Physics 201    Fall 2023

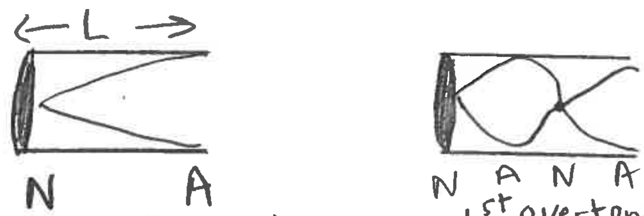
Name (signature as on ID) ____________________  Name (printed) ___Key___________

Lab Section _________   Instructor (Ford, Holt, Kelly, Schuessler) ____________________

Exam 4  Chapters 12, 13, 14, 15, 16 in Young, Adams 11e

Multiple choice questions. Circle the correct answer. No work needs to be shown and no partial credit will be given.

(5 pts) 1. The fundamental frequency of an organ pipe that is filled with air and that is open at one end and closed at the other end is 400 Hz. What is the frequency of the first overtone, the next higher frequency standing wave?




(a) 600 H
(b) 800 Hz
(c) 1000 Hz
d (d) 1200 Hz
(e) 1600 Hz
(f) none of the above answers

fundamental: $\frac{\lambda}{4} = L$, $\lambda = 4L$, $f_1 = \frac{v}{\lambda}$, $f_1 = \frac{v}{4L}$

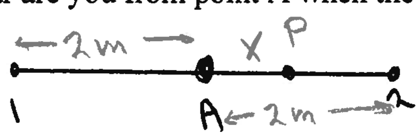
1st overtone: $3\left(\frac{\lambda}{4}\right) = L$, $\lambda = \frac{4L}{3}$

$f_3 = \frac{v}{\lambda} = 3\left(\frac{v}{4L}\right)$

$f_3 = 3f_1 = 3(400\,Hz)$

$f_3 = 1200\,Hz$

(5 pts) 2. You are standing between two speakers 1 and 2 that are emitting in phase sound waves of wavelength 0.200 m. The distance between the two speakers is 4.00 m. When you are at a point (point A) that is midway between the two speakers the interference is constructive. You start to walk toward speaker 2. How far are you from point A when the interference first becomes destructive?




a (a) 0.050 m
(b) 0.100 m
(c) 0.150 m
(d) 0.200 m
(e) 0.500 m
(f) none of the above answers

path difference = $2m + x - (2m - x)$

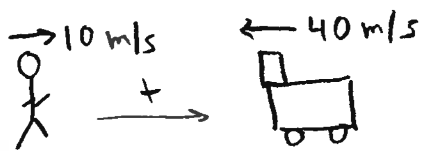
path difference = $2x$

destructive so path difference = $\frac{\lambda}{2}$

$2x = \frac{\lambda}{2}$

$x = \frac{\lambda}{4} = \frac{0.2\,m}{4} = 0.05\,m$

(5 pts) 3. A train is moving toward you at a speed of 40.0 m/s relative to the air and you are moving toward the train with a speed of 10.0 m/s relative to the air. If the frequency of the sound emitted by the train whistle is 600 Hz, what frequency do you hear? Take the speed of sound in air to be 340 m/s.




(a) 521 Hz
(b) 553 Hz
(c) 660 Hz
d (d) 700 Hz
(e) 760 Hz
(f) none of the above answers

$f_L = f_s\left(\frac{V + V_L}{V + V_s}\right)$

$f_L = 600\,Hz\left(\frac{340 + 10}{340 - 40}\right) = 700\,Hz$

(5 pts) 4. A wire with length 60.0 cm is tied down at both ends. The fundamental standing wave frequency for the wire is 50.0 Hz. What is the speed of transverse waves on the wire?

(a) 30 m/s
b (b) 60 m/s
(c) 90 m/s
(d) 120 m/s
(e) 150 m/s
(f) none of the above answers

N A N

$\frac{\lambda}{2} = L$

$\lambda = 2L = 1.20\ m$

$V = f\lambda = (50\ Hz)(1.2\ m) = 60\ Hz$

(5 pts) 5. When a block is suspended from the lower end of a light string and totally immersed in water (density $1.00\times10^3\ kg/m^3$) the tension in the string is 39.0 N. The volume of the block is $2.00\times10^{-3}\ m^3$. What is the mass of the block?

(a) 2.0 kg
(b) 3.0 kg
(c) 4.0 kg
(d) 5.0 kg
e (e) 6.0 kg
(f) none of the above answers

$a = 0$

$\sum F_y = ma_y$

$T + F_B - mg = 0$

$F_B = \rho_{fl} V_{displ}\, g = (1000\ kg/m^3)(2.00\times10^{-3}\ m^3)(9.8\ m/s^2)$

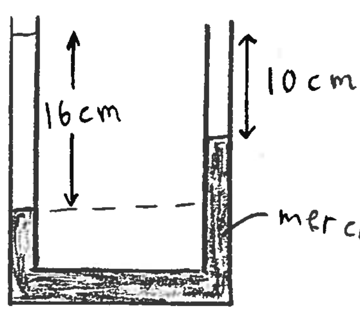
$F_B = 19.6\ N$

$mg = T + F_B = 39.0\ N + 19.6\ N = 58.6\ N$

$m = \frac{58.6\ N}{9.8\ m/s^2} = 6.0\ kg$

(5 pts) 6. A U-shaped tube open to the air at both ends contains some mercury (density $13.6\times10^3\ kg/m^3$). A quantity of a liquid is carefully poured into the left arm of the U-shaped tube until the vertical height of the liquid column is 16.0 cm. The vertical distance from the top of the liquid column in the left arm to the top of the mercury in the right arm is 10.0 cm. What is the density of the liquid?

(a) $1360\ kg/m^3$
(b) $4400\ kg/m^3$
c (c) $5100\ kg/m^3$
(d) $6600\ kg/m^3$
(e) $8500\ kg/m^3$
(f) none of the above answers




$P_{air} + \rho_{liq}(0.16\ m)g = P_{air} + \rho_{Hg}(0.06\ m)g$

$\rho_{liq} = \rho_{Hg}\left(\frac{0.06\ m}{0.16\ m}\right) = 13.6\times10^3\left(\frac{0.06}{0.16}\right)$

$\rho_{liq} = 5100\ kg/m^3$

(5 pts) 7. What mass of ice at 0.0 °C must be added to 2.00 kg of water initially at 80.0 °C to have the final temperature of the system be 30.0 °C. Assume no heat is lost to the surroundings.

(a) 0.33 kg
(b) 0.91 kg
(c) 3.3 kg
(d) 9.1 kg
(e) 12.8 kg
(f) none of the above answers

b

$Q_{ice} = m_{ice} L_f + m_{ice} C_w (30°C - 0°C)$

$Q_{ice} = m_{ice} (3.34\times10^5 J/kg + (4190 J/kg \cdot C°)(30C°))$

$Q_{ice} = m_{ice} (4.597\times10^5 J/kg)$

$Q_w = m C_w \Delta T = (2kg)(4190 J/(kg \cdot C°))(30°C - 80°C)$

$Q_w = -4.19\times10^5 J$

$Q_{ice} + Q_w = 0$

$m_{ice} = \frac{4.19\times10^5}{4.597\times10^5} = 0.91 kg$

(5 pts) 8. One end of an insulated metal rod is maintained at 100.0 °C and the other end is in an ice-water that is at 0.0 °C. The length of the rod is 0.500 m and it has a uniform cross-sectional area of $2.00\times10^{-5}$ m$^2$. If the rod is copper (thermal conductivity 385 W/(m•K), how long does it take the heat conducted by the rod to melt 0.0200 kg of ice?

(a) 36 min
(b) 72 min
(c) 110 min
(d) 180 min
(e) 240 min
(f) none of the above answers

b

$H = \frac{Q}{t} = kA\left(\frac{T_H - T_C}{L}\right) = (385)(2\times10^{-5})\frac{(100)}{0.5} = 1.54 J/s$

$Q = mL_f = (0.02kg)(3.34\times10^5 J/kg) = 6.68\times10^3 J$

$t = \frac{Q}{1.54 J/s} = \frac{6.68\times10^3 J}{1.54 J/s} = 4.34\times10^3 s$

$t = 72.3$ min

(5 pts) 9. A metal block with mass 0.0500 kg and a temperature of 100.0 °C is placed into 0.019 kg of water that is in an insulated container of negligible mass. The initial temperature of the water is 20.0 °C. If the final temperature of the system is 32.0 °C, what is the specific heat capacity of the metal in the block?

(a) 150 J/(kg•K)
(b) 210 J/(kg•K)
(c) 280 J/(kg•K)
(d) 360 J/(kg•K)
(e) 410 J/(kg•K)
(f) none of the above answers

c

$Q_w = m C_w \Delta T = (0.019kg)(4190 J/kg \cdot C°)(32°C - 20°C)$

$Q_w = 955.3 J$

$Q_m = m C_m \Delta T = (0.05kg) C_m (32°C - 100°C)$

$Q_m = -(3.4 kg \cdot C°) C_m$

$Q_w + Q_m = 0$

$955.3 J - (3.4 kg \cdot C°) C_m$

$C_m = 281 J/(kg \cdot C°)$

(5 pts) 10. A spherical pot of coffee has a surface area of $0.400\ m^2$ and an emissivity of 0.500. The surroundings have a temperature of $22.0\ ^{o}C$. When the coffee has a temperature of $77.0\ ^{o}C$ what is the net rate (of heat) loss by the coffee due to radiation?

(a) 32 W
b (b) 84 W
(c) 98 W
(d) 152 W
(e) 170 W
(f) none of the above answers

$H_{net} = e\sigma A(T^4 - T_s^4)$

$T = 350\ K,\ T_s = 295\ K$

$H_{net} = (0.5)(5.67\times10^{-8})(0.4)[(350)^4 - (295)^4]$

$H_{net} = 84.3\ W$

(5 pts) 11. 2.00 mol of a monatomic ideal (gas) is heated at constant pressure from 100 K to 300 K. What is the change in the internal energy of the gas?

(a) zero
b (b) 5000 J
(c) 6600 J
(d) 8300 J
(e) 9600 J
(f) none of the above answers

$\Delta U = nC_v\Delta T$, all processes for an ideal gas

$\Delta U = (2.0\ mol)(\frac{3}{2})(8.314)(200) = 5000\ J$

(5 pts) 12. A gas in a cylinder is held at a constant pressure of $2.00\times10^5$ Pa while its volume increases from $1.50\ m^3$ to $2.00\ m^3$. In this process the internal energy of the gas increases by $1.60\times10^5\ J$. What is the heat flow for the gas?

a (a) $2.60\times10^5$ J into the gas
(b) $2.60\times10^5$ J out of the gas
(c) $0.60\times10^5$ J into the gas
(d) $0.60\times10^5$ J out of the gas
(e) none of the above answers

$\Delta U = Q - W$

$Q = \Delta U + W$

$W = p\Delta V = (2\times10^5)(2.0 - 1.5) = 1.0\times10^5\ J$

$Q = 1.6\times10^5\ J + 1.0\times10^5\ J = 2.6\times10^5\ J$

(5 pts) 13. A Carnot heat engine operates between a high temperature reservoir at 600 K and a low temperature reservoir at 200 K. In each cycle the engines does 900 J of work. In one cycle what is the magnitude heat that the engine rejects into the low temperature reservoir?

(a) 350 J
(b) 450 J
(c) 550 J
(d) 650 J
(e) 750 J
(f) none of the above answers

b

$\downarrow Q_H > 0$ → engine → $W > 0$, $\downarrow Q_C < 0$

$Q_H + Q_C = W$

$|Q_H| - |Q_C| = |W|$

Carnot so $\frac{|Q_H|}{|Q_C|} = \frac{T_H}{T_C} = \frac{600K}{200K} = 3$

$|Q_H| = 3|Q_C|$

$3|Q_C| - |Q_C| = |W|$

$2|Q_C| = |W|$

$|Q_C| = 450 J$

(5 pts) 14. In each cycle a heat engine does 800 J of work and rejects heat of magnitude 200 J into the low temperature. What is the thermal efficiency of the engine?

(a) 20%
(b) 40%
(c) 50%
(d) 60 %
(e) 80%
(f) none of the above answers

e

$\downarrow Q_H > 0$ → engine → $W > 0$, $\downarrow Q_C < 0$

$Q_H + Q_C = W$

$|Q_H| - |Q_C| = |W|$

$|Q_H| = |Q_C| + |W| = 1000 J$

$e = \frac{W}{Q_H} = \frac{800 J}{1000 J} = 0.80$

(5 pts) 15. Four moles of an ideal gas undergo a reversible isothermal expansion at 27.0°C. During this expansion the gas does 1500 J of work. For this process what is the entropy change of the gas?

(a) +10.0 J/K
(b) −10.0 J/K
(c) +5.0 J/K
(d) −5.0 J/K
(e) zero
(f) none of the above answers

c

$T_K = 300 K$

$\Delta S = \frac{Q}{T}$

$\Delta T = 0$ so $\Delta U = 0$ and $Q = W$, expansion so $W > 0$

$\Delta S = \frac{1500 J}{300 K} = +5 J/K$

(5 pts) 16. In each cycle a refrigerator absorbs 800 J of heat from the low temperature reservoir and 600 J of mechanical energy is supplied to operate the refrigerator. In each cycle what magnitude of heat is rejected into the high temperature reservoir?

(a) 200 J
(b) 600
(c) 800J
(d) 1400 J
(e) zero
(f) none of the above answers

d

$\uparrow Q_H < 0$, refrig ← $W < 0$, $\uparrow Q_C > 0$

$Q_H + Q_C = W$

$|Q_H| - |Q_C| = -|W|$

$|Q_H| = |Q_C| + |W| = 800J + 600J = 1400J$

(5 pts) 17. A mixture of ideal gas A and ideal gas B is at thermal equilibrium. The mass of each atom of gas B is larger than the mass of each atom of gas A ( $m_B > m_A$ ). Which statement about the average kinetic energy per atom is correct?

a (a) $K_A = K_B$ $K_{av} = \frac{3}{2}kT$

(b) $K_A < K_B$

(c) $K_A > K_B$

(5 pts) 18 Which of the following must be true about an ideal gas that undergoes an isothermal compression?

$\Delta U = nC_v\Delta T = 0$

(a) no heat enters the gas
(b) the pressure of the gas decreases
(c) the internal energy of the gas does not change
(d) the gas does positive work

c

a also correct

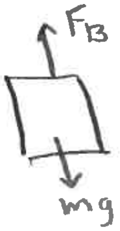
$\Delta U = Q - W = 0$, $Q = W$
compression so $W < 0$ and $Q < 0$
$pV = nRT$ = constant
compression so V decreases, p must increase to keep pV constant

(5 pts) 19. A wooden block with mass 200 kg and volume $0.500 \text{ m}^3$ is floating in water (density $1000 \text{ kg/m}^3$). What volume of the block is beneath the surface of the water?

(a) $0.05 \text{ m}^3$
(b) $0.10 \text{ m}^3$
(c) $0.20 \text{ m}^3$
(d) $0.30 \text{ m}^3$
(e) $0.40 \text{ m}^3$
(f) none of the above answers

c

$a = 0$




$\Sigma F_y = ma_y$

$F_B - mg = 0$

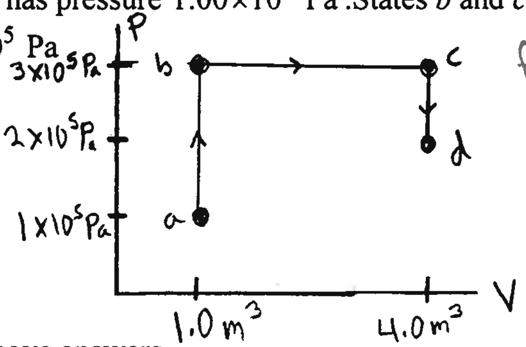
$\rho_w V_{sub} g = mg$

$V_{sub} = \frac{m}{\rho_w} = \frac{200 \text{ kg}}{1000 \text{ kg/m}^3} = 0.20 \text{ m}^3$

(5 pts) 20. For the process shown in the $pV$ diagram what is the total work done in going from state $a$ to state $d$ along the path shown? (States $a$ and $b$ have volume $1.00 \text{ m}^3$. States $c$ and $d$ have volume $4.00 \text{ m}^3$. State $a$ has pressure $1.00\times10^5$ Pa. States $b$ and $c$ have pressure $3.00\times10^5$ Pa. State $d$ has pressure $2.00\times10^5$ Pa

(a) $15.0\times10^5$ J
(b) $9.0\times10^5$ J
(c) $6.0\times10^5$ J
(d) $1.0\times10^5$ J
(e) zero
(f) none of the above answers

b




for $a \to b$ and $c \to d$, $\Delta V = 0$ so $W = 0$

for $b \to c$, $W = p\Delta V$

$W = (3\times10^5 \text{ Pa})(4\text{ m}^3 - 1\text{ m}^3) = 9\times10^5 \text{ J}$

PHYS 201 Formula Sheet

**Chapters 12 --16 (Exam 4)**

$v = f\lambda$ $\quad v = \sqrt{\frac{F_T}{\mu}}$ $\quad y(x,t) = A\sin\left[2\pi f\left(t - \frac{x}{v}\right)\right] = A\sin\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)\right]$

$f_n = n\left(\frac{v}{2L}\right), n = 1,2,3,...$ $\quad f_n = n\left(\frac{v}{4L}\right), n = 1,3,5,...$

$I = \frac{P}{4\pi r^2}$ $\quad \beta = (10\text{ dB})\log\left(\frac{I}{I_0}\right)$ $\quad f_{\text{beat}} = f_1 - f_2$ $\quad f_L = \left(\frac{v+v_L}{v+v_S}\right)f_S$

$\rho = \frac{m}{V}$ $\quad p = \frac{F_\perp}{A}$ $\quad p_0 = p_{\text{atm}} + \rho gh$

$T_F = \frac{9}{5}T_C + 32^\circ$ $\quad T_C = \frac{5}{9}(T_F - 32^\circ)$ $\quad T_K = T_C + 273.15^\circ$ $\quad 1\ C^\circ = \frac{9}{5}\ F^\circ$

$\Delta L = \alpha L_0 \Delta T$ $\quad \Delta V = V_0 \beta \Delta T$ $\quad \frac{F}{A} = -Y\alpha\Delta T$

$Q = mc\Delta T$ $\quad Q = \pm mL$ $\quad H = kA\frac{T_H - T_C}{L}$ $\quad H = Ae\sigma T^4$

For ice, $c_{\text{ice}} = 2010$ J/(kg/K) and for liquid water $c_{\text{water}} = 4190$ J/(kg/K)

For water $L_f = 3.34 \times 10^5$ J/kg and $L_v = 2.256 \times 10^6$ J/kg

$\sigma = 5.67 \times 10^{-8}\ W/(m^2 \cdot K^4)$ $\quad N = 6.022 \times 10^{23}$ molecules/mol $\quad m_{\text{total}} = nM$

$pV = nRT$ $\quad \rho = \frac{pM}{RT}$ $\quad R = 8.314\ \text{J}/(\text{mol}\cdot K)$

$k = 1.381 \times 10^{-23}$ J/molecule $\cdot K$

$K_{tr} = \frac{3}{2}nRT$ $\quad K_{av} = \frac{1}{2}m(v^2)_{av} = \frac{3}{2}kT$ $\quad pV = NkT$ $\quad v_{\text{rms}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$

$Q = nC\Delta T$ $\quad W = p\Delta V$ $\quad W = nRT\ln\left(\frac{V_2}{V_1}\right)$ $\quad \Delta U = Q - W$

$C_p = C_V + R$ $\quad p_1V_1^\gamma = p_2V_2^\gamma$ $\quad T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ $\quad \gamma = C_p/C_V$

For a monatomic ideal gas $C_V = 3R/2, C_p = 5R/2$

$W = Q = |Q_H| - |Q_C|$ $\quad e = \frac{W}{Q_H} = 1 - \left|\frac{Q_C}{Q_H}\right|$ $\quad K = \frac{Q_C}{|W|} = \frac{|Q_C|}{|Q_H| - |Q_C|}$

Carnot: $\frac{Q_C}{Q_H} = -\frac{T_C}{T_H}$ $\quad e_{\text{Carnot}} = 1 - \frac{T_C}{T_H}$ $\quad \Delta S = \frac{Q}{T}$