General Physics I Exam 5 - Chs. 13,14,15 - Heat, Kinetic Theory, Thermodynamics Dec. 11, 2012

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) Typical room temperature is 23.0 °C. What is this in Kelvin and in degrees Fahrenheit?

2. (2) Water initially at 4.0°C will expand if the temperature is changed to

a. 6.0°C. b. 2.0°C. c. both a and b. d. neither a nor b.

3. (2) A mole of a substance is defined as the quantity that contains

a. a volume of 1.00 m^3. b. a volume of 1.00 L. c. a mass of 1.00 kg. d. 6.02×10^{23} particles.

4. (2) Of these elements, which has the greatest number of atoms in a 1.00 gram sample?

a. hydrogen (H) b. carbon (C) c. nickel (Ni) d. copper (Cu) e. all tie.

5. (2) Of these elements, which has the least number of atoms in a mole?

a. hydrogen (H) b. carbon (C) c. nickel (Ni) d. copper (Cu) e. all tie.

6. (2) Under typical conditions air acts like an ideal gas, with $PV = nRT$. If some air is held at constant volume, while the temperature increases, its pressure

a. increases. b. decreases. c. does not change.

7. (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 lowest density?

a. oxygen (O_2) b. carbon dioxide (CO_2) c. propane (C_3H_8) d. nitrous oxide (N_2O) e. all tie.

8. (2) Which gas, as a pure sample under normal conditions (1 atm, 22 °C), has the most molecules per cm^3?

a. oxygen (O_2) b. carbon dioxide (CO_2) c. propane (C_3H_8) d. nitrous oxide (N_2O) e. all tie.

9. (12) A bottle has a fixed 5.00 L volume. It is filled with oxygen gas, initially at at temperature of 295 K and a pressure of 250.0 atm.

a) (6) What mass of oxygen gas is inside the bottle?

b) (6) Suppose the oxygen is replaced by an **equal mass** of helium. If the temperature is still 295 K, what is the pressure in the bottle?

10. (3) Normal body temperature is said to be 98.6 °F. What is that in degrees Celsius?

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11. (2) **T F** The average internal translational KE of ideal gas molecules is proportional to their mass.

12. (2) **T F** The lightest molecules in a mixture of ideal gases have the greatest rms speeds.

13. (2) **T F** Doubling the absolute temperature of an ideal gas will double the rms speed.

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14. (8) Consider helium gas atoms at a typical room temperature of 22°C and 1.00 atm pressure.

(a) (4) Calculate the rms speed of the helium atoms.

(b) (4) Calculate the average translational kinetic energy in a mole of helium atoms for these conditions.

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

16. (2) **T F** A liter of water at 0°C weighs more than a liter of water at 4°C.

17. (2) **T F** A liter of ice at 0°C weighs less than a liter of water at 4°C.

18. (2) **T F** The internal energy of an ideal gas increases with the pressure.

19. (2) **T F** Compared to water, a metal like copper heats up easily because of its large specific heat.

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20. (8) Consider a 1.00 mole sample of (diatomic) hydrogen gas. Use the ideal gas law to determine its density in kg/m^3 at 295 K.

21. (12) A 50-gram lead bullet moving at 450 m/s is brought to rest when shot into a block of wood. Assume that 85% of the bullet's kinetic energy goes to heating the bullet. The specific heat of lead is 130 kJ/kg°C.

a) (6) What quantity of kinetic energy (in kJ) goes into heating the bullet?

b) (6) What temperature change in degrees Celsius does the bullet experience?

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22. (14) Consider 4.0 kg of water initially at 0.0°C.

a) (2) **T F** The water must lose heat in order to freeze.

b) (6) What amount of heat (in kJ) must be transferred to or from the water to convert it into ice at 0.0°C?

c) (6) What amount of heat must be transferred to or from the water to bring it up to a temperature of 100.0°C?

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23. (6) Solar radiation of intensity of 860 W/m^2 strikes a horizontal 3.0 m $\times$ 4.0 m ice sheet. The Sun is 25° above the horizon. If the emissivity of the ice is 0.050, at what rate in kilowatts does it absorb solar energy?

24. (2) The first law of thermodynamics is based on the physical law of conservation of

a. work. b. matter. c. energy. d. momentum.

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

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

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

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28. (14) A 2.40 mole sample of a monatomic ideal gas expands isothermally at 298 K, doing 4200 J of work.

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

b) (4) How large is the temperature change of the gas in this process.

c) (4) How large is the change in internal energy of the gas in this process.

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

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29. (6) In some process, a gas is compressed without absorbing or losing any heat.

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

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

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

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30. (8) The pressure in 5.0 moles of ideal gas is cut in half slowly, while being kept in a container with rigid walls. In the process, 170 kJ of heat leaves the gas.

a) (4) How much work was done during this process?

b) (4) What was the change in internal energy of the gas during this process?

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

$\sin\theta = \frac{\text{(opp)}}{\text{(hyp)}}$, $\cos\theta = \frac{\text{(adj)}}{\text{(hyp)}}$, $\tan\theta = \frac{\text{(opp)}}{\text{(adj)}}$, $\text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2$.
$\sin\theta = \sin(180° - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180° + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

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$=\rho/\rho_{H_2O}$, $\rho_{H_2O} = 1000$ kg/m^3 = 1.00 g/cm^3 (at 4°C).
Static Fluids:
$P = F/A$, $P_2 = P_1 + \rho g h$, $\Delta P = \rho g h$, $P = P_{atm.} + P_G$, $B = \rho g V$ 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:
$\overline{\text{KE}} = \frac{1}{2} m v_{\text{rms}}^2 = \frac{3}{2} kT$, $v_{\text{rms}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M_A}}$, $m = M_A/N_A$.

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°, $c_{\text{ice}} = 0.50$ 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:
$P_{\text{ave}} = \frac{W}{t}$, or use $P_{\text{ave}} = \frac{\text{energy}}{\text{time}}$.