

## Modern Physics - Problem Set # 5

### TABLE OF INFORMATION

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	$R = 8.31$ 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 <sup>2</sup> /(newton · meter <sup>2</sup> )
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ meter <sup>3</sup> /(kilogram · second <sup>2</sup> )
Acceleration due to gravity	$g = 9.80$ m/s <sup>2</sup> = 980 cm/s <sup>2</sup>
1 atmosphere pressure	1 atm = $1.0 \times 10^5$ newton/meter <sup>2</sup> = $1.0 \times 10^5$ pascals (Pa)
1 angstrom	1 Å = $1 \times 10^{-10}$ meter
	1 weber/m <sup>2</sup> = 1 tesla = $10^4$ gauss

### Moments of inertia about center of mass

Rod	$\frac{1}{12}MR^2$
Disc	$\frac{1}{2}MR^2$
Sphere	$\frac{2}{5}MR^2$

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41. A  $3p$  electron is found in the  ${}^3P_{3/2}$  energy level of a hydrogen atom. Which of the following is true about the electron in this state?
- (A) It is allowed to make an electric dipole transition to the  ${}^2S_{1/2}$  level.
  - (B) It is allowed to make an electric dipole transition to the  ${}^2P_{1/2}$  level.
  - (C) It has quantum numbers  $l = 3, j = 3/2, s = 1/2$
  - (D) It has quantum numbers  $n = 3, j = l, s = 3/2$ .
  - (E) It has exactly the same energy as it would in the  ${}^3D_{3/2}$  level.
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42. Light of wavelength 500 nanometers is incident on sodium, with work function 2.28 electron volts. What is the maximum kinetic energy of the ejected photoelectrons?
- (A) 0.03 eV
  - (B) 0.2 eV
  - (C) 0.6 eV
  - (D) 1.3 eV
  - (E) 2.0 eV
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48. The half-life of a  $\pi^+$  meson at rest is  $2.5 \times 10^{-8}$  second. A beam of  $\pi^+$  mesons is generated at a point 15 meters from a detector. Only  $\frac{1}{2}$  of the  $\pi^+$  mesons live to reach the detector. The speed of the  $\pi^+$  mesons is
- (A)  $\frac{1}{2}c$
  - (B)  $\sqrt{\frac{2}{5}}c$
  - (C)  $\frac{2}{\sqrt{5}}c$
  - (D)  $c$
  - (E)  $2c$
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50. In inertial frame  $S$ , two events occur at the same instant in time and  $3c \cdot \text{minutes}$  apart in space. In inertial frame  $S'$ , the same events occur at  $5c \cdot \text{minutes}$  apart. What is the time interval between the events in  $S'$ ?

- (A) 0 min
  - (B) 2 min
  - (C) 4 min
  - (D) 8 min
  - (E) 16 min
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53. Positronium is the bound state of an electron and a positron. Consider only the states of zero orbital angular momentum ( $l = 0$ ). The most probable decay product of any such state of positronium with spin zero (singlet) is

- (A) 0 photons
  - (B) 1 photon
  - (C) 2 photons
  - (D) 3 photons
  - (E) 4 photons
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63. According to the Standard Model of elementary particles, which of the following is NOT a composite object?

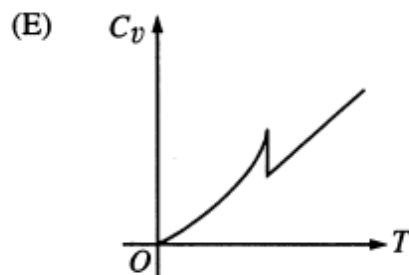
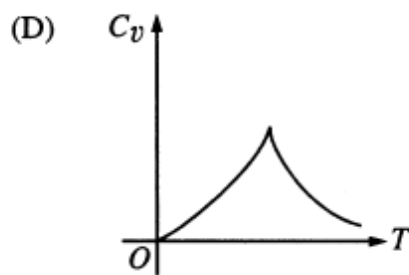
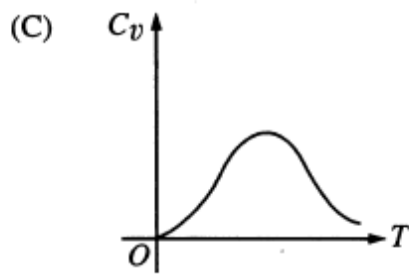
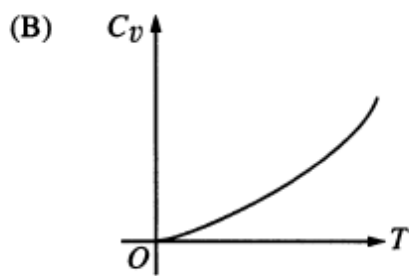
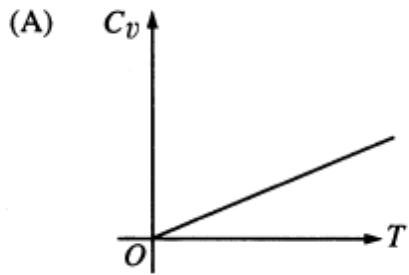
- (A) Muon
- (B) Pi-meson
- (C) Neutron
- (D) Deuteron
- (E) Alpha particle

64. The binding energy of a heavy nucleus is about 7 million electron volts per nucleon, whereas the binding energy of a medium-weight nucleus is about 8 million electron volts per nucleon. Therefore, the total kinetic energy liberated when a heavy nucleus undergoes symmetric fission is most nearly

- (A) 1876 MeV
  - (B) 938 MeV
  - (C) 200 MeV
  - (D) 8 MeV
  - (E) 7 MeV
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67. A black hole is an object whose gravitational field is so strong that even light cannot escape. To what approximate radius would Earth (mass =  $5.98 \times 10^{24}$  kilograms) have to be compressed in order to become a black hole?
- (A) 1 nm
  - (B) 1  $\mu\text{m}$
  - (C) 1 cm
  - (D) 100 m
  - (E) 10 km
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78. In an  $n$ -type semiconductor, which of the following is true of impurity atoms?
- (A) They accept electrons from the filled valence band into empty energy levels just above the valence band.
  - (B) They accept electrons from the filled valence band into empty energy levels just below the valence band.
  - (C) They accept electrons from the conduction band into empty energy levels just below the conduction band.
  - (D) They donate electrons to the filled valence band from donor levels just above the valence band.
  - (E) They donate electrons to the conduction band from filled donor levels just below the conduction band.
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95. Which of the following curves is characteristic of the specific heat  $C_v$  of a metal such as lead, tin, or aluminum in the temperature region where it becomes superconducting?



96. Which of the following reasons explains why a photon cannot decay to an electron and a positron ( $\gamma \rightarrow e^+ + e^-$ ) in free space?
- (A) Linear momentum and energy are not both conserved.
  - (B) Linear momentum and angular momentum are not both conserved.
  - (C) Angular momentum and parity are not both conserved.
  - (D) Parity and strangeness are not both conserved.
  - (E) Charge and lepton number are not both conserved.
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