Problem 1:

Which of the following ions CANNOT be used as a dopant in germanium to make an n-type semiconductor?

(A) As
(B) P
(C) Sb
(D) B
(E) N

Problem 2:

The discovery of the J/ψ particle was especially significant because it provided evidence for which of the following?

(A) Parity violation in weak interactions
(B) Massive neutrinos
(C) Higgs bosons
(D) Charmed quarks
(E) Strange quarks

Problem 3:

X rays of wavelength $\lambda = 0.250$ nm are incident on the face of a crystal at angle θ, measured from the crystal surface. The smallest angle that yields an intense reflected beam is $\theta = 14.5°$. Which of the following gives the value of the interplanar spacing d? $(\sin 14.5° \approx 1/4)$

(A) 0.125 nm
(B) 0.250 nm
(C) 0.500 nm
(D) 0.625 nm
(E) 0.750 nm

Problem 4:

Which of the following is the principal decay mode of the positive muon μ^+?

(A) $\mu^+ \rightarrow e^+ + \nu_e$
(B) $\mu^+ \rightarrow p + \nu_\mu$
(C) $\mu^+ \rightarrow n + e^+ + \nu_e$
(D) $\mu^+ \rightarrow e^+ + \nu_e + \overline{\nu}_\mu$
(E) $\mu^+ \rightarrow \pi^+ + \overline{\nu}_e + \nu_\mu$

Problem 5:

The partition function Z in statistical mechanics can be written as

$$Z = \sum_r e^{-E_r/kT},$$

where the index r ranges over all possible microstates of a system and E_r is the energy of microstate r. For a single quantum mechanical harmonic oscillator with energies

$$E_n = \left(n + \frac{1}{2}\right)\hbar\omega, \text{ where } n = 0, 1, 2, \ldots,$$

the partition function Z is given by which of the following?

(A) $Z = e^{-\frac{1}{2}\hbar\omega/kT}$

(B) $Z = e^{\frac{1}{2}\hbar\omega/kT}$

(C) $Z = e^{\frac{1}{2}\hbar\omega/kT} - 1$

(D) $Z = e^{\frac{1}{2}\hbar\omega/kT} + 1$

(E) $Z = \dfrac{e^{\frac{1}{2}\hbar\omega/kT}}{e^{\hbar\omega/kT} - 1}$

Problem 6:

According to the BCS theory, the attraction between Cooper pairs in a superconductor is due to

(A) the weak nuclear force
(B) the strong nuclear force
(C) vacuum polarization
(D) interactions with the ionic lattice
(E) the Casimir effect

Problem 7:

$$^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$$

The nuclear decay above is an example of a process induced by the

(A) Mössbauer effect
(B) Casimir effect
(C) photoelectric effect
(D) weak interaction
(E) strong interaction

Problem 8:

Which of the following are the eigenvalues of the Hermitian matrix $\begin{pmatrix} 2 & i \\ -i & 2 \end{pmatrix}$?

(A) 1, 0
(B) 1, 3
(C) 2, 2
(D) i, $-i$
(E) $1 + i$, $1 - i$

Problem 9:

Which of the following statements concerning the electrical conductivities at room temperature of a pure copper sample and a pure silicon sample is NOT true?

(A) The conductivity of the copper sample is many orders of magnitude greater than that of the silicon sample.
(B) If the temperature of the copper sample is increased, its conductivity will decrease.
(C) If the temperature of the silicon sample is increased, its conductivity will increase.
(D) The addition of an impurity in the copper sample always decreases its conductivity.
(E) The addition of an impurity in the silicon sample always decreases its conductivity.

Problem 10:

In the diamond structure of elemental carbon, the nearest neighbors of each C atom lie at the corners of a

(A) square
(B) hexagon
(C) cube
(D) tetrahedron
(E) octahedron

Problem 11:

What are the changes in the mass number A and atomic number Z of a nucleus that undergoes electron capture?

(A) A is unchanged; Z decreases by 2.
(B) A is unchanged; Z decreases by 1.
(C) A is unchanged; Z increases by 1.
(D) A decreases by 2; Z increases by 1.
(E) A decreases by 4; Z decreases by 2.

Problem 12:

The particle decay $\Lambda \rightarrow p + \pi^-$ must be a weak interaction because

(A) the π^- is a lepton.
(B) the Λ has spin zero
(C) no neutrino is produced in the decay
(D) it does not conserve angular momentum
(E) it does not conserve strangeness

Problem 13:

Which of the following reactions or decays is allowed by the laws of nature?

(A) $p \rightarrow \pi^+ + \pi^0$

(B) $\pi^- + p \rightarrow K^+ + \Sigma^-$

(C) $\pi^- \rightarrow e^- + \gamma$

(D) $p \rightarrow \Sigma^+ + \pi^0$

(E) $p + p \rightarrow n + p + \pi^+ + \pi^- + \pi^0$

Problem 14:

At the present time, the temperature of the universe (i.e., the microwave radiation background) is about 3 K. When the temperature was 12 K, typical objects in the universe, such as galaxies, were

(A) one-quarter as distant as they are today
(B) one-half as distant as they are today
(C) separated by about the same distances as they are today
(D) two times as distant as they are today
(E) four times as distant as they are today

Problem 15:

Electrons of kinetic energy 20 keV are brought to rest by colliding with a solid. Which of the following is true of the shortest wavelength photon that may be emitted?

(A) It has an energy of 20 keV.
(B) It has an energy equal to the ionization energy of an atom in the solid.
(C) It must have a wavelength given by Bragg's law for diffraction.
(D) It is in the infrared range.
(E) It is one of the characteristic x-rays of the solid.