these results?
34. Calculate the drift velocity of electrons in an Aluminum wire of diameter 0.9 mm carrying current of 6 A. Assume that 4.5×10^{28} electrons/m^3 are available for conduction.
35. The density of Copper is 8.96 g/cm^3 and its atomic weight is 63.5 g/mole. Determine the current density if the current of 5.0 A is maintained in copper wire of radius 0.7 mm. Assume that only one electron of an atom takes part in conduction. Also calculate the drift velocity of electrons.
36. For a given semiconductor bar, the dimensions along the axes are y=0.1 mm, z=10 μm, x=5 mm, I_x=1 mA, $B_z=10^{-4}$ Wb/cm^2, V_H= -2mV. Find the type and concentration of the majority carriers.
37. A Copper wire is 1 m long and has a uniform cross section of 0.1 mm^2. The resistance of the wire at room temperature is 0.172 Ω. What is the resistivity of the material?
38. A uniform Silver wire has a resistivity of 1.54×10^{-8} Ωm at room temperature. For an electric field along the wire of 1 V/cm compute the drift velocity of the electrons assuming there are 5.8×10^{28} electrons per m^3. Also calculate the mobility of the electrons.
39. Find the resistance of an intrinsic germanium rod 1 cm long, 1 mm wide and 1 mm thick at 300 K. (μ_e=0.39 m^2/Vs, μ_h=0.19 m^2/Vs, $n=2.5\times10^{19}$ m^{-3})
40. Show that the Fermi-Dirac distribution function is symmetric about the Fermi energy for all temperatures i.e. $f(\varepsilon_f+\delta)=1- f(\varepsilon_f-\delta)$.
41. The Fermi energy of Lithium is 4.72 eV. (a) Calculate the Fermi velocity. (b) Calculate the de Broglie wavelength of an electron moving at the Fermi velocity.
42. Find the probability for an electronic state to be occupied at room temperature (k_BT=0.025eV) if the energy of this state lies 0.1 eV above the Fermi level. Do the same for a state which lies 0.1 eV below the Fermi level.

43. Fermi energy level in Silver is at 5.5 eV. What are the energies for which the probabilities of occupancy at a temperature of 300 K are 0.99, 0.01 and 0.5?