

Thermo, Optics, and Experimental – Problem Set # 2

TABLE OF INFORMATION

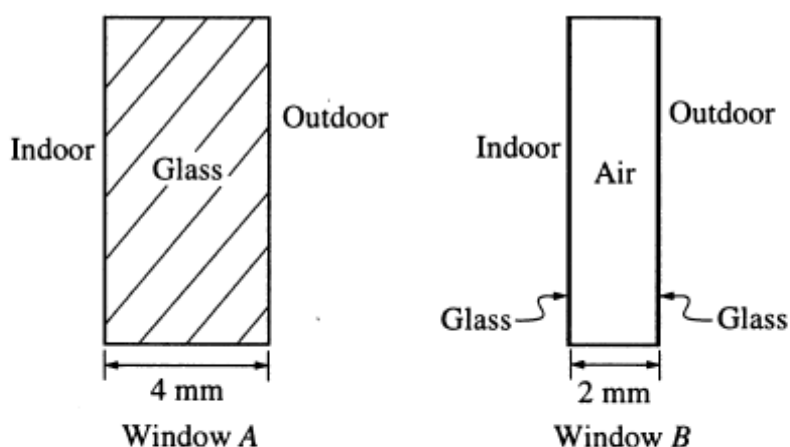
Rest mass of the electron	$m_e = 9.11 \times 10^{-31}$ kilogram = 9.11×10^{-28} gram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb = 4.80×10^{-10} statcoulomb (esu)
Avogadro's number	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.31$ joules/(mole · K)
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ joule/K = 1.38×10^{-16} erg/K
Speed of light	$c = 3.00 \times 10^8$ m/s = 3.00×10^{10} cm/s
Planck's constant	$h = 6.63 \times 10^{-34}$ joule · second = 4.14×10^{-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 = 1.0×10^5 newton/meter ² = 1.0×10^5 pascals (Pa)
1 angstrom	1 Å = 1×10^{-10} meter
	1 weber/m ² = 1 tesla = 10^4 gauss

Moments of inertia about center of mass

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

74. A body of mass m with specific heat C at temperature 500 K is brought into contact with an identical body at temperature 100 K, and the two are isolated from their surroundings. The change in entropy of the system is equal to

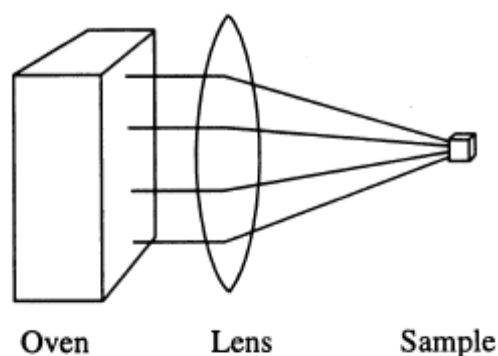
- (A) $(4/3)mC$
- (B) $mC\ln(9/5)$
- (C) $mC\ln(3)$
- (D) $-mC\ln(5/3)$
- (E) 0



75. Window A is a pane of glass 4 millimeters thick, as shown above. Window B is a sandwich consisting of two extremely thin layers of glass separated by an air gap 2 millimeters thick, as shown above. If the thermal conductivities of glass and air are 0.8 watt/meter $^{\circ}\text{C}$ and 0.025 watt/meter $^{\circ}\text{C}$, respectively, then the ratio of the heat flow through window A to the heat flow through window B is

- (A) 2
- (B) 4
- (C) 8
- (D) 16
- (E) 32

79. For an ideal diatomic gas in thermal equilibrium, the ratio of the molar heat capacity at constant volume at very high temperatures to that at very low temperatures is equal to
- (A) 1
 - (B) $5/3$
 - (C) 2
 - (D) $7/3$
 - (E) 3
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91. An experimenter needs to heat a small sample to 900 K, but the only available oven has a maximum temperature of 600 K. Could the experimenter heat the sample to 900 K by using a large lens to concentrate the radiation from the oven onto the sample, as shown above?
- (A) Yes, if the volume of the oven is at least $3/2$ the volume of the sample.
 - (B) Yes, if the area of the front of the oven is at least $3/2$ the area of the front of the sample.
 - (C) Yes, if the sample is placed at the focal point of the lens.
 - (D) No, because it would violate conservation of energy.
 - (E) No, because it would violate the second law of thermodynamics.
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94. A system consists of N weakly interacting subsystems, each with two internal quantum states with energies 0 and ϵ . The internal energy for this system at absolute temperature T is equal to

(A) $N\epsilon$

(B) $\frac{3}{2}NkT$

(C) $N\epsilon e^{-\epsilon/kT}$

(D) $\frac{N\epsilon}{(e^{\epsilon/kT} + 1)}$

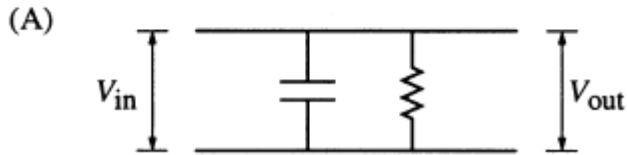
(E) $\frac{N\epsilon}{(1 + e^{-\epsilon/kT})}$

58. A collimated laser beam emerging from a commercial HeNe laser has a diameter of about 1 millimeter. In order to convert this beam into a well-collimated beam of diameter 10 millimeters, two convex lenses are to be used. The first lens is of focal length 1.5 centimeters and is to be mounted at the output of the laser. What is the focal length, f , of the second lens and how far from the first lens should it be placed?

	<u>f</u>	<u>Distance</u>
(A)	4.5 cm	6.0 cm
(B)	10 cm	10 cm
(C)	10 cm	11.5 cm
(D)	15 cm	15 cm
(E)	15 cm	16.5 cm

59. The approximate number of photons in a femto-second (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}
60. The Lyman alpha spectral line of hydrogen ($\lambda = 122$ nanometers) differs by 1.8×10^{-12} meter in spectra taken at opposite ends of the Sun's equator. What is the speed of a particle on the equator due to the Sun's rotation, in kilometers per second?
- (A) 0.22
 - (B) 2.2
 - (C) 22
 - (D) 220
 - (E) 2200
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82. Consider two horizontal glass plates with a thin film of air between them. For what values of the thickness of the film of air will the film, as seen by reflected light, appear bright if it is illuminated normally from above by blue light of wavelength 488 nanometers?
- (A) 0, 122 nm, 244 nm
 - (B) 0, 122 nm, 366 nm
 - (C) 0, 244 nm, 488 nm
 - (D) 122 nm, 244 nm, 366 nm
 - (E) 122 nm, 366 nm, 610 nm
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45. 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?



72. In a voltage amplifier, which of the following is NOT usually a result of introducing negative feedback?
- (A) Increased amplification
 - (B) Increased bandwidth
 - (C) Increased stability
 - (D) Decreased distortion
 - (E) Decreased voltage gain
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