

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  $J/\psi$  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  $\theta$ , measured from the crystal surface. The smallest angle that yields an intense reflected beam is  $\theta = 14.5^\circ$ . Which of the following gives the value of the interplanar spacing  $d$ ? ( $\sin 14.5^\circ \approx 1/4$ )

- (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  $\mu^+$ ?

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

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

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

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

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

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

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

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

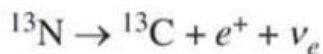
(E)  $Z = \frac{e^{\frac{1}{2}h\omega/kT}}{e^{h\omega/kT} - 1}$

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:



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  $\pi^-$  is a lepton.
- (B) the  $\Lambda$  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.