2. The longest wavelength x-ray that can undergo Bragg diffraction in a crystal for a given family of planes of spacing $d$ is

(A) $\frac{d}{4}$

(B) $\frac{d}{2}$

(C) $d$

(D) $2d$

(E) $4d$

3. The ratio of the energies of the $K$ characteristic x-rays of carbon ($Z = 6$) to those of magnesium ($Z = 12$) is most nearly

(A) $\frac{1}{4}$

(B) $\frac{1}{2}$

(C) 1

(D) 2

(E) 4
14. The total energy of a blackbody radiation source is collected for one minute and used to heat water. The temperature of the water increases from 20.0 °C to 20.5 °C. If the absolute temperature of the blackbody were doubled and the experiment repeated, which of the following statements would be most nearly correct?

(A) The temperature of the water would increase from 20 °C to a final temperature of 21 °C.
(B) The temperature of the water would increase from 20 °C to a final temperature of 24 °C.
(C) The temperature of the water would increase from 20 °C to a final temperature of 28 °C.
(D) The temperature of the water would increase from 20 °C to a final temperature of 36 °C.
(E) The water would boil within the one-minute time period.

23. The Fermi temperature of Cu is about 80,000 K. Which of the following is most nearly equal to the average speed of a conduction electron in Cu?

(A) 2 \times 10^{-2} \text{ m/s}
(B) 2 \text{ m/s}
(C) 2 \times 10^{2} \text{ m/s}
(D) 2 \times 10^{4} \text{ m/s}
(E) 2 \times 10^{6} \text{ m/s}

24. Solid argon is held together by which of the following bonding mechanisms?

(A) Ionic bond only
(B) Covalent bond only
(C) Partly covalent and partly ionic bond
(D) Metallic bond
(E) van der Waals bond
25. In experiments located deep underground, the two types of cosmic rays that most commonly reach the experimental apparatus are

(A) alpha particles and neutrons
(B) protons and electrons
(C) iron nuclei and carbon nuclei
(D) muons and neutrinos
(E) positrons and electrons

\[ \log_{10} 2 = 0.30; \quad \log_{10} e = 0.43 \]

26. A radioactive nucleus decays, with the activity shown in the graph above. The half-life of the nucleus is

(A) 2 min
(B) 7 min
(C) 11 min
(D) 18 min
(E) 23 min
30. Given that the binding energy of the hydrogen atom ground state is \( E_0 = 13.6 \text{ eV} \), the binding energy of the \( n = 2 \) state of positronium (positron-electron system) is
   (A) \( 8E_0 \)
   (B) \( 4E_0 \)
   (C) \( E_0 \)
   (D) \( \frac{E_0}{4} \)
   (E) \( \frac{E_0}{8} \)

31. In a \( ^2S \) state of the helium atom, the possible values of the total electronic angular momentum quantum number are
   (A) 0 only
   (B) 1 only
   (C) 0 and 1 only
   (D) 0, \( \frac{1}{2} \), and 1
   (E) 0, 1, and 2
37. A $\pi^0$ meson (rest mass energy 135 MeV) is moving
with velocity $0.8c \mathbf{\hat{k}}$ in the laboratory rest frame
when it decays into two photons, $\gamma_1$ and $\gamma_2$. In the $\pi^0$
rest frame, $\gamma_1$ is emitted forward and $\gamma_2$ is emitted
backward relative to the $\pi^0$ direction of flight. The velocity of $\gamma_2$ in the laboratory rest frame is

(A) $-1.0c \mathbf{\hat{k}}$
(B) $-0.2c \mathbf{\hat{k}}$
(C) $+0.8c \mathbf{\hat{k}}$
(D) $+1.0c \mathbf{\hat{k}}$
(E) $+1.8c \mathbf{\hat{k}}$

38. Tau leptons are observed to have an average half-life
of $\Delta t_1$ in the frame $S_1$ in which the leptons are at rest.
In an inertial frame $S_2$, which is moving at a
speed $v_{12}$ relative to $S_1$, the leptons are observed to
have an average half-life of $\Delta t_2$. In another inertial
reference frame $S_3$, which is moving at a speed $v_{13}$
relative to $S_1$ and $v_{23}$ relative to $S_2$, the leptons
have an observed half-life of $\Delta t_3$. Which of the
following is a correct relationship among two of the
half-lives, $\Delta t_1$, $\Delta t_2$, and $\Delta t_3$?

(A) $\Delta t_2 = \Delta t_1 \sqrt{1 - (v_{12})^2/c^2}$
(B) $\Delta t_1 = \Delta t_2 \sqrt{1 - (v_{13})^2/c^2}$
(C) $\Delta t_2 = \Delta t_3 \sqrt{1 - (v_{23})^2/c^2}$
(D) $\Delta t_3 = \Delta t_2 \sqrt{1 - (v_{23})^2/c^2}$
(E) $\Delta t_1 = \Delta t_2 \sqrt{1 - (v_{23})^2/c^2}$