Modern Physics – Problem Set # 3

Rest mass of the electron	$m_e = 9.11 \times 10^{-31}$ kilogram $= 9.11 \times 10^{-28}$ gram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb $= 4.80 \times 10^{-10}$ statcoulomb (esu)
Avogadro's number	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.32$ joules/(mole · K)
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ joule/K $= 1.38 \times 10^{-16}$ erg/K
Speed of light	$c = 3.00 \times 10^{8}$ m/s $= 3.00 \times 10^{10}$ cm/s
Planck's constant	$h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second
	$\hbar = h/2\pi$
Vacuum permittivity	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton · meter^2)
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram · second^2)
Acceleration due to gravity	$g = 9.80$ m/s^2 $= 980$ cm/s^2
1 atmosphere pressure	1 atm $= 1.0 \times 10^5$ newton/meter^2 $= 1.0 \times 10^5$ pascals (Pa)
1 angstrom	1 Å $= 1 \times 10^{-10}$ meter

1 weber/m^2 = 1 tesla $= 10^4$ gauss

15. A classical model of a diatomic molecule is a springy dumbbell, as shown above, where the dumbbell is free to rotate about axes perpendicular to the spring. In the limit of high temperature, what is the specific heat per mole at constant volume?

(A) $\frac{3}{2}R$

(B) $\frac{5}{2}R$

(C) $\frac{7}{2}R$

(D) $\frac{9}{2}R$

(E) $\frac{11}{2}R$

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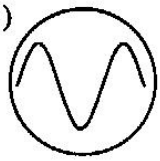
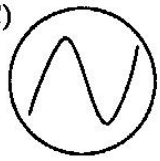
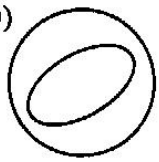
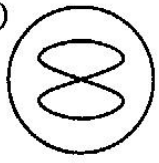
17. The outputs of two electrical oscillators are compared on an oscilloscope screen. The oscilloscope spot is initially at the center of the screen. Oscillator Y is connected to the vertical terminals of the oscilloscope and oscillator X to the horizontal terminals. Which of the following patterns could appear on the oscilloscope screen, if the frequency of oscillator Y is twice that of oscillator X?

(A) 

(B) 

(C) 

(D) 

(E) 

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76. The configuration of three electrons ls2p3p has which of the following as the value of its maximum possible total angular momentum quantum number?

(A) $\frac{7}{2}$

(B) 3

(C) $\frac{5}{2}$

(D) 2

(E) $\frac{3}{2}$

77. Consider a heavy nucleus with spin $\frac{1}{2}$. The magnitude of the ratio of the intrinsic magnetic moment of this nucleus to that of an electron is

(A) zero, because the nucleus has no intrinsic magnetic moment
(B) greater than 1, because the nucleus contains many protons
(C) greater than 1, because the nucleus is so much larger in diameter than the electron
(D) less than 1, because of the strong interactions among the nucleons in a nucleus
(E) less than 1, because the nucleus has a mass much larger than that of the electron

80. A beam of electrons is accelerated through a potential difference of 25 kilovolts in an x-ray tube. The continuous x-ray spectrum emitted by the target of the tube will have a short wavelength limit of most nearly

(A) 0.1 Å

(B) 0.5 Å

(C) 2 Å

(D) 25 Å

(E) 50 Å

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85. A free electron (rest mass $m_e = 0.5$ MeV/c^2) has a total energy of 1.5 MeV. Its momentum p in units of MeV/c is about

(A) 0.86
(B) 1.0
(C) 1.4
(D) 1.5
(E) 2.0

90. The spacing of the rotational energy levels for the hydrogen molecule H_2 is most nearly

(A) 10^{-9} eV
(B) 10^{-3} eV
(C) 10 eV
(D) 10 MeV
(E) 100 MeV

91. 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

94. Which of the following is a Lorentz transformation? (Assume a system of units such that the velocity of light is 1.)

(A) $x' = 4x$
$y' = y$
$z' = z$
$t' = .25t$

(B) $x' = x - .75t$
$y' = y$
$z' = z$
$t' = t$

(C) $x' = 1.25x - .75t$
$y' = y$
$z' = z$
$t' = 1.25t - .75x$

(D) $x' = 1.25x - .75t$
$y' = y$
$z' = z$
$t' = .75t - 1.25x$

(E) None of the above

95. A beam of 10^{12} protons per second is incident on a target containing 10^{20} nuclei per square centimeter. At an angle of 10 degrees, there are 10^{2} protons per second elastically scattered into a detector that subtends a solid angle of 10^{-4} steradians. What is the differential elastic scattering cross section, in units of square centimeters per steradian?

(A) 10^{-24}
(B) 10^{-25}
(C) 10^{-26}
(D) 10^{-27}
(E) 10^{-28}

97. Lattice forces affect the motion of electrons in a metallic crystal, so that the relationship between the energy E and wave number k is not the classical equation $E = \hbar^2 k^2/2m$, where m is the electron mass. Instead, it is possible to use an effective mass m^* given by which of the following?

(A) $m^* = \frac{1}{2}\hbar^2 k\left(\frac{dk}{dE}\right)$

(B) $m^* = \dfrac{\hbar^2 k}{\left(\dfrac{dk}{dE}\right)}$

(C) $m^* = \hbar^2 k\left(\dfrac{d^2k}{dE^2}\right)^{\frac{1}{3}}$

(D) $m^* = \dfrac{\hbar^2}{\left(\dfrac{d^2E}{dk^2}\right)}$

(E) $m^* = \frac{1}{2}\hbar^2 m^2\left(\dfrac{d^2E}{dk^2}\right)$