General Physics I Exam 5 - Chs. 13,14,15 - Heat, Kinetic Theory, Thermodynamics Dec. 14, 2010

Name Rec. Instr. Rec. Time

For full credit, make your work clear to the grader. Show formulas used, essential steps, and results with correct units and significant figures. Partial credit is available if your work is clear. Points shown in parenthesis. For TF and MC, choose the *best* answer.

1. (6) Air in a container has a temperature of 63.0 °F. Calculate its temperature in degrees Celsius and in Kelvin.

2. (2) Which of these is the highest temperature?
   a. 46.0 °F. b. 15.0 °C. c. 278 K.

3. (2) At which of these temperatures does 1.0 kg of liquid water have the smallest volume?
   a. 0 °C. b. 4 °C. c. 8 °C. d. 25 °C.

4. (2) At 1.00 atm pressure and 0 °C, 1.00 mole of any ideal gas occupies a volume of
   a. 1.00 m^3. b. 1.00 L. c. 22.4 m^3. d. 22.4 L.

5. (2) In solid copper, atomic theory shows that the typical distance between neighboring atoms is closest to
   a. 0.2 mm b. 0.2 μm c. 0.2 nm d. 0.2 pm

6. (2) Of these elements, which has the least number of atoms in a kilogram?
   a. hydrogen (H) b. oxygen (O) c. iron (Fe) d. gold (Au) e. all tie.

7. (2) Of these elements, which has the greatest number of atoms in a mole?
   a. hydrogen (H) b. oxygen (O) c. iron (Fe) d. gold (Au) e. all tie.

8. (2) Under standard conditions air acts like an ideal gas, $PV = nRT$. If some air is held at constant pressure, while the temperature increases, its volume
   a. increases. b. decreases. c. does not change.

9. (2) The following compounds all behave as ideal gases under normal room conditions. Which gas, as a pure sample under normal conditions (1 atm, 22 °C), has the highest density?
   a. oxygen (O_2) b. carbon-dioxide (CO_2) c. helium (He) d. methane (CH_4) e. all the same density.

10. (8) A 2.0-liter bottle of fixed volume contains pressurized helium, initially at at temperature of 3.00×10^2 K and a pressure of 1.00 atm.

a) (2) If the temperature is doubled, by what factor does the pressure change?
   a. 1/2 b. $1/\sqrt{2}$ c. 1.00 d. $\sqrt{2}$ e. 2 f. 4

b) (2) If the temperature is doubled, by what factor does the rms molecular speed change?
   a. 1/2 b. $1/\sqrt{2}$ c. 1.00 d. $\sqrt{2}$ e. 2 f. 4

c) (2) If the helium atoms are replaced by an equal number of O_2 molecules (keeping the same temperature), by what factor does the pressure change?
   a. 1/8 b. $1/\sqrt{8}$ c. 1.00 d. $\sqrt{8}$ e. 8

d) (2) If the helium gas is replaced by an equal mass of O_2 gas (keeping the same temperature), by what factor does the pressure change?
   a. 1/8 b. $1/\sqrt{8}$ c. 1.00 d. $\sqrt{8}$ e. 8

11. (2) **T F** Different gases in a gas mixture have the same average translational kinetic energy per molecule.

12. (2) **T F** In a mixture of ideal gases, the heavier molecules move faster, on average.

13. (2) **T F** A gas behaves as "ideal" when at high density, where the molecules are close together.

14. (8) Air contains a mixture of many molecules, including oxygen, carbon-dioxide, methane, and water vapor.

a) (2) In normal air at 295 K, which of these listed molecules has the highest rms speed?

a. O_2 b. CO_2 c. H_2O d. CH_4 e. all have the same rms speeds.

b) (6) Find the numerical value of the rms speed at 295 K for the slowest of the molecules listed.

---

15. (12) A 5.00-liter capacity metal gas cylinder is filled with compressed propane (C_3H_8) and has a pressure of 125 atm at a temperature of 65.0 °C when initially filled.

a) (4) How many moles of propane are in the cylinder?

b) (4) Calculate the mass of propane inside the cylinder.

c) (4) After some time, the cylinder and its contents cools to 25.0 °C. What is the pressure in the tank after it has cooled off?

---

16. (2) **T F** Just like any liquid, water always expands when it is heated.

17. (2) **T F** The internal energy of an ideal gas is due to potential energy between the molecules.

18. (2) **T F** The internal energy of an ideal gas is proportional to its absolute temperature.

19. (2) **T F** When 1 kg of water absorbs 1 kJ of heat, its temperature increases more than a 1 kg aluminum sample that absorbs 1 kJ of heat.

---

20. (6) A 1600-kg car moving at 130 km/h suddenly brakes to a stop. How much heat in kilocalories, at most, could be generated in its brakes?

21. (10) A 5.0-kg block of ice initially at -22.0 °C is to be converted completely to water vapor at +100.0 °C by adding heat to it.

a) (5) What amount of heat (in kJ) is needed to convert the ice at -22.0 °C to water at 0.00 °C?

b) (5) What additional amount of heat (in kJ) is needed to convert the water at 0.00 °C to vapor at 100.0 °C?

---

22. (14) A 0.55 mole sample of a monatomic ideal gas expands adiabatically, causing its temperature to change from 420 K to 280 K.

a) (2) Which applies to an adiabatic process? a. $Q = 0$. b. $W = 0$. c. $\Delta U = 0$. d. $\Delta P = 0$.

b) (4) How large is the heat added to or removed from the gas in this process.

c) (4) Calculate the change in internal energy of the gas in this process.

d) (4) Calculate the work done by the gas in this process.

---

23. (6) A 54-kg marathoner runs a 26-mile race, utilizing food energy at a rate of 120 kcal/mile. If the generated heat is dissipated soley by evaporation of perspiration, how much mass (of water) would she lose during the race? (Suppose she does not drink water to replenish that lost.)

24. (2) **T** **F** In an isothermal expansion, the temperature of a gas goes down.

25. (2) **T** **F** In an adiabatic compression, the temperature of a gas increases.

26. (2) **T** **F** There is no work done by a gas that absorbs heat at constant volume.

---

27. (6) In some process, a gas expands but does not change its temperature.

a) (2) The work done by the gas is a. negative. b. zero. c. positive.

b) (2) The heat added to the gas is a. negative. b. zero. c. positive.

c) (2) The change of internal energy of the gas is a. negative. b. zero. c. positive.

---

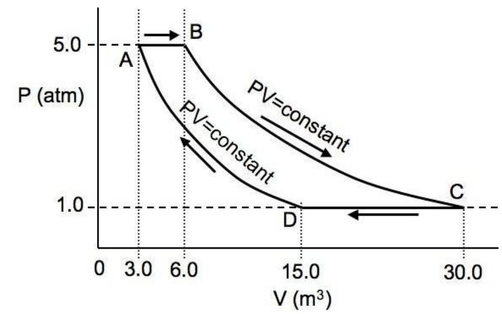
28. (10) The PV diagram below shows what happens to 6.00×10^{-3} mol of ideal gas. Processes BC and DA take place at constant PV = pressure × volume.

a) (2) Which process is isothermal expansion? a. AB b. BC c. CD d. DA e. not present.

b) (2) Which process is adiabatic compression? a. AB b. BC c. CD d. DA e. not present.

c) (2) Which process is isobaric compression? a. AB b. BC c. CD d. DA e. not present.

d) (4) Calculate the work done by the gas in process AB.

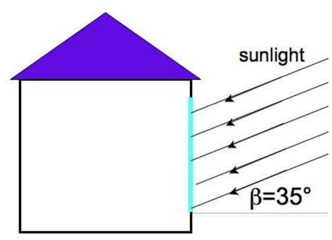


---

29. (6) A hot surface of emissivity $e = 0.50$ and temperature 310 K is losing heat by emitting blackbody radiation into its very cold surroundings. At what rate in J/s (or watts) is heat radiated from an area of 30.0 cm × 30.0 cm?

---

30. (6) One day the radiation from the Sun arrives at Earth's surface with an intensity of 800 W/m^2. The Sun is 35° above the horizon and shines through a house window 2.5 m high by 4.0 m wide. At what maximum rate in kW can solar energy enter the house through this window?



Score = ___________/134.

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$c = 299792458$ m/s (speed of light)
$u = 1.6605 \times 10^{-27}$ kg (atomic mass unit)
$R = 8.314$ J/mol·K (gas constant)

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (Gravitational constant)
$R_E = 6380$ km (mean radius of Earth)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4 (Stefan-Boltzmann constant)
$N_A = 6.022 \times 10^{23}$/mol (Avogadro's number)
$k = 1.38 \times 10^{-23}$ J/K (Boltzmann's constant)

Units and Conversions

1 inch = 1 in = 2.54 cm (exactly)
1 mile = 5280 ft
1 m/s = 3.6 km/hour
1 acre = 43560 ft^2 = (1 mile)^2/640

1 foot = 1 ft = 12 in = 30.48 cm (exactly)
1 mile = 1609.344 m = 1.609344 km
1 ft/s = 0.6818 mile/hour
1 hectare = 10^4 m^2

Some Elemental Properties

symbol	element	atomic number	mass number
H	hydrogen	1	1.00794
He	helium	2	4.00260
C	carbon	6	12.0107
N	nitrogen	7	14.0067
O	oxygen	8	15.9994
Ne	neon	10	20.180
Ar	argon	18	39.948
Fe	iron	26	55.845
Ni	nickel	28	58.693
Cu	copper	29	63.546
Au	gold	79	196.97
U	uranium	92	238.03

Mass numbers are atomic masses in units of "u" where 1 u = 1.6605×10^{-27} kg, or, molar masses for the element (1 mole = 6.02×10^{23} atoms), measured in grams. ($N_A \times 1$ u = 1 gram)

Trig summary

$\sin\theta = \frac{(\text{opp})}{(\text{hyp})}$, $\cos\theta = \frac{(\text{adj})}{(\text{hyp})}$, $\tan\theta = \frac{(\text{opp})}{(\text{adj})}$, $(\text{opp})^2 + (\text{adj})^2 = (\text{hyp})^2$.

$\sin\theta = \sin(180^\circ - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180^\circ + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

Vectors

Written $\vec{V}$ or $\mathbf{V}$, described by magnitude=V, direction=θ or by components (V_x, V_y).

$V_x = V\cos\theta$, $V_y = V\sin\theta$,

$V = \sqrt{V_x^2 + V_y^2}$, $\tan\theta = \frac{V_y}{V_x}$. θ is the angle from $\vec{V}$ to x-axis.

Addition: $\mathbf{A} + \mathbf{B}$, head to tail. Subtraction: $\mathbf{A} - \mathbf{B}$ is $\mathbf{A} + (-\mathbf{B})$, $-\mathbf{B}$ is $\mathbf{B}$ reversed.

Energy, Force, Power

Work & Kinetic & Potential Energies:

$W = Fd\cos\theta$, $\text{KE} = \frac{1}{2}mv^2$, $\text{PE}_{\text{gravity}} = mgy$, $\text{PE}_{\text{spring}} = \frac{1}{2}kx^2$. θ = angle btwn $\vec{F}$ and $\vec{d}$.

Conservation or Transformation of Energy:

Work-KE theorem:

$\Delta\text{KE} = W_{\text{net}}$ = work of all forces.

General energy-conservation law:

$\Delta\text{KE} + \Delta\text{PE} = W_{\text{NC}}$ = work of non-conservative forces.

Power:

$P_{\text{ave}} = \frac{W}{t}$, or use $P_{\text{ave}} = \frac{\text{energy}}{\text{time}}$.

Fluids

Density:

$\rho = m/V$, SG=$\rho/\rho_{\mathrm{H_2O}}$, $\rho_{\mathrm{H_2O}} = 1000$ kg/m^3 = 1.00 g/cm^3 (at 4°C).

Static Fluids:

$P = F/A$, $P_2 = P_1 + \rho g h$, $\Delta P = \rho g h$, $P = P_{\mathrm{atm.}} + P_G$, $B = \rho g V$ or $F_B = \rho g V$.

Pressure Units:

1 Pa = 1 N/m^2, 1 bar = 10^5 Pa = 100 kPa, 1 mm-Hg = 133.3 Pa.

1.00 atm = 101.3 kPa = 1.013 bar = 760 torr = 760 mm-Hg =14.7 lb/in^2.

Moving Fluids:

$A_1 v_1 = A_2 v_2$ = a constant, $P + \frac{1}{2}\rho v^2 + \rho g y$ = a constant.

Chapter 13 Equations

Atomic Theory & Moles:

$n = \frac{N}{N_A}$, $n = \frac{m}{M_A}$, $N_A = 6.022 \times 10^{23}$/mol, 1 u = $\frac{1 \text{ gram}}{N_A} = 1.6605 \times 10^{-27}$ kg.

Temperature scales:

T(°C) = $\frac{5}{9}$[T(°F)-32], T(°F)=$\frac{9}{5}$ T(°C)+32, T(K)=T(°C)+273.15

Thermal Expansion:

$\Delta L = \alpha L_0 \Delta T$, $\Delta V = \beta V_0 \Delta T$.

Ideal Gas Law:

$PV = nRT$, or $PV = NkT$, $R = 8.314$ J/mol·K, $k = \frac{R}{N_A} = 1.38 \times 10^{-23}$ J/K.

Kinetic Theory:

$\overline{\mathrm{KE}} = \frac{1}{2} m v_{\mathrm{rms}}^2 = \frac{3}{2} kT$, $v_{\mathrm{rms}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M_A}}$, $m = M_A/N_A$.

Chapter 14 Equations

Internal Energy:

$U = \frac{3}{2} NkT = \frac{3}{2} nRT$, for ideal monatomic gases.

Mechanical Equivalent of Heat, Specific Heat, Latent Heat:

1 cal = 4.186 J, $Q = mc\Delta T$, $Q = mL_F$, $Q = mL_V$.

For water, $c = 1.00$ cal/g·C° = 4.186 kJ/kg ·C°, $c_{\mathrm{ice}} = 0.50$ cal/g·C° = 2.1 kJ/kg ·C°.

$L_F = 79.7$ kcal/kg = 333 kJ/kg, $L_V = 539$ kcal/kg = 2260 kJ/kg.

Heat Transfer:

Conduction: $P = \frac{Q}{t} = kA\frac{\Delta T}{l}$.

Radiation: $P = \frac{\Delta Q}{\Delta t} = e\sigma A T^4$, $P = \frac{\Delta Q}{\Delta t} = e\sigma A(T_1^4 - T_2^4)$, $\sigma = 5.67 \times 10^{-8}$ W/m^2· K^4.

Solar Energy: $P = \frac{\Delta Q}{\Delta t} \approx (1000 \text{ W/m}^2)\, eA\cos\theta$

Chapter 15 Equations

First Law of Thermodynamics (U = internal energy):

$\Delta U = Q - W$ or $\Delta KE + \Delta PE + \Delta U = Q - W$

work = W = area under $P(V)$ curve. $W = P\Delta V$ for isobaric processes.

heat = Q = heat absorbed by the system. $Q = 0$ for adiabatic processes.

Heat Engines:

$W = Q_H - Q_L$, efficiency $e = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$, $\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$ for ideal Carnot cycle.

Cooling Machines, Heat Pumps:

$W = Q_H - Q_L$, refrigerators: COP = $\frac{Q_L}{W}$, heat pumps: COP = $\frac{Q_H}{W}$, $\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$ for ideal Carnot.

Power:

$P_{\mathrm{ave}} = \frac{W}{t}$, or use $P_{\mathrm{ave}} = \frac{\text{energy}}{\text{time}}$.