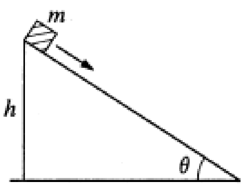
Practice Test 1

Problem 1:



A block of mass m sliding down an incline at constant speed is initially at a height h above the ground, as shown in the figure above. The coefficient of kinetic friction between the mass and the incline is μ. If the mass continues to slide down the incline at a constant speed, how much energy is dissipated by friction by the time the mass reaches the bottom of the incline?

(A) mgh/μ
(B) mgh
(C) $\mu mgh/\sin\theta$
(D) $mgh\sin\theta$
(E) 0

Problem 2:

The approximate number of photons in a femtosecond (10^{-15}s) pulse of 600 nanometers wavelength light from a 10-kilowatt peak-power dye laser is

(A) 10^3
(B) 10^7
(C) 10^{11}
(D) 10^{15}
(E) 10^{18}

Problem 3:

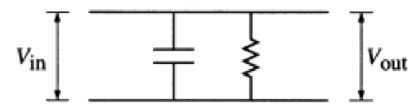
A $3p$ electron is found in the $3P_{3/2}$ energy level of a hydrogen atom. Which of the following is true about the electron in this state?

(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 $\ell = 3$, $j = 3/2$, $s = 1/2$.
(D) It has quantum numbers $n = 3$, $j = \ell$, $s = 3/2$.
(E) It has exactly the same energy as it would in the $3D_{3/2}$ level.

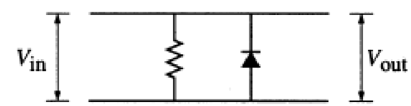
Problem 4:

The circuits below consist of two-element combinations of capacitors, diodes, and resistors. V_{in} represents an ac-voltage with variable frequency. It is desired to build a circuit for which $V_{out} \approx V_{in}$ at high frequencies and $V_{out} \approx 0$ at low frequencies. Which of the following circuits will perform this task?

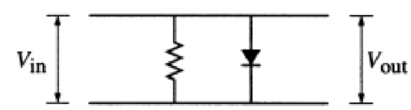
(A)



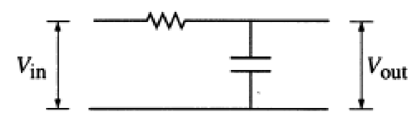
(B)



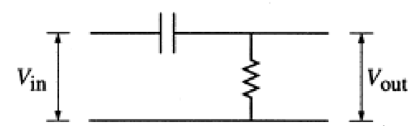
(C)



(D)



(E)



Problem 5:

The magnetic field inside a solenoid of length L with 100 turns of wire carrying a current I has magnitude B. If the number of turns of wire is doubled while L and I remain constant, the magnitude of the field will be:

(A) ½B
(B) $2^{1/2}$B
(C) 2B
(D) 4B
(E) B

Problem 6:

Which of the following equations is a consequence of the equation $\nabla \times \mathbf{H} = \dot{\mathbf{D}} + \mathbf{J}$?

(A) $\nabla \cdot (\dot{\mathbf{D}} + \mathbf{J}) = 0$

(B) $\nabla \times (\dot{\mathbf{D}} + \mathbf{J}) = 0$

(C) $\nabla (\dot{\mathbf{D}} \cdot \mathbf{J}) = 0$

(D) $\dot{\mathbf{D}} + \mathbf{J} = 0$

(E) $\dot{\mathbf{D}} \cdot \mathbf{J} = 0$

Problem 7:

A blackbody at temperature T_1 radiates energy at a power level of 10 milliwatts (mW). The same blackbody, when at a temperature $2T_1$, radiates energy at a power level of

(A) 10 mW (B) 20 mW (C) 40 mW
(D) 80 mW (E) 160 mW

Problem 8:

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) 2×10^{-2} m/s
(B) 2 m/s
(C) 2×10^{2} m/s
(D) 2×10^{4} m/s
(E) 2×10^{6} m/s

Problem 9:

An atom moving at speed $0.3c$ emits an electron along the same direction with speed $0.6c$ in the internal rest frame of the atom. The speed of the electron in the lab frame is equal to

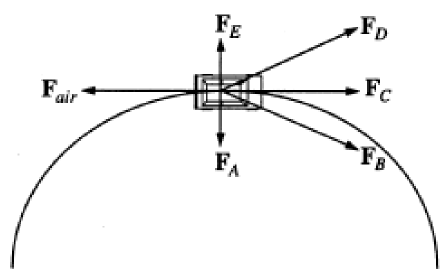
(A) $0.25c$
(B) $0.51c$
(C) $0.66c$
(D) $0.76c$
(E) $0.90c$

Problem 10:

The emission spectrum of an atomic gas in a magnetic field differs from that of the gas in the absence of a magnetic field. Which of the following is true of the phenomenon?

(A) It is called the Stern-Gerlach effect.
(B) It is called the Stark effect.
(C) It is due primarily to the nuclear magnetic moment of the atoms.
(D) The number of emission lines observed for the gas in a magnetic field is always twice the number observed in the absence of a magnetic field.
(E) The number of emission lines observed for the gas in a magnetic field is either greater than or equal to the number observed in the absence of a magnetic field.

Problem 11:



A car travels with constant speed on a circular road on level ground. In the diagram above, $\mathbf{F}_{air}$ is the force of air resistance on the car. Which of the other forces shown best represents the horizontal force of the road on the car's tires?

(A) $\mathbf{F}_A$
(B) $\mathbf{F}_B$
(C) $\mathbf{F}_C$
(D) $\mathbf{F}_D$
(E) $\mathbf{F}_E$

Problem 12:

The positronium "atom" consists of an electron and a positron bound together by their mutual Coulomb attraction and moving about their center of mass, which is located halfway between them. Thus the positronium "atom" is somewhat analogous to a hydrogen atom. The ground-state binding energy of hydrogen is 13.6 electron volts. What is the ground-state binding energy of positronium?

(A) $\left(\frac{1}{2}\right)^2 \times 13.6$ eV

(B) $\frac{1}{2} \times 13.6$ eV

(C) 13.6 eV

(D) 2×13.6 eV

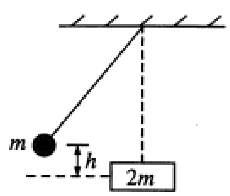
(E) $(2)^2 \times 13.6$ eV

Problem 13:

Equal charges of value -Q each are arranged at the eight vertices of a non-conducting skeleton cube of side 'a'. If a point charge +Q is placed at the center of the cube, the electrostatic force exerted by the eight negative charges on the positive charge at the centre is

(A) $Q^2/3\pi\varepsilon_0 a^2$
(B) $4Q^2/3\pi\varepsilon_0 a^2$
(C) $8Q^2/3\pi\varepsilon_0 a^2$
(D) $16Q^2/3\pi\varepsilon_0 a^2$
(E) zero

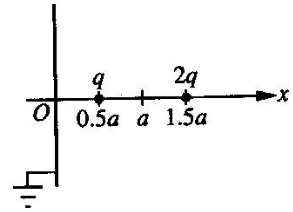
Problem 14:



As shown above, a ball of mass m, suspended on the end of a wire, is released from height h and collides elastically, when it is at its lowest point, with a block of mass $2m$ at rest on a frictionless surface. After the collision, the ball rises to a final height equal to

(A) 1/9 h
(B) 1/8 h
(C) 1/3 h
(D) 1/2 h
(E) 2/3 h

Problem 15:



Two positive charges of q and $2q$ coulombs are located on the x-axis at $x = 0.5a$ and $1.5a$, respectively, as shown above. There is an infinite, grounded conducting plane at $x = 0$. What is the magnitude of the net force on the charge q?

(A) $\frac{1}{4\pi\epsilon_0}\frac{q^2}{a^2}$

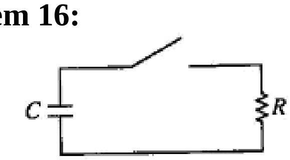
(B) $\frac{1}{4\pi\epsilon_0}\frac{3q^2}{2a^2}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{2q^2}{a^2}$

(D) $\frac{1}{4\pi\epsilon_0}\frac{3q^2}{a^2}$

(E) $\frac{1}{4\pi\epsilon_0}\frac{7q^2}{2a^2}$

Problem 16:



The capacitor in the circuit shown above is initially charged. After closing the switch, how much time elapses until one-half of the capacitor's initial stored energy is dissipated?

(A) RC

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

(C) $\frac{RC}{4}$

(D) $2RC\ln(2)$

(E) $\frac{RC\ln(2)}{2}$

Problem 17:

A diatomic molecule is initially in the state $\Psi(\Theta, \Phi) = (5Y_1^{1} + 3Y_5^{1} + 2Y_5^{-1})/(38)^{1/2}$, where Y_ℓ^m is a spherical harmonic. If measurements are made of the total angular momentum quantum number ℓ and of the azimuthal angular momentum quantum number m, what is the probability of obtaining the result $\ell = 5$?

(A) 36/1444
(B) 9/38
(C) 13/38
(D) $5/(38)^{1/2}$
(E) 34/38

Problem 18:

A lump of clay whose rest mass is 4 kilograms is traveling at three-fifths the speed of light when it collides head-on with an identical lump going the opposite direction at the same speed. If the two lumps stick together and no energy is radiated away, what is the mass of the composite lump?

(A) 4 kg
(B) 6.4 kg
(C) 8 kg
(D) 10 kg
(E) 13.3 kg

Problem 19:
In a hydrogen atom the electron is making 6.6×10^{15} revolutions per second around the nucleus in an orbit of radius 0.528 Å. The equivalent magnetic dipole moment is approximately (in Am^2)
(A) 10^{-10}
(B) 10^{-15}
(C) 10^{-23}
(D) 10^{-25}
(E) 10^{-17}

Problem 20:

Light from a laser falls on a pair of very narrow slits separated by 0.5 micrometer, and bright fringes separated by 1.0 millimeter are observed on a distant screen. If the frequency of the laser light is doubled, what will be the separation of the bright fringes?

(A) 0.25 mm
(B) 0.5 mm
(C) 1.0 mm
(D) 2.0 mm
(E) 2.5 mm

Problem 21:

A particle moves in a force field given by $\mathbf{F} = r^2\,\mathbf{r}$, where $\mathbf{r}$ is the position vector. If there are no other forces, quantities that remain constant include which of the following?

I. Total energy
II. Torque about the origin
III. Angular momentum about the origin

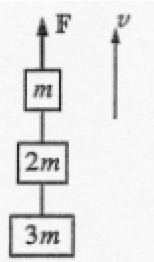
(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

Problem 22:

A 100-watt electric heating element is placed in a pan containing one liter of water. Although the heating element is on for a long time, the water, though close to boiling, does not boil. When the heating element is removed, approximately how long will it take the water to cool by 1° C ? (Assume that the specific heat for water is 4.2 kilojoules/kilogram °C.)

(A) 20 s
(B) 40 s
(C) 60 s
(D) 130 s
(E) 200 s

Problem 23:

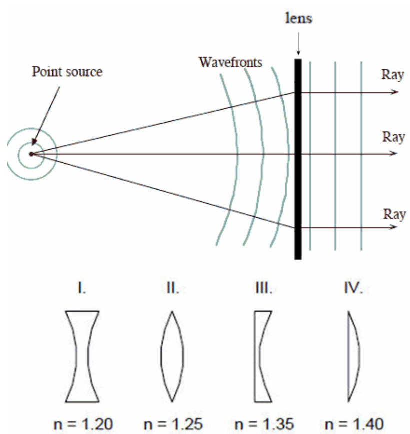


Three blocks with masses of *m*, 2*m*, and 3*m* are connected by strings, as shown in the figure above. After an upward force **F** is applied on block *m*, the masses move upward at constant speed *v*. What is the net force on the block of mass 2*m*?

(A) zero (B) 2mg (C) 3mg
(D) 6mg (E) mg

Problem 24:

A diverging beam of light is emitted by a point source in water with index of refraction n = 1.3. The beam propagates in water. To render it parallel, which of the following lenses could be used in water?



(A) I only (B) I or II (C) I or IV
(D) II or III (E) II or IV

Problem 25:

Which of the following best describes the principle of magnetic resonance imaging (MRI) used in medical research?

(A) mapping the magnetic field generated by electron transitions in molecules
(B) measuring the energy absorbed as nuclear magnetic moments flip between spin states
(C) using a magnetic field to focus the paths of emissions from a radioisotope
(D) producing high-energy electromagnetic waves using superconducting magnets
(E) using magnetic lenses in electron microscopes to produce images