Name= **Studio Day/Time=**

Eng. Phys. I **Exam 5 - Chs. 14, 1,2 - Fluids, Heat, Kinetic Theory, Ideal Gases** **Dec. 3, 2021**

Write **neat** & **clear** work. Show **formulas** used, essential steps, results with correct **units** and **significant figures**. Points shown in parenthesis. For TF and MC, choose the *best* answer. Use $g = 9.80$ m/s^2.

1. (2) The concept that any change in pressure applied to an enclosed fluid is transmitted undiminished to all portions of the fluid is known as

a. Archimedes' principle. b. Bernoulli's law. c. Poiseuille's law. d. Pascal's principle.

2. (2) **T** **F** At increasing elevation above ground level, the pressure in the air increases.

3. (2) **T** **F** At the bottom of a filled swimming pool, the absolute pressure is greater than the gauge pressure.

4. (2) **T** **F** For equal-mass samples of wood and tungsten, the tungsten will have the smaller volume.

5. (12) Joe is 1.90 m tall. The density of blood is 1.05 g/cm^3 $= 1.05 \times 10^3$ kg/m^3.

a) (6) Estimate the difference in blood pressure (on average) between the bottom of his feet and the top of his head, in units of mm-Hg.

b) (6) A femoral artery in Joe's leg has a diameter of 8.0 mm and the average flow rate through it is 290 mL/minute. On average, how fast is the blood flowing through it?

6. (24) Alicia is scuba diving in the ocean at a depth where the absolute pressure is 4.37 atm, the water temperature is a uniform 25°C and the density of the salt water is 1.027 kg/L.

a) (6) If the area of her face mask is 125 cm^2, how large is the pressure force acting on its outer surface?

b) (6) How deep below the surface is Alicia diving?

c) (6) A bubble of oxygen gas (O_2) escapes from her regulator with a volume of 2.85 mL. What mass of oxygen is in the bubble? Oxygen atoms have atomic number 8 and mass number 16.

d) (6) The O_2 bubble rises to the surface without losing any mass. By what factor does its volume increase?

7. (2) **T** **F** The buoyant force on a sunken ship is zero.

8. (2) **T** **F** The buoyant force on a floating object equals its weight, mg.

9. (2) **T** **F** The Bernoulli equation predicts that faster moving fluid has lower pressure.

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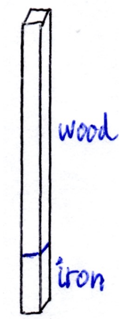
10. (12) A rod has dimensions 2.0 cm $\times$ 2.0 cm $\times$ 100.0 cm. The bottom 5.0 cm of the length is made from iron (density $\rho_{\mathrm{Fe}} = 7.860\ \mathrm{g/cm^3}$) and the remaining top 95.0 cm is made from pine wood (density $\rho_{\mathrm{pine}} = 0.373\ \mathrm{g/cm^3}$).



a) (6) When placed in water at 4°C, will it float or sink? Hint: Check its average density. Then, answer only part (b) or part (c).

b) (6) If it floats, what fraction of its volume will be below the water?

c) (6) If it sinks, what is the net force that accelerates its descent towards the bottom?

11. (2) **T F** When liquid water freezes to form ice, it gives heat to its surroundings.

12. (2) **T F** The three methods of heat transfer are conduction, convection, and circulation.

13. (2) **T F** When absorbing equal amounts of heat, an object with a smaller heat capacity undergoes a higher temperature change than an object with a larger heat capacity.

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14. (10) A 12.0 cm $\times$ 24.0 cm cross-section heating duct is supplying air to a room at a flow rate of 2.50 m^3/minute. The furnace supplying the duct increases the air temperature by 15.0 °C. Assume that the air stays nearly at constant 1.00 atm pressure and 1.21 kg/m^3 density, and has a constant-pressure specific heat of 1015 J/(kg °C). At what rate in watts is the furnace supplying heat to the air in this duct?

15. (8) A 22.0 m/s strong wind is blowing parallel to a 9.0 m $\times$ 6.0 m section of a roof. The air density is 1.21 kg/m^3. Estimate how much force is developed on the roof section by the wind blowing over it.

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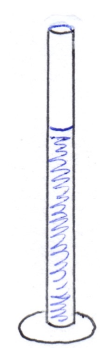
16. (8) The coefficient of volume expansion for water is $\beta = 210 \times 10^{-6}$ °C^{-1}. Initially a nonexpanding quartz cylinder contains a 1.00-m high column of water at 19 °C. By how much will the depth of water increase if the water is uniformly heated to 99 °C?



17. (6) The rms speed of O_2 molecules in the air is 556 m/s. What is the air's absolute temperature in kelvin?

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18. (8) Diatomic nitrogen in the air behaves as an ideal gas around room temperature. If a 1.00-kg sample of N_2 gas is held in a container of fixed 0.880 m^3 volume, how many joules of absorbed heat will raise its temperature from 0.00° C to 20.0° C?

Score = ______________/108.

Prefixes

z=10^{-21}, zepto, a=10^{-18}, atto, f=10^{-15}, femto, p=10^{-12}, pico, n=10^{-9}, nano, $\mu = 10^{-6}$, micro, m=10^{-3}, milli, c=10^{-2}, centi, k=10^{3}, kilo, M=10^{6}, mega, G=10^{9}, giga, T=10^{12}, tera, P=10^{15}, peta, E=10^{18}, exa, Z=10^{21} zeta.

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration)
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (gravitational constant)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth)
$R_E = 6380$ km (mean radius of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$c = 299\ 792\ 458$ m/s (speed of light)
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4 (Stefan-Boltzmann constant)
u $= 1.6605402 \times 10^{-27}$ kg (atomic mass unit)
$N_A = 6.022 \times 10^{23}$/mol (Avogadro's number)
$R = 8.314$ J/mol·K (gas constant)
$k_\mathrm{B} = 1.3806 \times 10^{-23}$ J/K (Boltzmann's constant)

Units & Conversions

1 inch = 1 in = 2.54 cm
1 foot = 1 ft = 12 in = 0.3048 m
1 mile = 5280 ft =1760 yards
1 mile = 1609.344 m = 1.609344 km
1 m/s = 3.6 km/hour
88 ft/s = 60 mile/hour
1 acre = (1 mile)^2/640 = 43 560 ft^2
1 hectare = (100 m)^2 = 10^4 m^2
1 lb = 4.45 N
1 N = 0.225 lb
1 J = 1 joule = 1 N·m

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 = 1.6605×10^{-27} kg, or, molar masses for the element (1 mole = 6.022×10^{23} atoms), measured in grams. ($N_A \times 1$ u = 1 gram).

Geometry

Triangles: $A = \frac{1}{2}bh$, Circles; $C = 2\pi r$, $A = \pi r^2$, arc $= s = r\theta$. Spheres: $A = 4\pi r^2$, $V = \frac{4\pi}{3}r^3$

Trigonometry

$\sin\theta = \frac{\text{(opp)}}{\text{(hyp)}}$, $\cos\theta = \frac{\text{(adj)}}{\text{(hyp)}}$, $\tan\theta = \frac{\text{(opp)}}{\text{(adj)}}$.
$\text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2$, $a^2 + b^2 - 2ab\cos\gamma = c^2$, $\frac{\sin\alpha}{a} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{c}$.

Chapter 2 - Vectors - Magnitude & Direction

2D Vectors:	$\vec{\mathbf{a}} = a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}}$,	magnitude = $a = \sqrt{a_x^2 + a_y^2}$,	direction $\to \tan\theta = a_y/a_x$.
Components:	$a_x = a\cos\theta$,	$a_y = a\sin\theta$,	θ=angle to $+x$-axis.
Addition:	$\vec{\mathbf{a}} + \vec{\mathbf{b}}$, head to tail.	Subtraction: $\vec{\mathbf{a}} - \vec{\mathbf{b}}$ is $\vec{\mathbf{a}} + (-\vec{\mathbf{b}})$,	$-\vec{\mathbf{b}}$ is $\vec{\mathbf{b}}$ reversed.
Scalar product:	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = ab\cos\phi$,	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = a_xb_x + a_yb_y + a_zb_z$,	$\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = 1$, $\hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = 0$, etc.
Cross product:	$\lvert\vec{\mathbf{a}} \times \vec{\mathbf{b}}\rvert = ab\sin\phi$,	$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, etc.	$\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} = 0$.

Chapter 3 - 1D Kinematics - Straight-line motion

Velocity:	$v_\text{ave} = \frac{\Delta x}{\Delta t}$,	$\Delta x = x - x_0$,	$v(t) = \frac{dx}{dt}$= slope of $x(t)$.
Acceleration:	$a_\text{ave} = \frac{\Delta v}{\Delta t}$,	$\Delta v = v - v_0$,	$a(t) = \frac{dv}{dt}$= slope of $v(t)$.
Constant acceleration:	$v = v_0 + at$,	$v_\text{ave} = \frac{1}{2}(v_0 + v)$.	
	$x = x_0 + v_0t + \frac{1}{2}at^2$.	$x = x_0 + v_\text{ave}t$,	$v^2 = v_0^2 + 2a\Delta x$.
Free fall ($+y$-axis is up):	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	$v_y = v_{0y} - gt$,	$v_y^2 = v_{0y}^2 - 2g\Delta y$.

Chapter 5 - Newton's laws and forces

Newton's 1st Law:	$\vec{a} = \frac{d\vec{v}}{dt} = 0$ unless $\vec{F}_{\text{net}} \neq 0$,	$\vec{F}_{\text{net}} = \sum \vec{F}_i$ = sum of all forces on a mass.
Newton's 2nd Law:	$\vec{F}_{\text{net}} = m\vec{a}$,	$F_{\text{net},x} = ma_x,\ F_{\text{net},y} = ma_y,\ F_{\text{net},z} = ma_z$.
Newton's 3rd Law:	$\vec{F}_{AB} = -\vec{F}_{BA}$,	Forces exist in action-reaction pairs.
Gravitational force near Earth:	$F_G = mg$, downward.	Apparent weight is force measured by a scales.
Gravity components on inclines:	$F_\parallel = mg\sin\theta,\ F_\perp = mg\cos\theta$,	← for incline at angle θ to horizontal.
Spring force:	$F_s = -kx$,	x is the displacement from equilibrium.

Chapter 7 - Work and kinetic energy

Work done by a force:	$dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = F\ dr\ \cos\theta$,	$W_{AB} = \int_A^B \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$ (along the path $A \to B$).
Work of a constant force:	$W = \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}}$,	$\Delta\mathbf{r} = \vec{\mathbf{r}}_B - \vec{\mathbf{r}}_A$ = displacement.
Work done by a spring:	$W_s = -\frac{1}{2}k(x_B^2 - x_A^2)$,	B=final stretch, A =initial stretch.
Work-KE theorem, power:	$\Delta\text{KE} = W_{\text{net}}$ = all works on m.	$\text{KE} = \frac{1}{2}mv^2, \quad P = \frac{dW}{dt}, \quad P_{\text{ave}} = \frac{\Delta W}{\Delta t}$.

Chapter 8 - Potential energy and Conservation of energy

PE for gravity:	$\Delta U = mg\Delta y$,	$U(y) = mgy +$ constant,	←(near Earth' surface).
PE for springs:	$\Delta U = \frac{1}{2}k(x_B^2 - x_A^2)$,	$U(x) = \frac{1}{2}kx^2$ + constant.	
Any arbitrary system:	$\Delta E_{\text{total}} = 0$,	$E_{\text{total}} = E_{\text{mec}} + E_{\text{thermal}} + E_{\text{other}}$.	

Chapter 17 - Sound

Speed of sound:	$v = \sqrt{B/\rho}$ (fluids),	$v = \sqrt{Y/\rho}$ (solids),	$v = \sqrt{\gamma RT/M_A}$ (ideal gas).
Speed in air:	$v = (331\text{m/s})\sqrt{1 + T_C/273°\text{C}}$,	$v(0°\text{C}) = 331$ m/s,	$v(20°\text{C}) = 343$ m/s.
Intensity I:	$I = P/A$,	$I = P/4\pi r^2$.	
Sound level β:	$\beta = (10\text{ dB})\log\frac{I}{I_0}$,	$I = I_0\ 10^{\beta/(10\text{ dB})}$,	$I_0 = 10^{-12}\ \text{W/m}^2$ (threshold).
Standing waves:	nodes @ ends of strings,	nodes @ ends of closed tubes,	antinodes @ ends of open tubes.
Doppler shift:	$f_O = f_S\frac{v+v_O}{v+v_S}$ (use x-comps.),	v=sound,	v_O=observer, v_S=source.

Chapter 14 - Fluids

1 atmosphere = 1 atm = 101.3 kPa = 1.013 bar = 760 torr = 760 mm Hg = 14.7 lb/in^2.

Units:	1 Pa = 1 N/m^2,	1 bar = 10^5 Pa,	1 mm Hg = 133.3 Pa.
Density:	$\rho = m/V$,	$\rho_{\text{H}_2\text{O}} = 10^3\ \text{kg/m}^3\ (4°\text{C})$,	$10^3\ \text{kg/m}^3 = 1\ \text{g/cm}^3$.
Pressure:	$p = F/A$,	$p_2 = p_1 + \rho g d$,	$p_{\text{abs}} = p_{\text{atm}} + p_{\text{gauge}}$.
Archimedes:	$F_B = \rho_{\text{fluid}} g V_s$,	Bernoulli energy conserv.→	$p + \rho g y + \frac{1}{2}\rho v^2$ = const.
Flow rates:	$Q = Av$,	$Q_m = \rho A v$,	$Q = (p_2 - p_1)\pi r^4/(8\eta L)$.
Viscosity:	$F = \eta v A/L$,	$N_R = 2\rho v r/\eta$,	$N_R < 2000$ laminar, $N_R > 3000$ turbulent.

V2 - Chapter 1 - Temperature & Heat transfer

Moles:	$n = N/N_A$,	$n = M/M_A$,	$N_A = 6.022 \times 10^{23}$/mol,	1 u $\times N_A$ = 1 gram.
Temperatures:	$T_\text{C} = \frac{5}{9}(T_\text{F} - 32)$,	$T_\text{F} = \frac{9}{5}T_\text{C} + 32$,	$T_\text{K} = T_\text{C} + 273.15$,	$T = \frac{p}{p_{\text{TP}}}T_{\text{TP}}$.
Expansion:	$\Delta L = \alpha L_0 \Delta T$,	$\Delta A = 2\alpha A_0 \Delta T$,	$\Delta V = \beta V_0 \Delta T$,	$\beta = 3\alpha$ (solids).
Heat transfers:	$Q = mc\Delta T$,	$Q = mL_F$,	$Q = mL_V$,	1 cal = 4.186 J.
Heat flow:	$P = kA\Delta T/d$,	$P = \sigma e A(T_2^4 - T_1^4)$,	$P_{\text{solar}} \approx (1\ \text{kW/m}^2)eA\cos\theta$.	

V2 - Chapter 2 - Kinetic theory & Ideal gases

Ideal gases:	$PV = nRT$,	$PV = Nk_\text{B}T$,	$R = 8.314\ \frac{\text{J}}{\text{mol}\cdot\text{K}}$,	$k_\text{B} = R/N_A$.
Kinetic theory:	$\overline{\text{KE}}_{\text{trans}} = \frac{m}{2}v_{\text{rms}}^2 = \frac{3}{2}k_\text{B}T$,	$v_{\text{rms}} = \sqrt{\frac{3k_\text{B}T}{m}} = \sqrt{\frac{3RT}{M_A}}$,	$m = M_A/N_A$,	m =molecule.
Internal energy:	$E_{\text{int}} = \frac{d}{2}Nk_\text{B}T$,	$E_{\text{int}} = \frac{d}{2}nRT$,	$d = 3, 5, 7$	
Molecules:	monatomic, $d = 3$,	diatomic, $d = 5$,	polyatomic, $d = 7$,	← room temp.
Specific heats:	$Q = nC\Delta T$,	$C_V = \frac{d}{2}R$,	$C_P = C_V + R$,	$\gamma \equiv C_P/C_V$.
Sound speed:	$v = \sqrt{\gamma RT/M_A}$,	$v_{\text{air}} = (331\frac{\text{m}}{\text{s}})\sqrt{\frac{T}{273\text{K}}}$.		