24. Which of the following statements about entropy changes is true for the cycle described in the above problem?

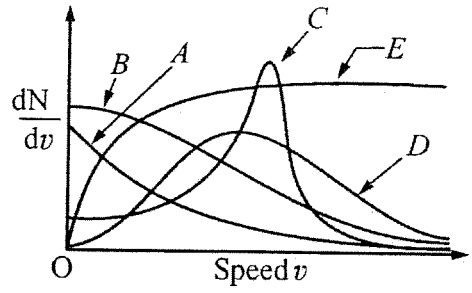
(A) The entropy of the surroundings remains constant during each of the three processes.

(B) The combined entropy of the gas and surroundings remains constant during each of the three processes.

(C) For the complete cycle, the combined entropy of the gas and surroundings increases.

(D) For the complete cycle, the entropy of the gas increases.

25. Which of the curves in the graph above best represents the distribution of speeds of the molecules in an ideal gas at thermal equilibrium? (Ignore the curve labelled E)



(A) A

(B) B

(C) C

(D) D

26. Gaseous O_2 (molecular mass 32 amu) and N_2 (molecular mass 28 amu) are maintained in equilibrium at constant temperatures of 400 K and 200 K respectively. What is the ratio $v_{rms}(N_2)/v_{rms}(O_2)$ of the root-mean-square speeds of the molecules?

(A) 7/8

(B) $\sqrt{7/8}$

(C) $\sqrt{8/7}$

(D) $\sqrt{4/7}$

27. An electron and a proton, both with kinetic energy 5 eV, are incident upon a potential step of height 9 eV. The ratio of the penetration depth of the electron to that of the proton is about

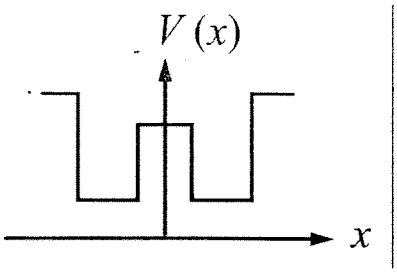
(A) 1834

(B) 42.8

(C) 1/1834

(D) 1/42.8

28. The sketch below shows a one-dimensional potential for an electron. The potential is symmetric about the V-axis.



Which of the following statements correctly describes the ground state of the system with one electron present?

(A) A single electron must be localized in one well.

(B) The kinetic energy of the ground state will be one-half its potential energy.

(C) The wave function of the ground state will be antisymmetric with respect to the V-axis.

(D) The wave function of the ground state will be symmetric with respect to the V-axis.

29. Three electrons all with spins pointing up are placed placed in a potential $V(x) = \frac{1}{2} m_e \omega^2 x^2$. The ground state energy of the system is

(A) 0

(B) $3\hbar\omega/2$

(C) $5\hbar\omega/2$

(D) $9\hbar\omega/2$

30. A sodium atom in the excited $3P$ state has a lifetime of 16 ns for decaying to the ground $3S$ state. The wavelength of the emitted photon is 589 nm. The corresponding linewidth of the transition (in frequency) is close to

(A) 1.7×10^6 Hz

(B) 10^7 Hz

(C) 10^8 Hz

(D) 5×10^{14} Hz

31. A gas of rubidium atoms is at 25°C. The dominant transition at $\lambda = 780$ nm is Doppler broadened (due to the random thermal motion) to a linewidth of 550 MHz. If the temperature of the gas is raised to 250°C, the Doppler width becomes

(A) 728 MHz

(B) 965 MHz

(C) 1739 MHz

(D) 5500 MHz

32. A tungsten surface is illuminated with UV light of wavelength 200 nm. The emitted photoelectrons are collected on an electrode kept near this surface. Given that the work function of the tungsten surface is 4.6 eV, the potential that must be applied to the electrode in order to stop electrons from being collected is

(A) 6.2 V

(B) 3 V

(C) 1.6 V

(D) 4.6 V

33. A beam of monoenergetic electrons passes through a narrow slit and a diffraction pattern is observed on a distant screen. What can be done to increase the separation between the two minima on either side of the central maximum by a factor of 2?

(A) Increase the speed of the electrons by a factor of 2

(B) Increase the speed of the electrons by a factor of $\sqrt{2}$

(C) Decrease the width of the slit by a factor of 2

(D) Decrease the width of the slit by a factor of $\sqrt{2}$

34. Which of the following properties of the hydrogen atom can be predicted most accurately from the simple Bohr model?

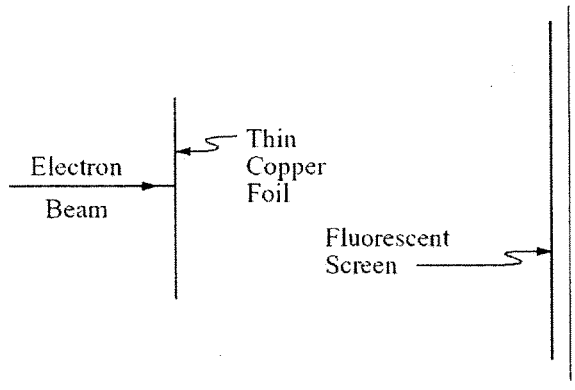
(A) Energy differences between states

(B) Angular momentum of the ground state

(C) Degeneracy of states

(D) Transition probabilities

35. In order to observe a ring diffraction pattern on the screen shown below, which of the following conditions must be met?



(A) The electron beam must be polarized.

(B) The electron beam must be approximately mono-energetic.

(C) The copper foil must be a single crystal specimen.

(D) The copper foil must be of uniform thickness.

36. The total energy necessary to remove all three electrons from a lithium atom is most nearly

(A) 2000 eV

(B) 200 eV

(C) 20 eV

(D) 2 eV

37. A beam of electrons with kinetic energy 1 keV is diffracted as it passes through a polycrystalline metal foil. The metal has a cubic crystal structure with a lattice spacing of 1 Å. The Bragg angle for the first diffraction maximum is

(A) 1.12°

(B) 5.59°

(C) 11.18°

(D) 22.36°

38. A particle of mass m_A decays at rest into two particles of mass m_B each. The magnitude of the momentum of the particle m_B is

(A) $\dfrac{\sqrt{m_A^2 - 4m_B^2}\, c}{2}$

(B) $\dfrac{\sqrt{m_A^2 + 4m_B^2}\, c}{2m_A}$

(C) $\sqrt{m_A^2 + 4m_B^2}\, c$

(D) $(m_A^2 + 4m_B^2)\, c$

39. A tube of water is travelling at $(1/2)\, c$ relative to the laboratory frame when a beam of light travelling in the same direction as the tube enters it. What is the speed of light in the water relative to the lab frame? (The index of refraction of water is 4/3.)

(A) $(1/2)\, c$

(B) $(3/4)\, c$

(C) $(10/11)\, c$

(D) c

40. Which of the following is most useful for measuring temperatures of about 3000 K?

(A) Optical pyrometer

(B) Carbon resistor

(C) Gas-bulb thermometer

(D) Thermocouple

41. The characteristic length scale at which quantum gravitational effects become significant, called the Planck length, can be obtained by suitably combining the physical constants G, $\hbar$ and c. Which of the following correctly gives the Planck length?

(A) $G\hbar c$

(B) $G\hbar^2 c^3$

(C) $G^2\hbar c$

(D) $(G\hbar/c^3)^{1/2}$

42. Two resistors each of nominal value 50 Ω and having a standard deviation of 5 Ω are connected in series. The resultant resistance has a value of

(A) 100 $\Omega \pm$ 2.5 Ω

(B) 100 $\Omega \pm$ 5 Ω

(C) 100 $\Omega \pm$ 7 Ω

(D) 100 $\Omega \pm$ 10 Ω

43. A certain material undergoes radioactive decay. If initially there is 50 mg of the material present, and after 2 hours the material has lost 10% of its original mass, what is the half-life of the material?

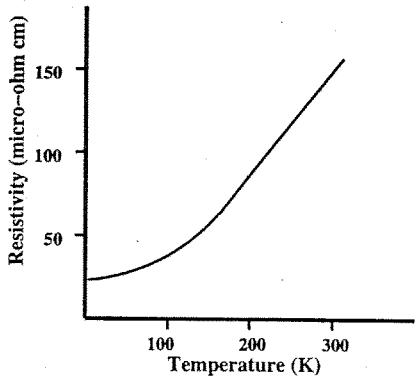
(A) 13 hours

(B) 10 hours

(C) 5 hours

(D) 6.5 hours

44. The figure below is a plot of the electrical resistivity of a solid as a function of temperature. From the graph we can infer that this solid is a



(A) metal

(B) insulator

(C) semiconductor

(D) superconductor