Engineer Physics 1220_02 (PHYS1220CHIEN02)

My Courses | Course Settings

University Physics with Modern Physics, 13e
Young/Freedman

Instructor Resources eText Study Area

Course Home | **Assignments** | Roster | Gradebook | Item Library

HW Bonus 3 [Edit]

Overview | Summary View | Diagnostics View | **Print View with Answers**

HW Bonus 3

Due: 11:00am on Friday, May 2, 2014

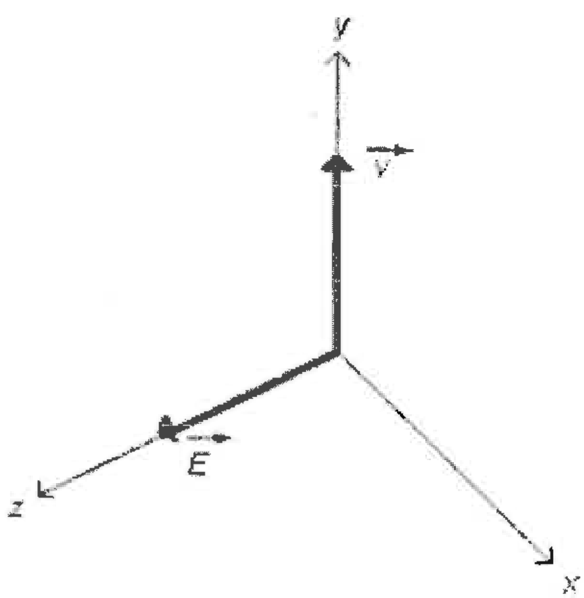
You will receive no credit for items you complete after the assignment is due. Grading Policy

Conceptual Question 32.06

Description: (a) An electromagnetic wave propagates along the +y direction as shown in the figure. If the electric field at the origin is along the +z direction, what is the direction of the magnetic field?

Part A

An electromagnetic wave propagates along the $+y$ direction as shown in the figure. If the electric field at the origin is along the $+z$ direction, what is the direction of the magnetic field?



$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

ANSWER:

- ○ $-x$
- ○ $+y$
- ○ $-z$
- ○ $+z$
- ◉ $+x$

Problem 32.40

Description: (a) For a sinusoidal electromagnetic wave in vacuum, such as that described by the equations E_y(x,t)=E_maxcos(kx-omega t) and B_z(x,t)=B_maxcos(kx-omega t), find the average energy density in the electric field in terms of the average energy...

Part A

For a sinusoidal electromagnetic wave in vacuum, such as that described by the equations $E_y(x,t) = E_{max}\cos(kx - \omega t)$ and $B_z(x,t) = B_{max}\cos(kx - \omega t)$, find the *average* energy density in the electric field in terms of the *average* energy density in the magnetic field (u_M).

$E_{rms} = \frac{E_{max}}{\sqrt{2}}$; $B_{rms} = \frac{B_{max}}{\sqrt{2}}$

Express your answer in terms of the variable u_M and appropriate constants.

ANSWER:

$u_{E,av}$ = u_M

Also accepted: u_m

$u_E = \frac{1}{2}\epsilon_0 E^2 \Rightarrow u_{E,ave} = \frac{1}{2}\epsilon_0 E_{rms}^2$

$u_M = \frac{1}{2}\frac{1}{\mu_0}B^2$ $\quad u_{M,ave} = \frac{1}{2}\frac{1}{\mu_0}B_{rms}^2$

$E_{max} = cB_{max} = \frac{1}{\sqrt{\epsilon_0\mu_0}}B_{max}$

$\therefore u_{E,ave} = \frac{1}{2}\cdot\epsilon_0\cdot\frac{1}{2}\cdot\frac{1}{\epsilon_0\mu_0}B_{max}^2 = u_{M,ave}$

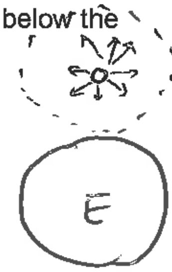
Problem 32.41

Description: A satellite d above the earth's surface transmits sinusoidal electromagnetic waves of frequency f uniformly in all directions, with a power of 25.0 kW. (a) What is the intensity of these waves as they reach a receiver at the surface of the earth...

A satellite 565km above the earth's surface transmits sinusoidal electromagnetic waves of frequency 92.0MHz uniformly in all directions, with a power of 25.0 kW.

Part A

What is the intensity of these waves as they reach a receiver at the surface of the earth directly below the satellite?



ANSWER:

$I = \frac{25000}{4\pi d^2}$ = 6.23×10^{-9} $\mathrm{W/m^2}$

$I = \frac{P}{A} = \frac{25\times10^3}{4\pi d^2} = \frac{25\times10^3}{4\pi(565\times10^3)^2}$

Part B

What is the amplitude of the electric field at the receiver?

ANSWER:

$$E_{max} = \sqrt{\frac{\frac{2\cdot 25000}{4\pi d^2}}{8.85\cdot 10^{-12}\cdot 3\cdot 10^{8}}} = 2.17\times 10^{-3}\ \mathrm{N/C}$$

$$I = |\vec{S}|_{ave} = \frac{1}{\mu_0} E_{rms} B_{rms} = \epsilon_0 c E_{rms}^2$$

$$\Rightarrow E_{rms}^2 = \frac{I}{\epsilon_0 c} = \frac{E_{max}^2}{2}$$

$$E_{max} = \sqrt{\frac{2I}{\epsilon_0 c}}$$

Part C

What is the amplitude of the magnetic field at the receiver?

ANSWER:

$$B_{max} = \frac{\sqrt{\frac{\frac{2\cdot 25000}{4\pi d^2}}{8.85\cdot 10^{-12}\cdot 3\cdot 10^{8}}}}{3\cdot 10^{8}} = 7.22\times 10^{-12}\ \mathrm{T}$$

$$B_{max} = \frac{E_{max}}{c}$$

Part D

If the receiver has a totally absorbing panel measuring 15.0cm by 35.0cm oriented with its plane perpendicular to the direction the waves travel, what average force do these waves exert on the panel?

ANSWER:

$$F = \frac{\frac{25000}{4\pi d^2}}{3\cdot 10^{8}} ab = 1.09\times 10^{-18}\ \mathrm{N}$$

(pressure)

$$P_{rad} = \frac{I}{c}$$

$$F = P_{rad}\cdot A = \frac{I}{c}\cdot a\cdot b$$

Part E

Is this force large enough to cause significant effects?

ANSWER:

- ○ yes
- ◉ no

Problem 17.78

Description: A 250 kg weight is hanging from the ceiling by a thin copper wire. In its fundamental mode, this wire vibrates at the frequency of concert A (440 Hz). You then increase the temperature of the wire by 40 degree(s) C. (a) By how much will the...

A 250 kg weight is hanging from the ceiling by a thin copper wire. In its fundamental mode, this wire vibrates at the frequency of concert A (440 Hz). You then increase the temperature of the wire by 40 $^\circ\mathrm{C}$.

Part A

By how much will the fundamental frequency change?

Express your answer using two significant figures.

ANSWER:

$|\Delta f|$ = 0.15 Hz

~~m $\Rightarrow T = 2\pi\sqrt{\frac{L}{g}} = \frac{1}{f}$~~

~~$f = \frac{1}{2\pi}\sqrt{\frac{g}{L}} = 440$ (Hz)~~

~~$\Delta L = \alpha L_0 \Delta T = 1.9\times10^{-5} \times L \times 40$~~

~~$L_{final} = L + \Delta L$~~

~~$f_{final} = \frac{1}{2\pi}\sqrt{\frac{g}{L_{final}}} \Rightarrow \Delta f = f_{final} - f$~~

Part B

Will it increase or decrease?

ANSWER:

- ○ it will increase
- ◉ it will decrease

~~$f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$~~

~~larger L (thermal expansion), smaller f.~~

see attachment.

Part C

By what percentage will the speed of a wave on the wire change?

Express your answer using two significant figures.

ANSWER:

$\frac{|\Delta v|}{v}$ = 3.4×10^{-2} %

$v = \sqrt{\frac{T}{\mu}}$ (v: speed of wave; T: tension; μ = linear mass density)

T is constant (m doesn't change) ← hanging mass

$\mu = \frac{m_{cu}}{L}$ ← Cu string mass

$\mu_{final} = \frac{m_{cu}}{L_{final}}$

$\frac{|\Delta v|}{v} = \frac{\sqrt{\frac{T}{\mu_{final}}} - \sqrt{\frac{T}{\mu}}}{\sqrt{\frac{T}{\mu}}}$

Part D

By what percentage will the wavelength of the fundamental standing wave change?

Express your answer using two significant figures.

ANSWER:

$\frac{|\Delta\lambda|}{\lambda}$ = 6.8×10^{-2} %

$\frac{1}{2}\lambda = L \Rightarrow \lambda = 2L$

$\lambda_{final} = 2L_{final}$

$\frac{|\Delta\lambda|}{\lambda} = \frac{2L_{final} - 2L}{2L}$

Part E

Will wavelength increase or decrease?

ANSWER:

$\lambda = 2L \Rightarrow$ larger L

larger λ

- [x] it will increase
- [ ] it will decrease

Problem 17.97

Description: (a) A typical student listening attentively to a physics lecture has a heat output of P. How much heat energy does a class of N physics students release into a lecture hall over the course of a 50 min lecture? (b) Assume that all the heat energy in ...

Part A

A typical student listening attentively to a physics lecture has a heat output of $120 \mathrm{W}$. How much heat energy does a class of 50 physics students release into a lecture hall over the course of a 50 min lecture?

Express your answer using two significant figures.

ANSWER:

$Q = NP \cdot 50 \cdot 60 = 1.8 \times 10^7$ J

$Q = P \cdot \Delta t \times N$

$= \underbrace{120}_{W} \times \underbrace{50 \times 60}_{s} \; 50$

Part B

Assume that all the heat energy in part (a) is transferred to the $3600 \mathrm{m}^3$ of air in the room. The air has specific heat capacity 1020 $\mathrm{J/(kg \cdot K)}$ and density 1.20 $\mathrm{kg/m^3}$. If none of the heat escapes and the air conditioning system is off, how much will the temperature of the air in the room rise during the 50 min lecture?

Express your answer using two significant figures.

ANSWER:

$\Delta T = \dfrac{\frac{NP \cdot 50 \cdot 60}{1020 \cdot V}}{1.20} = 4.1$ °C

$Q = mc\Delta T$

$= \rho \cdot V \cdot c \cdot \Delta T$

$\Delta T = \dfrac{Q}{\rho V c} = \dfrac{Q}{1.2 \times 3600 \times 1020}$

Part C

If the class is taking an exam, the heat output per student rises to $260 \mathrm{W}$. What is the temperature rise during 50 min in this case?

Express your answer using two significant figures.

ANSWER:

$\Delta T = \dfrac{Q}{1.2 \times 3600 \times 1020}$

$Q = P \cdot \Delta t \cdot N$

$= 260 \cdot 50 \times 60 \cdot 50$

$$\Delta T = \frac{[illegible]}{1.20} = 8.9 \ ^\circ\mathrm{C}$$

Problem 17.83

Description: A metal rod, made from metal 1, with a length of ## cm expands by ## cm when its temperature is raised from 0.0 degree(s) C to 100.0 degree(s) C. A rod of a different metal (metal 2) and of the same length expands by a distance of ## cm for the...

A metal rod, made from metal 1, with a length of 30.0cm expands by 6.40×10^{-2}cm when its temperature is raised from 0.0 $^\circ\mathrm{C}$ to 100.0 $^\circ\mathrm{C}$. A rod of a different metal (metal 2) and of the same length expands by a distance of 3.80×10^{-2}cm for the same rise in temperature. A third rod, also with a length of 30.0cm , is made up of pieces of each of the above metals placed end-to-end and expands by a distance of 5.40×10^{-2}cm between 0.0 $^\circ\mathrm{C}$ and 100.0 $^\circ\mathrm{C}$.

$\Delta L = \alpha L \Delta T \qquad \alpha = \frac{\Delta L}{L \Delta T}$

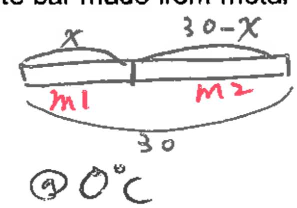
Part A

$\alpha_2 = \frac{3.8\times10^{-2}}{30 \times 100} \qquad \alpha_1 = \frac{6.4\times10^{-2}}{30 \cdot 100}$

Find the unexpanded length of the portion of the composite bar made from metal 1.

ANSWER:

$\frac{x_3 - x_2}{x_1 - x_2} L$ = 18.5 cm



$\Rightarrow \Delta L = \alpha_1 x \Delta T + \alpha_2 (30-x) \Delta T$

$5.4\times10^{-2} = \alpha_1 x \cdot 100 + \alpha_2 (30-x) 100$

$\Rightarrow$ solve x

Part B

Find the unexpanded length of the portion of the composite bar made from metal 2.

ANSWER:

$30 - x$

$\left(1 - \frac{x_3 - x_2}{x_1 - x_2}\right) L$ = 11.5 cm

Problem 18.69

Description: You have two identical containers, one containing gas A and the other gas B. The masses of these molecules are m_A= 3.34 * 10^(- 27) (kg) and m_B = 5.34 * 10^(- 26) (kg). Both gases are under the same pressure and are at T. (a) Which molecules (A ...

You have two identical containers, one containing gas *A* and the other gas *B*. The masses of these molecules are $m_A = 3.34 \times 10^{-27}\mathrm{kg}$ and $m_B = 5.34 \times 10^{-26}\mathrm{kg}$. Both gases are under the same pressure and are at 15.0 $^\circ\mathrm{C}$.

Part A

same ?

Which molecules (*A* or *B*) have greater translational kinetic energy per molecule? $K_{tr} = \frac{3}{2} nRT$

same

$pV = nRT$

same

ANSWER:

- ○ *A*
- ○ *B*
- ◉ Same

Part B

Which molecules (*A* or *B*) have greater rms speeds?

$E_k = \underline{\frac{1}{2} m V_{rms}^2} = \frac{3}{2} kT$

same

large m, smaller V_{rms}

ANSWER:

- ◉ *A*
- ○ *B*
- ○ Same

Part C

Now you want to raise the temperature of only one of these containers so that both gases will have the same rms speed. For which gas should you raise the temperature?

ANSWER:

see above

- ○ *A*
- ◉ *B*
- ○ Same

Part D

At what temperature will you accomplish your goal?

$\frac{1}{2} m_A V_{rms}^2 = \frac{3}{2} k T_1$

15 °C

same

$\frac{1}{2} m_B V_{rms}^2 = \frac{3}{2} k T'$

$\frac{m_A}{m_B} = \frac{T_1}{T'}$ ⇒ solve T'

ANSWER:

$T = \mathrm{round}\left(\frac{5.34\cdot 10^{-26}}{3.34\cdot 10^{-27}} T - 273, 1\right)$ = 4330 °C

Part E

Once you have accomplished your goal, which molecules (*A* or *B*) now have greater average translational kinetic energy per molecule?

ANSWER:

$E_k = \frac{3}{2} kT$ higher T, higher E_k

- ○ A
- ◉ B
- ○ Same

Problem 18.83

Description: (a) Compute the value of the molar heat capacity at constant volume, C_V (kern 1pt), for (CO)_2 on the assumption that there is no vibrational energy. (Note: (CO)_2 is linear; (SO)_2 and H_2 S are not. Recall that a linear polyatomic molecule...

Part A

Compute the value of the molar heat capacity at constant volume, C_V , for CO_2 on the assumption that there is no vibrational energy. (*Note:* CO_2 is linear; SO_2 and H_2S are not. Recall that a linear polyatomic molecule has two rotational degrees of freedom, and a nonlinear molecule has three.)

Express your answer using four significant figures.

$C_V = \frac{dof}{2} R$; $R = 8.314 \frac{J}{mol \cdot K}$

ANSWER:

C_V = 20.79 $J/(mol \cdot K)$

CO_2 O − C − O (linear)

$dof = \underbrace{3}_{translational} + \underbrace{2}_{rotational}$

$C_V = \frac{5}{2} R$

Part B

Compute the value of the molar heat capacity at constant volume, C_V , for SO_2 on the assumption that there is no vibrational energy. (*Note:* CO_2 is linear; SO_2 and H_2S are not. Recall that a linear polyatomic molecule has two rotational degrees of freedom, and a nonlinear molecule has three.)

Express your answer using four significant figures.

$C_V = \frac{dof}{2} R$; $dof = 3 + 3$

ANSWER:

C_V = 24.94 $J/(mol \cdot K)$

$\Rightarrow C_V = \frac{6}{2} R = 3R$

Part C

Compute the value of the molar heat capacity at constant volume, C_V , for H_2S on the assumption that there is no vibrational energy. (*Note:* CO_2 is linear; SO_2 and H_2S are not. Recall that a linear polyatomic molecule has two rotational degrees of freedom, and a nonlinear molecule has three.)

Express your answer using four significant figures.

same as above

ANSWER:

C_V = 24.94 $J/(mol \cdot K)$

Part D

Compare with the measured values: for CO_2 C_V=28.46 $J/(mol \cdot K)$, for SO_2 C_V=31.39 $J/(mol \cdot K)$, for H_2S C_V=25.95 $J/(mol \cdot K)$, and compute the fraction of the total heat capacity that is due to vibration for CO_2. (*Note:* CO_2 is linear; SO_2 and H_2S are not. Recall that a linear polyatomic molecule has two rotational degrees of freedom, and a nonlinear molecule has three.)

analysed above

ANSWER:

$$C_{V(measured)} = C_{V(T+R)} + C_{V(V)}$$

translational rotational vibrational

$$\frac{C_{V\ vibrational}}{C_V} = 0.270$$

$$\frac{28.46 - 20.79}{28.46}$$

$$C_{V(V)} = C_{V(measured)} - C_{V(T+R)}$$

Part E

Compute the fraction of the total heat capacity that is due to vibration for SO_2. (*Note:* CO_2 is linear; SO_2 and H_2S are not. Recall that a linear polyatomic molecule has two rotational degrees of freedom, and a nonlinear molecule has three.)

$$\frac{31.39 - 24.94}{31.39}$$

ANSWER:

$$\frac{C_{V\ vibrational}}{C_V} = 0.205$$

Part F

Compute the fraction of the total heat capacity that is due to vibration for H_2S. (*Note:* CO_2 is linear; SO_2 and H_2S are not. Recall that a linear polyatomic molecule has two rotational degrees of freedom, and a nonlinear molecule has three.)

$$\frac{25.95 - 24.94}{25.95}$$

ANSWER:

$$\frac{C_{V\ vibrational}}{C_V} = 3.89 \times 10^{-2}$$

Problem 18.79

Description: (a) For what mass of molecule or particle is the rms speed equal to v_rms at a temperature of T? (b) If the particle is an ice crystal, how many molecules does it contain? The molar mass of water is M. (c) Calculate the diameter of the particle if ...

Part A

For what mass of molecule or particle is the rms speed equal to 1.05mm/s at a temperature of 289K ?

ANSWER:

$$E_k = \frac{1}{2} m V_{rms}^2 = \frac{3}{2} kT \Rightarrow m = \frac{3kT}{V_{rms}^2}$$

$m = \dfrac{3k_BT}{v_{\rm rms}^2}$ = 1.09×10^{-14} kg

Part B

If the particle is an ice crystal, how many molecules does it contain? The molar mass of water is $18.0 \mathrm{g/mol}$.

ANSWER:

$N = \dfrac{3N_A k_B T}{v_{\rm rms}^2 M}$ = 3.63×10^{11}

$18 \dfrac{\cancel{g}}{\cancel{mol}} \times \dfrac{1}{N_A} \dfrac{\cancel{mol}}{\#} \times \dfrac{1}{10^3} \dfrac{kg}{\cancel{g}}$

$= \dfrac{18}{N_A \cdot 10^3} \dfrac{kg}{\#}$

$N = \dfrac{m}{\frac{18}{N_A 10^3}}$

Part C

Calculate the diameter of the particle if it is a spherical piece of ice.

ANSWER:

$d = 2\sqrt[3]{\dfrac{9k_BT}{v_{\rm rms}^2 \rho 4\pi}}$ = 2.82×10^{-6} m

$d = 2r$

$\rho = \dfrac{m}{V} = \dfrac{m}{\frac{4}{3}\pi r^3} = \dfrac{m}{\frac{4}{3}\pi \left(\frac{d}{2}\right)^3}$

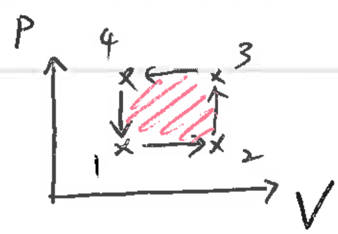
4

density of ice: $0.9167 \ \frac{g}{cm^3}$

Problem 19.44

Description: Three moles of argon gas (assumed to be an ideal gas) originally at a pressure of 1.50 * 10^4 (Pa) and a volume of V_1 are first heated and expanded at constant pressure to a volume of V_2, then heated at constant volume until the pressure reaches...

Three moles of argon gas (assumed to be an ideal gas) originally at a pressure of $1.50 \times 10^4 \ \mathrm{Pa}$ and a volume of 3.00×10^{-2}m^3 are first heated and expanded at constant pressure to a volume of 4.45×10^{-2}m^3 , then heated at constant volume until the pressure reaches $3.50 \times 10^4 \mathrm{Pa}$, then cooled and compressed at constant pressure until the volume is again 3.00×10^{-2}m^3 , and finally cooled at constant volume until the pressure drops to its original value of $1.50 \times 10^4 \ \mathrm{Pa}$.



Part A

Calculate the total work done by the gas during the cycle.

ANSWER:

$W = -\left(3.5 \cdot 10^4 - 1.5 \cdot 10^4\right)\left(V_2 - V_1\right)$ = -290 J

$W < 0$

area in P-V diagram

$: -\Delta P \cdot \Delta V$

$-\left(3.5\times10^4 - 1.5\times10^4\right)\left(4.45\times10^{-2} - 3\times10^{-2}\right)$

Part B

Calculate the net heat exchanged with the surroundings.

ANSWER:

$|Q| = (3.5\cdot 10^4 - 1.5\cdot 10^4)(V_2 - V_1) = 290$ J

$Q = \underbrace{\Delta U}_{\substack{\parallel \\ 0}} + W$ (cycle processes)

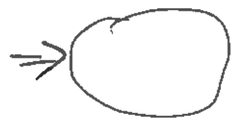
$|Q| = |W|$

Part C

Does the gas gain or lose heat overall?

ANSWER:

- ○ gas gains heat
- ◉ gas loses heat

$Q \Rightarrow$  $\Rightarrow W$

$Q < 0$ means heat comes out

$W < 0$ means work done onto the system

Problem 19.45

Description: Two moles of an ideal monatomic gas go through the cycle abc. For the complete cycle, Q of heat flows out of the gas. Process ab is at constant pressure, and process bc is at constant volume. States a and b have temperatures T_a=## K and T_b=## K. (a)...

Two moles of an ideal monatomic gas go through the cycle abc. For the complete cycle, 750J of heat flows out of the gas. Process ab is at constant pressure, and process bc is at constant volume. States a and b have temperatures T_a = 205K and T_b = 320K .

(cycle process)

Part A

What is the work W for the process ca?

ANSWER:

$W = -Q - 2\cdot 8.314(T_b - T_a) = -2660$ J

$W_{ca} = -750 - 2\times 8.314(320-205)$

$Q = \cancel{\Delta U}^{\,0} + W$ constant V

$-750 = W_{ab} + \cancel{W_{bc}} + W_{ca}$

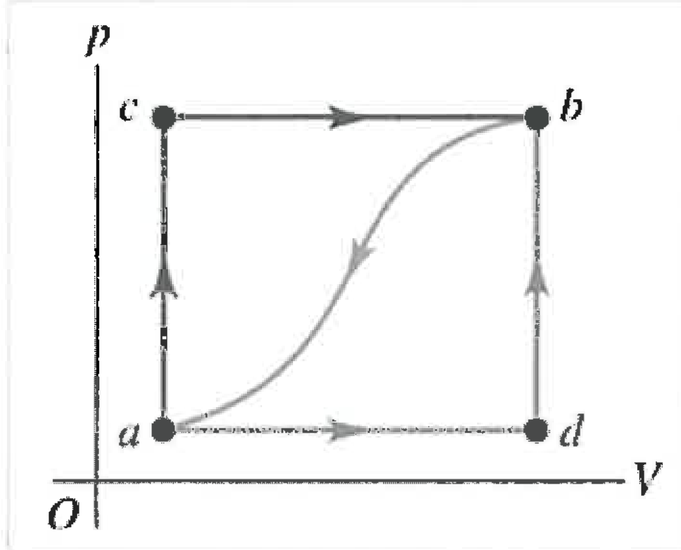
$W_{ab} = \int_a^b p\,dV = p(V_b - V_a) = p\Delta V$

$= nR\Delta T = 2\times 8.314(320-205)$

Problem 19.41

Description: When a system is taken from state a to state b in the figure along the path acb, Q of heat flows into the system and W_1 of work is done by the system. (a) How much heat flows into the system along path adb if the work done by the system...

When a system is taken from state a to state b in the figure along the path acb, 95.0J of heat flows into the system and 63.0J of work is done by the system.



for $a \to c \to b$

$Q = \Delta U + W$

$95 = (U_b - U_a) + 63$

$U_b - U_a = 32\ (J)$

Part A

How much heat flows into the system along path adb if the work done by the system is 20.0J ?

ANSWER:

$Q = Q - W_1 + W_2 = 52.0$ J

$a \to d \to b$

$Q = \Delta U + W$

$= (U_b - U_a) + 20$

$= 32 + 20 = 52$

Part B

When the system is returned from b to a along the curved path, the absolute value of the work done by the system is 34.0J . How much heat does the system liberate?

ANSWER:

$Q = -(-(Q - W_1) - W_3) = 66.0$ J

$b \to a$ (curved)

$Q = \Delta U + W$

$Q = (U_a - U_b) + (-34)$

$= -32 - 34 = \cancel{66}\ -66\ (J)$

negative work

$\because$ V decreases

Part C

If the internal energy is zero in state a and 13.0J in state d, find the heat absorbed in the processes ad.

ANSWER:

$Q = U_d + W_2 = 33.0$ J

$a \to d$

$Q = \Delta U + W$

$= U_d - U_a + \underline{p \Delta V}$ $\Rightarrow$ same work done as $a \to d \to b$ $\Rightarrow 20$

$= 13 - 0 + 20$

$= 33\ (J)$

Part D

Find the heat absorbed in the processes db.

ANSWER:

$Q = Q - W_1 - U_d$ = 19.0 J

(∵ constant V)

$d \to b$

$Q = \Delta U + \cancel{W}^{\,0}$

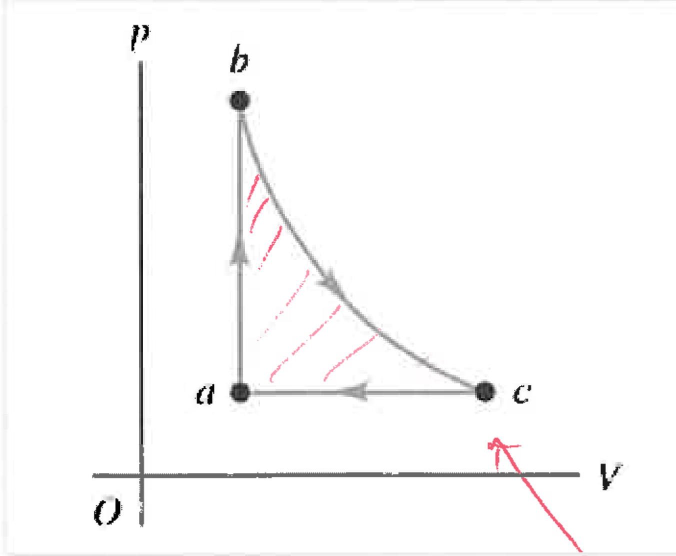
$= U_b - U_d = 32 - 13 = 19\ (J)$

$U_b - U_a = 32$

Problem 20.43

Description: A heat engine operates using the cycle shown in the figure . The working substance is 2.00 moles of helium gas, which reaches a maximum temperature of 327 degree(s) C. Assume the helium can be treated as an ideal gas. Process bc is isothermal. The...

A heat engine operates using the cycle shown in the figure . The working substance is 2.00 moles of helium gas, which reaches a maximum temperature of 327 $^\circ\mathrm{C}$. Assume the helium can be treated as an ideal gas. Process bc is isothermal. The pressure in states a and c is $1.00 \times 10^5\,\mathrm{Pa}$ and the pressure in state b is $3.00 \times 10^5\,\mathrm{Pa}$.



Part A

How much heat enters the gas each cycle?

ANSWER:

2.10×10^4 J

~~a → b → c ← cycle~~

~~$Q = \Delta U + W$ ← dashed area~~

~~$W = \int_b^c p\,dV$ — $P_c \cdot (V_a - V_c)$~~

see attached sheet

Part B

How much heat leaves the gas each cycle?

ANSWER:

1.66×10^4 J

see attached sheet

Part C

How much work does the engine do each cycle?

Express your answer using two significant figures.

ANSWER:

$W = W_{bc} + W_{ca}$

$= nRT_c \ln \frac{V_c}{V_b} + P_c (V_a - V_c)$

W = 4300 J

Also accepted: 4400

Part D

What is the efficiency of this engine?

$e = \frac{W}{|Q_H|} = \frac{\text{part C}}{\text{part A}}$

Express your answer using two significant figures.

ANSWER:

e = 21 %

Part E

What is the maximum possible efficiency attainable with the hot and cold reservoirs used by this cycle?

Express your answer using two significant figures.

carnot cycle is the max e

ANSWER:

$e_{Carnot} = \frac{T_H - T_C}{T_H} = \frac{(327+273) - \quad}{327+273}$

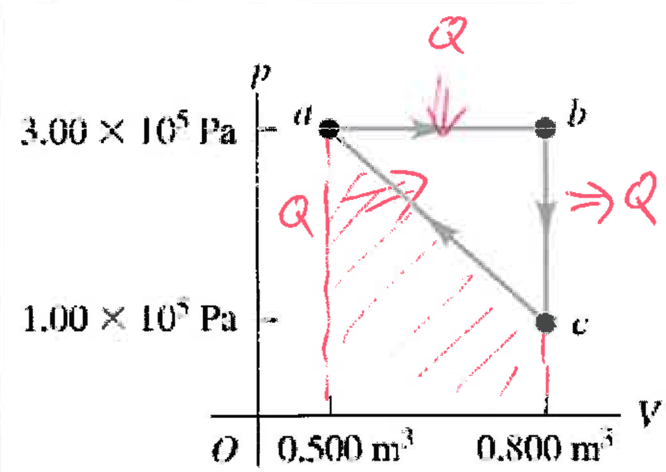
e = 67 %

$T_C = T_a = \frac{P_a V_a}{nR}$

Problem 20.51

Description: A monatomic ideal gas is taken around the cycle shown in the figure in the direction shown in the figure. The path for process c rightarrow a is a straight line in the pV-diagram. (a) Calculate Q for the process a rightarrow b. (b) Calculate W for...

A monatomic ideal gas is taken around the cycle shown in the figure in the direction shown in the figure. The path for process $c \rightarrow a$ is a straight line in the pV-diagram.



Part A

Calculate Q for the process $a \to b$.

ANSWER:

Q = 2.25×10^5 J

$a \to b$

$Q_{ab} = \Delta U_{ab} + W_{ab}$

$= \frac{3}{2} nR \Delta T_{ab} + P_a (V_b - V_a)$

$= \frac{3}{2} P_a (V_b - V_a) + P_a (V_b - V_a)$

$= \frac{5}{2} P_a (V_b - V_a)$

Part B

Calculate W for the process $a \to b$.

ANSWER:

W = 9.00×10^4 J

$W_{ab} = P_a (V_b - V_a)$

Part C

Calculate ΔU for the process $a \to b$.

ANSWER:

ΔU = 1.35×10^5 J

$\Delta U_{ab} = \frac{3}{2} P_a (V_b - V_a)$

Part D

Calculate Q for the process $b \to c$.

ANSWER:

Q = -2.40×10^5 J

$b \to c$

$Q_{bc} = \Delta U_{bc} + \cancel{W_{bc}} \to 0$ $\Delta V = 0$

$= \frac{3}{2} nR \Delta T_{bc} = \frac{3}{2} V_b (P_c - P_b)$

Part E

Calculate W for the process $b \to c$.

ANSWER:

W = 0 J

$\Delta V = 0 \Rightarrow W = 0$

Part F

Calculate ΔU for the process $b \to c$.

ANSWER:

ΔU = -2.40×10^5 J

$\frac{3}{2} V_b (P_c - P_b)$

Part G

Calculate Q for the process $c \to a$.

ANSWER:

Q = 4.50×10^4 J

$c \to a$

$Q_{ca} = \Delta U_{ca} + W_{ca}$

$= \frac{3}{2} nR\Delta T_{ca} + \frac{(P_a+P_c)}{2} \times (V_a - V_c)$

$= \frac{3}{2}(P_aV_a - P_cV_c) + \frac{(P_a+P_c)}{2}(V_a - V_c)$

Part H

Calculate W for the process $c \to a$.

ANSWER:

W = −6.00×10^4 J

$W_{ca} = \frac{P_a+P_c}{2}(V_a - V_c)$

Part I

Calculate ΔU for the process $c \to a$.

ANSWER:

ΔU = 1.05×10^5 J

$\Delta U_{ca} = \frac{3}{2}(P_aV_a - P_cV_c)$

Part J

What is Q for one complete cycle?

ANSWER:

Q = 3.00×10^4 J

Q = part A + part D + part G

Part K

What is W for one complete cycle?

ANSWER:

W = 3.00×10^4 J

W = part B + part E + part H

Part L

What is ΔU for one complete cycle?

ANSWER:

ΔU = part C + part F + part I

$= 0$

ΔU = 0 J

Part M

What is the efficiency of the cycle?

ANSWER:

e = 11.1 %

$e = \frac{W}{|Q_H|} = \frac{\text{part K}}{\text{part A + part G}}$

note: Q_c = part D ($Q < 0$ in part D)

Problem 20.37

Description: A certain heat engine operating on a Carnot cycle absorbs Qh of heat per cycle at its hot reservoir at Th and has a thermal efficiency of e. (a) How much work does this engine do per cycle? (b) How much heat does the engine waste each cycle? (c)...

A certain heat engine operating on a Carnot cycle absorbs 146J of heat per cycle at its hot reservoir at 130$^\circ \mathrm{C}$ and has a thermal efficiency of 23.0$\%$.

Part A

How much work does this engine do per cycle?

ANSWER:

W = W = 33.6 J

$Q_H = 146$

$e_{\text{Carn}} = 23\% = \frac{W}{|Q_H|}$

$\Rightarrow W = 146 \times 0.23$

Part B

How much heat does the engine waste each cycle?

ANSWER:

Q = $-Q_c$ = -112 J

$Q_c = Q_H - W$

$= 146 - 33.6$

Part C

What is the temperature of the cold reservoir?

ANSWER:

T_c = T_c = 37.3 $^\circ C$

$e_{\text{Carnot}} = \frac{T_H - T_c}{T_H} = 0.23 = \frac{(273)+130-T_c}{(130+273)}$

Part D

By how much does the engine change the entropy of the world each cycle?

ANSWER:

ΔS = 0 J/K

carnot cycle ~~has~~ all reversible processes $\Rightarrow \Delta S = 0$.

Part E

What mass of water could this engine pump per cycle from a well 37.0m deep?

each cycle $W = 33.6$

ANSWER:

m = m = 92.6 g

$\Delta U = mgh = m \times 9.8 \times 37 = 33.6$

potential energy of water

Problem 17.78

part A

$$v = \lambda \cdot f = \sqrt{\frac{T}{\mu}}$$

$$f = \sqrt{\frac{T}{\mu}}\,\frac{1}{\lambda} \quad ; \quad \lambda = 2L, \quad \mu = \frac{m_{cu}}{L}$$

$$= \sqrt{\frac{T}{m_{cu}}}\,\frac{1}{2L} \times \sqrt{L}$$

$$= \sqrt{\frac{T}{m_{cu}}}\,\frac{1}{2\sqrt{L}}$$

$$\Delta f = f' - f = \sqrt{\frac{T}{m_{cu}}}\,\frac{1}{2\sqrt{L'}} - \sqrt{\frac{T}{m_{cu}}}\,\frac{1}{2\sqrt{L}}$$

$$L' = L + \Delta L = L + \alpha L \Delta T = (1+\alpha\Delta T)L$$

$$\Delta f = \frac{\sqrt{T}}{\sqrt{m_{cu}}}\,\frac{1}{2\sqrt{L}}\left(\frac{1}{\sqrt{1+\alpha\Delta T}} - 1\right)$$

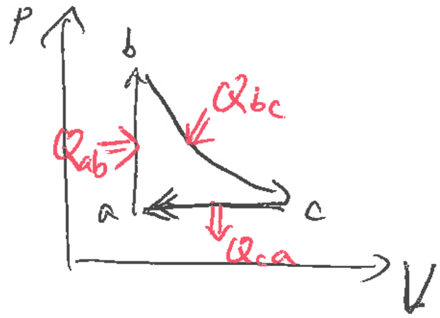
>1

part B

<1

<0

problem 20.43



$Q_{ab} > 0$

$Q_{bc} > 0$

$Q_{ca} < 0$

part A

$$Q_{in} = Q_{ab} + Q_{bc}$$

$a \to b$

$$Q_{ab} = \Delta U_{ab} + \cancel{W_{ab}}^{\,0} \quad (\Delta V = 0)$$

$$= U_b - U_a = \frac{3}{2} nR (T_b - T_a)$$

$$= \frac{3}{2} V_b (P_b - P_a)$$

$$V_b = \frac{nRT_b}{P_b} = \frac{2 \times 8.314 \times (327+273)}{3 \times 10^5}$$

$b \to c$

$$Q_{bc} = \cancel{\Delta U_{bc}}^{\,0} + W_{bc}$$

$\Delta T = 0$

$$= \int_b^c p\,dV = \int_b^c \frac{nRT}{V} dV = nRT \ln \frac{V_c}{V_b}$$

$$V_c = \frac{nRT_c}{P_c} = \frac{2 \times 8.314 \times (327+273)}{1 \times 10^5}$$

part B

$c \to a$

$$Q_{ca} = \Delta U_{ca} + W_{ca}$$

$$= \frac{3}{2} nR \Delta T_{ca} + P_c \cdot \Delta V$$

$V_a = V_b$

$$= \frac{3}{2} P_c \Delta V + P_c \Delta V = \frac{5}{2} P_c (V_a - V_c)$$