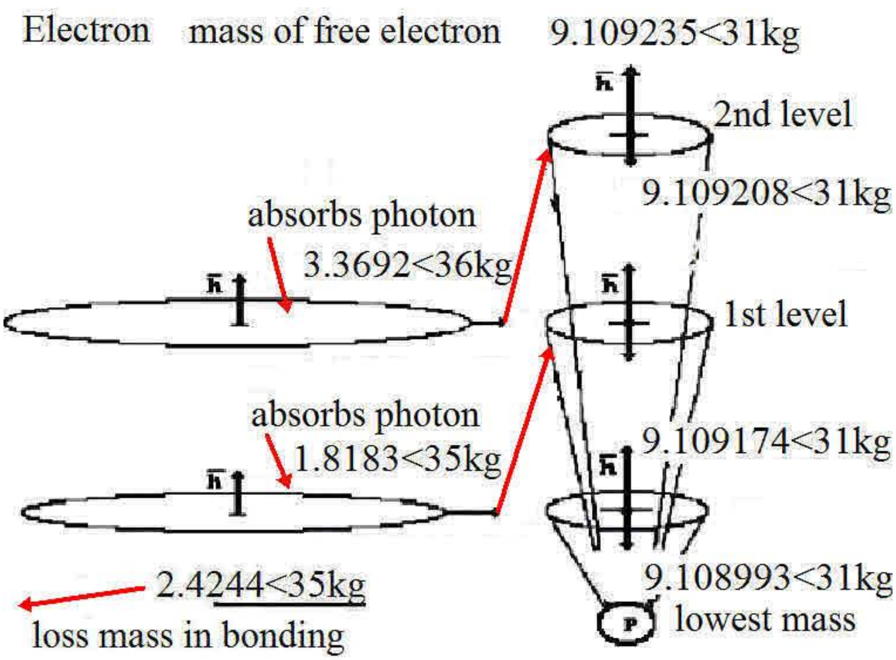
$(\varepsilon\alpha)$: $\varepsilon(emission)$ $\alpha(absorption)$ (OLD: 1st Law of Thermodynamics)

NEW: 1st Equation $[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}]$

- The emission and absorption of photons by electron in atoms and molecules creates the temperature difference in atoms and molecules.

Photon **emission** always **decreases** the **mass, frequency** and **temperature** and increases the radius of an electron in an atom or molecule.

Photon absorption always increases the mass, frequency and temperature and **decreases** the **radius** of an electron in an atom or molecule.



2nd level radius is larger than 1st lever radius

1st lever radius is larger than the lowest level radius

Largest radius of an electron in an atom or molecule.

A	B	C: (A-B=C)	
kg	kg	kg	
mass free electron	loss mass in bonding	lowest mass	
9.109235E-31	2.42440E-35	9.108993E-31	*MfT* decrease *r* increases
		C: (A+B-C)	
Lowest mass	absorb photon	1st level	
9.108993E-31	1.81830E-35	9.109174E-31	*MfT* increase *r* decreases
Lowest mass	absorb photon	2nd level	
9.108993E-31	3.3692E-36	9.109026E-31	*MfT* increase *r* decreases

When two objects have the same temperature, the electrons of the objects absorb and emit photons of the same mass, radius and frequency.

The Absolute Temperature of an ideal gas is a measure of its $(M\vec{a}d)$ per molecule. The motion of the atoms and molecules is dependent only on the temperature.

$\left[(1/2 M\vec{v}_{rms}^2 = 3/2 kT) \;\; \therefore \;\; (M\vec{v}_{rms}^2 = 3kT)\right]$ Solving for T: $\left[T = \frac{M\vec{v}_{rms}^2}{3k}\right]$

$$\left[\begin{array}{l} T = \frac{M\vec{v}_{rms}^2}{3k} = \frac{(M)\overbrace{(m/s^2)(m)}^{\vec{v}^2}}{(3)(1.381 > 23\frac{(kg)(m/s^2)(m)}{(T)}} = \frac{(M)\overbrace{(m/s^2)(m)}^{\vec{v}^2}}{4.143 > 23\frac{(kg)(m/s^2)(m)}{(T)}} \\ = \left(2.414 > 22\frac{T}{(kg)(m/s^2)(m)}\right)(M)(m/s^2)(m)\left[\overbrace{(kg)(m/s^2)(m)}^{M\vec{a}d\ units}\right] = 2.414 > 22(M\vec{v}^2) \end{array}\right]$$

$$\left[T = 2.414 > 22 Mv_{rms}^2 \overbrace{(M)(m/s^2)(m)}^{M\vec{a}d-units} = 2.424 > 22 Mv_{rms}^2\right]$$

The relation between: $\left[\begin{array}{l} (k = 1.381 > 23\frac{(kg)(m/s^2)(m)}{(T)}), \\ (R = 8314\frac{(kg)(m/s^2)(m)}{(kmol)(T)}), \\ (\#_A = 6.0222 > 26\frac{particles}{kmol}) \end{array}\right]$ is:

$$\left[k = \frac{R}{\#_A} = \frac{8314\frac{(kg)(m/s^2)(m)}{(kmol)(T)}}{6.0222 > 26\frac{particles}{kmol}} = 1.381 < 23\frac{(kg)(m/s^2)(m)}{T}\right]$$ Boltzmann's constant

Calculations: $\left[T = 2.424 > 22 M\vec{v}_{rms}^2\right]$

Hydrogen: H2 molecule: $(M = 3.34745 < 27 kg)$

When $(\vec{v}_{rms} = 1840\, m/s)$

$$\begin{bmatrix} T = 2.424 > 22 M\vec{v}_{rms}^2 = (2.424 > 22)(3.34745 < 27)(1840)^2 \\ = (2.424 > 22)(3.34745 < 27)(3385600) = 274.72^o T \end{bmatrix}$$

When $(\vec{v}_{rms} = 1923 m/s)$

$$\begin{bmatrix} T = 2.424 > 22 M\vec{v}_{rms}^2 = (2.424 > 22)(3.34745 < 27)(1923)^2 \\ = (2.424 > 22)(3.34745 < 27)(3697929) = 300^o T \end{bmatrix}$$

When $(\vec{v}_{rms} = 19230\, m/s)$

$$\begin{bmatrix} T = 2.424 > 22 M\vec{v}_{rms}^2 = (2.424 > 22)(3.34745 < 27)(19230)^2 \\ = (2.424 > 22)(3.34745 < 27)(369792900) = 30000^o T \end{bmatrix}$$

$$\begin{bmatrix} T = 2.424 > 22 M\vec{v}_{rms}^2 \quad \therefore \quad \vec{v}_{rms} = \sqrt{(4.1254 < 23)\frac{T}{M}} \\ \vec{v}_{rms} = 6.4229 < 12\sqrt{\frac{T}{M}} \end{bmatrix} \qquad \left[\vec{v}_{rms} = 6.4229 < 12\sqrt{\frac{T}{M}}\right]$$

When $(T = 273.15^o)$ for H2, what is $(\vec{v}_{rms})$?

$$\left[\vec{v}_{rms} = 6.4229 < 12\sqrt{\frac{273.15^o}{3.34745 < 27 kg}} = (6.4229 < 12)(28.5656 > 13\ ^o/kg) = 1834.74\, m/s\right]$$

When photons are absorbed or emitted by the electrons of atoms or molecules, there is a change in the $(M\vec{a}d)$ of the system of atoms and molecules. In a small expansion (ΔV), a fluid with a constant pressure $(P = M\vec{a}/A = M\vec{a}/m^2 = (kg)(m/s^2)/m^2)$ changes it $(M\vec{a}d)$ by: $[(M_{ab}\vec{a}d)_{in} = (M\vec{a}d/A_{area})(\Delta V)_{in} = (P\Delta V)_{in}]$ Photons absorption

$[(M_{em}\vec{a}d)_{out} = (M\vec{a}d/A_{area})(\Delta V)_{out} = (P\Delta V)_{out}]$ Photons emitted

The initial equation of photon absorption and emission is a statement on the conservation of $(M\vec{a}d)$. It states that if the electrons of atoms and molecules absorb photons and increases its $(M\vec{a}d)$, then the $(M\vec{a}d)$ must appear as increased internal $(M\vec{a}d)$ for the system and/or $[(M_{em}\vec{a}d)_{out}]$ done by the system on its surroundings.

The 1st equation is:

$$\left[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}\right]$$ Units are $\left[(kg)(m/s^2)(m)\right]$.

There are three variables:

- Constant pressure: $(P = M\vec{a}/A = M\vec{a}/m^2 = (kg)(m/s^2)/m^2)$
- Constant volume: (V_{volume})
- Constant temperature: $(T_{temperature-absolute})$

In a constant (V_{volume}) process with a gas, where $(\Delta V = 0)$

$$\left[\begin{array}{l}(M_{ab}\vec{a}d)_{in} \text{ or } (M_{em}\vec{a}d)_{out} = (M\vec{a}d/A_{area})(\Delta V) \\ = (M\vec{a}d/A_{area})(0) = 0\end{array}\right]$$

The initial equation becomes: $[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$

Any photons absorbed by the electrons of the atoms or molecules appear as increased internal $(M\vec{a}d)$ of the system.

In a constant $(T_{temperature})$ process with an ideal gas, where $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ is equal to zero.

For an ideal gas, the initial equation becomes:

$$[\varepsilon\alpha = (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}]$$

NOTE: Chapter 20 of Schaum's Outline, page 143, they state: However this is not true for many other systems. For example, $(\Delta U \neq 0)$ as ice melts to water at 0°C, even though the process is isothermal.
JK: Using the current knowledge supplied by Prof Kanarev, this now has a logical explanation: The process is NOT isothermal. Photons are being absorbed by the water molecules. There is no measureable temperature change until the ice melts.

For an ideal gas changing from $[P_1V_1 \text{ to } P_2V_2]$ Where $[P_1V_1 = P_2V_2]$,

$$\left[\varepsilon\alpha = (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out} = P_1V_1 \ln(\frac{V_2}{V_1}) = (2.3)P_1V_1 \log(\frac{V_2}{V_1})\right]$$

$(\ln base\ (e))$ and $(\log\ base\ 10)$.

In a process where the photons absorbed is equal to:

- the photons emitted by the system, where $(\Delta\varepsilon\alpha = 0)$
- the (P) or (V) change exactly equals the absorption or emission of photons.

$$[0 = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}]$$

Any $(M_{em}\vec{a}d)_{out}$ decreases the internal $(M\vec{a}d)$ of the system.

Any $(M_{ab}\vec{a}d)_{in}$ increases the internal $(M\vec{a}d)$ of the system.

For an ideal gas changing from conditions (P_1,V_1,T_1) to (P_2,V_2,T_2) when $(\varepsilon\alpha = 0)$, then:

$\left[P_1(V_1^{H^s_{cP}/H^s_{cV}}) = P_2(V_2^{H^s_{cP}/H^s_{cV}})\right]$ and $\left[T_1V_1^{(H^s_{cP}/H^s_{cV})-1} = T_2V_2^{(H^s_{cP}/H^s_{cV})-1}\right]$

Specific Heats of Gases:
When a gas absorbs photons at a *constant volume* (V), all the photons go into increasing the (T) and the $(\vec{v}_{rms})$ of the gas molecules.
When the gas absorbs photons at *constant* (P), the photons go into increasing the (T) and the $(\vec{v}_{rms})$ of the gas molecules and performs mechanical $(M\vec{a}d)$ by increasing the volume of the gas against the opposing *constant* (P).

Result: The specific heat of a gas at (H^s_{cP}) is greater than its specific heat at (H^s_{cV}).

For an ideal gas of molecular weight $(W)(\frac{kg}{kmol})$:

$\left[(H^s_{cP}) - (H^s_{cV}) = \frac{R}{W}\right]$ Ideal Gas $\left[R = 8314\frac{(kg)(m/s^2)(m)}{(kmol)(T)}\right]$

Specific Heat Ratio $\left[(H^s_{cP})/(H^s_{cV})\right]$: This ratio is greater than unity for a gas $\left[(H^s_{cP})/(H^s_{cV}) > 1\right]$.

For single-atom gases (such as He, Ne, Ar), $\left[(H^s_{cP})/(H^s_{cV}) = 1.67\right]$.

For two-atom gases (such as H2,O2,N2), $\left[(H^s_{cP})/(H^s_{cV}) = 1.40\right]$.
Both the single-atom and the two-atom gases are at ordinary temperatures.

$(M\vec{a}d)$ IS RELATED TO AREA in a (PV) diagram. The $(M\vec{a}d)$ done by a fluid in an expansion is equal to the area beneath the expansion curve on a (PV) diagram.
In a cyclic process, the output $(M\vec{a}d)$ per cycle done by a fluid is equal to the area enclosed by the (PV) diagram representing the cycle.

THE EFFICIENCY OF A HEAT ENGINE is defined as:

$$\left[eff = \frac{(M\vec{a}d)output}{(M\vec{a}d)input} \right]$$

The Carnot cycle is the most efficient cycle possible for a heat engine.

An engine using this cycle between a hot reservoir (T_h) and a cold reservoir (T_c) has an efficiency of:

$$\left[eff_{\max} = 1 - \frac{T_c}{T_h} \right]$$ Absolute Temperature must be used.

Since (T_{hot}) is greater than (T_{cold}), efficiency will be less than one.
Efficiency cannot be 100%.

PROBLEMS

1: In a certain process, $\left[8,000cal = 33,472(kg)(m/s^2)(m)\right]$ of heat is absorbed by the system while the system emits $(6,000(kg)(m/s^2)(m))$ of $(M\vec{a}d)$.

?: How much did the internal $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ of the system change during the process?

A: $\left[\varepsilon\alpha = (8000cal)(4.184(kg)(m/s^2)(m)/cal) = 33472(kg)(m/s^2)(m)\right]_{in}$ IN

And

$\left[(M\vec{a}d)_{out} = 6000(kg)(m/s^2)(m)\right]$OUT

Using the initial equation: $\left[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}\right]$

$\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = \varepsilon\alpha - (M_{em}\vec{a}d)_{out} = 33472 - 6000 = 27.472(kg)(m/s^2)(m)\right]$

2: The specific heat of water is $\left[1\dfrac{cal}{g^{o}C}\right]$.

?: How many $\left[(kg)(m/s^2)(m)\right]$ does the $\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}\right]$ of $(50g)$ of water change as it is heated from $(21^{o}C \ \ to \ \ 37^{o}C)$?

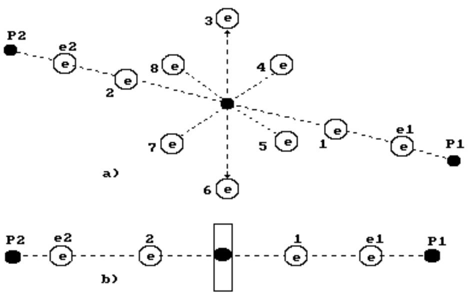
A: To heat water, the absorption of photons is:

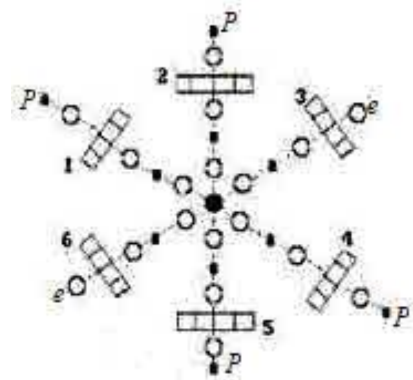
$$\left[\varepsilon\alpha=(1\frac{cal}{g^{o}C})(M)(\Delta T)=(1\frac{cal}{g^{o}C})(50g)(16^{o})=800cal\right] IT\ \ units$$

$$\left[(800cal)\left(4.184\frac{(kg)(m/s^2)(m)}{cal}\right)=3350(kg)(m/s^2)(m)\right] SI\ \ units$$

If we ignore the slight expansion of the water $[(\Delta V)=0 \text{ in } (M\vec{a}d/A_{area})(\Delta V)]$, then initial equation becomes: $\left[\varepsilon\alpha=(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}=3350(kg)(m/s^2)(m)\right]$.

JK: Because ice expands when it freezes, the volume increases. When ice melts to water, its volume decreases. Simple experiment: melt ice in small container of water; its volume will decrease.





Kanarev: When the water molecule is cooled, the six ring electrons of the oxygen atom emit photons and move closer to the oxygen nuclei. When water reaches the freezing temperature, the ring electrons move even closer to the oxygen nuclei and the axial electrons are pushed farther away. This is why water expands when it is cooled below the freezing point of water. The emission of electrons causes the water molecule to lose mass. This is why ice is lighter than liquid water and floats.

3-?: How much does the $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ change when $(5g)$ of ice at (0^oC) increase as it is changed to water at (0^oC)?

A: In order to melt the ice, photons must be absorbed by the ice molecules.

Experiments show that it takes $(80\,cal/g)$ to melt ice at (0^oC).

$$\left[\varepsilon\alpha = MH_f = (5g)(80\,cal/g) = 400cal\right]$$

No $(M_{em}\vec{a}d)_{out}$ photons were emitted; therefore $[(M_{em}\vec{a}d)_{out} = 0]$

The quantity of photons absorbed is described by the equation:

$$\begin{bmatrix} \varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out} \\ \varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} \end{bmatrix}$$

$$\left[(M_{ab}\vec{a}d)_{in} = (400cal)\left(\frac{4.184(kg)(m/s^2)(m)}{cal}\right) = 1670(kg)(m/s^2)(m)\right]$$

$$\left[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + 1670(kg)(m/s^2)(m)\right]:$$

Therefore $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ increases by $\left[1670(kg)(m/s^2)(m)\right]$

NOTE: Schaum's uses the $(\Delta Q = \Delta U + \Delta W)$. They state that $(\Delta W = 0)$. This is a major fault of this equation. Only (ΔW) OUT is equal to zero. (ΔW) IN is NOT equal to zero. Photons are absorbed by the ice molecules.

4: An $(8g = 0.008kg)$ metal bullet $(c = 0.16 cal/g^oC)$ has a velocity of $(70 m/s)$ when it strikes a block of wood and lodges in it.

?: If (60%) of the $(M\vec{a}d)$ in stopping the bullet goes into photon absorption by the metal, how much will the bullet's temperature rise?

A: Using the conversation of $(M\vec{a}d)$,

$$\left[(M\vec{a}d)_{in} = 1/2mv^2 = (1/2)(0.008kg)(70 m/s)^2 = 19.6(kg)(m/s^2)(m)\right]$$

(60%) goes into photon absorption by the metal.

$$\left[\varepsilon\alpha = (0.60)(19.6(kg)(m/s^2)(m)) = 11.8(kg)(m/s^2)(m)\right]$$

Converting $(kg)(m/s^2)(m)$ to (cal):

$$\left[\varepsilon\alpha = (11.8(kg)(m/s^2)(m))\left(\frac{1cal}{4.184(kg)(m/s^2)(m)}\right) = 2.81cal\right]$$

Using equation:

$$\left[\varepsilon\alpha = cM\Delta T \quad \text{or} \quad \Delta T = \frac{\varepsilon\alpha}{cM} = \frac{2.81cal}{(0.16 cal/g^oC)(8g)} = 2.2^oC\right]$$

$$\left[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}\right]$$

5-?: Find $[(M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}]$ andfor a $(6cm = 0.06m)$ cube of iron as it is heated from $(20^{o}C\ to\ 300^{o}C)$.

- Iron: $\left[c = 0.11 cal/g^{o}C\right]$
- Volume coefficient of thermal expansion (cote) is: $(\beta = 3.6 < 5/{}^{o}C)$
- The mass of the cube is: $(1700g)$

A: $\left[\varepsilon\alpha = cM\Delta T = (0.11 cal/g^{o}C)(1700g)(280^{o}C) = 52000 cal\right]$

The volume of the cube is: $\left[V = (6cm)^{3} = 216cm^{3}\right]$

From the (cote), $\left[\Delta V = V\beta\Delta T = (2.16 < 6m^{3})(3.6 < 5/{}^{o}C)(280^{o}C) = 2.18 < 6m^{3}\right]$

At an atmospheric pressure of $(1 > 5(kg)(m/s^{2})/m^{2})$

$$\left[(M_{ab}\vec{a}d)_{in} = (M\vec{a}/m^{2})(\Delta V) = (1 > 5(kg)(m/s^{2})/m^{2})(2.18 < 6m^{3}) = 0.22(kg)(m/s^{2})(m)\right]$$

From the initial equation:

$$\left[\begin{aligned} &(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = \varepsilon\alpha - (M_{ab}\vec{a}d)_{in} \\ &= (52000 cal)((4.184(kg)(m/s^{2})(m)/cal) - 0.22(kg)(m/s^{2})(m) \\ &= 218000(kg)(m/s^{2})(m) - 0.22(kg)(m/s^{2})(m) \approx 218000(kg)(m/s^{2})(m) \end{aligned}\right]$$

Observe that the volume expansion against atmospheric $(M\vec{a}/m^{2})$ is very small. Often, the volume expansion can be neglected when dealing with liquids and solids.

Units: Although BTU and Horsepower are the units of choice in commercial use, they are not very useful for doing scientific calculations. Some problems using these units will be converted to SI units.

$$\begin{bmatrix} 1lb = 0.453592kg & 1kg = 2.204624lb \\ 1[Btu/lb] = 2326[(kg)(m/s^2)(m)/kg] & 1[(kg)(m/s^2)(m)/kg] = 0.0004299[Btu/lb] \\ 1[Btu] = 1055.05585[(kg)(m/s^2)(m)] & 1[(kg)(m/s^2)(m)] = 0.0009478[Btu] \\ 1\,foot = 0.3048m & 1m = 3.2808\,feet \\ 1\,ftlb = 0.13825kgm & 1kgm = 7.2333\,ftlb \\ 1\,ftlb = 0.001285927Btu & 1Btu = 778\,ftlb \quad \therefore \quad 778\,ftlb/Btu = 1 \\ 10000Btu = 10550558.5[(kg)(m/s^2)(m)] & \\ 778[ftlb/Btu] = 0.101949441[kgm/(kg)(m/s^2)(m)] & \\ 7780000\,ftlb = 1075623.55kgm & \end{bmatrix}$$

6: one pound of fuel, having a heat of combustion of $(10000\,Btu/lb)$, was burned in an engine that raised $(6000lbs)$ of water $(110\,ft)$.

Converting to SI units:

$(0.453592kg)$ of fuel, having a heat of combustion of $[2326(kg)(m/s^2)(m)/kg]$, was burned in an engine that raised $(2721.552kg)$ of water $(33.528m)$.

?: What percentage of the heat was transformed into useful $(\Delta M_{em}\vec{a}d)_{out}$?

A:

$$\begin{bmatrix} eff = \frac{(M_{em}\vec{a}d)_{out}}{(M_{ab}\vec{a}d)_{in}} = \frac{(2721.552kg)(33.528m)}{[10550558.5(kg)(m/s^2)(m)][(0.101949441kgm/(kg)(m/s^2)(m)]} \\ = \frac{91248.19546kgm}{1075623.55kgm} = 0.085 = 8.5\% \end{bmatrix}$$

Schaum's answer in Btu units.

$$\text{efficiency} = \frac{\text{work done by engine}}{\text{work equivalent of heat supplied}}$$

$$= \frac{(6000\text{ lb})(110\text{ ft})}{(10\,000\text{ Btu})(778\text{ ft}\cdot\text{lb}/\text{Btu})} = 0.085 = 8.5\%$$

$$\left[1hp = 745.699872(kg)(m/s^2)(m)/s\right]$$

7: A motor supplies $(0.4hp = 298.3(kg)(m/s^2)(m)/s)$ to stir $(5kg)$ of water.

?: If all the $(M_{ab}\vec{a}d)_{in}$ goes into friction heating, how long will it take to increase the temperature of the water by (6^oC)?

A: Heat required to heat water is:

$$\left[\varepsilon\alpha = cM\Delta T = (1cal/g^oC)(5000g)(6^oC) = 30000cal\right]$$

The friction $[(M_{ab}\vec{a}d)_{in}]$:

$$\left[\varepsilon\alpha = (30000cal)(4.184(kg)(m/s^2)(m)/cal) = 1.26 > 5(kg)(m/s^2)(m)\right]$$

This is the $[(M_{ab}\vec{a}d)_{in}]$ done by the motor.

The motor supplied $\left[298.3(kg)(m/s^2)(m)/s = 298.3\frac{(kg)(m/s^2)(m)}{t}\right]$

Time: $$\left[t = \frac{[(M_{em}\vec{a}d)_{out}]}{[(M_{ab}\vec{a}d)_{in}]} = \frac{1.26 > 5(kg)(m/s^2)(m)}{298.3(kg)(m/s^2)(m)/s} = 420s = 7\min\right]$$

$$\left[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}\right]$$
$$\left[1cal = 4.184(kg)(m/s^2)(m)/cal\right]$$

OBSERVE HOW MUCH EASIER THE MATH BECOMES WHEN YOU ELIMINATE DASHES-CROSSES IN THE MATH.

8: In each of the following situations, find the change in $\left[\Delta(M\vec{a}d)_{\text{internal}}\right]$ of the system.

(a): A system absorbs $\left[(M_{ab}\vec{a}d)_{in} = 500cal = 2092(kg)(m/s^2)(m)\right]$ and at the same time does $\left[400(kg)(m/s^2)(m)\right]$ of $\left[(M_{em}\vec{a}d)_{out}\right]$.

A: $\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{ab}\vec{a}d)_{in} - (M_{em}\vec{a}d)_{out} = 2092 - 400 = 1692(kg)(m/s^2)(m)\right]$

(b): A system absorbs $\left[(M_{ab}\vec{a}d)_{in} = 300cal = 1255.2(kg)(m/s^2)(m)\right]$ and at the same time does $\left[420(kg)(m/s^2)(m)\right]$ of $\left[(\Delta M_{em}\vec{a}d)_{out}\right]$.

A: $\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{ab}\vec{a}d)_{in1} + (M_{ab}\vec{a}d)_{in2} = 1255.2 + 420 = 1675.2(kg)(m/s^2)(m)\right]$

(c): $\left[1200cal = 5020.8(kg)(m/s^2)(m)\right]$ are removed from a gas held at constant volume.

A: $\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{em}\vec{a}d)_{out} = 5020.8(kg)(m/s^2)(m)\right]$

$$\left[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}\right]$$

9: For each of the following $(\Delta\varepsilon\alpha = 0)$ processes, find the change in.

MAJOR NOTE: In the real world, there can be NO such process as $(\Delta\varepsilon\alpha = 0)$. Electrons are continuously absorbing and emitting photons. The resultant of all the absorptions and emissions may equal to zero, but absorption and emission of photons (mass) is always taking place.

(a): A gas does $\left[5(kg)(m/s^2)(m)\right]$ of $\left[(M_{em}\vec{a}d)_{out}\right]$ while the (V_{volume}) increases.

A: In a $(\varepsilon\alpha = 0)$, emission or absorption of photons is offset by an equal change in $\left[(M\vec{a}/A) \text{ or } (V)\right]$. Only the resultant is equal to zero.

$$\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{em}\vec{a}d)_{out} \text{ while } V_{\text{expands}} = 5(kg)(m/s^2)(m) \text{ while } \Delta V_{\text{expands to offset}}\right]$$

NOTE: No dashes or crosses are need in Symmetry Math.

(b): During a $(\varepsilon\alpha = 0)$ compression, $\left[80(kg)(m/s^2)(m)\right]$ of $\left[(M_{ab}\vec{a}d)_{in}\right]$ while the (V_{volume}) decreases.

A: $\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{ab}\vec{a}d)_{in} \text{ while } V_{decreases} = 80(kg)(m/s^2)(m) \text{ while } \Delta V_{decreases\ to\ offset}\right]$

- $\left[1\,Btu/lb = 2326(kg)(m/s^2)(m)/kg\right]\left[1Btu = 252cal = 778\,ftlb = 1054(kg)(m/s^2)(m)\right]$
- The density of water at $\left[212^o F = 100^o C \text{ is } 60\,lb/ft^3 = 961.1\,kg/m^3\right]$
- $\left[1lb = 0.453592kg = (0.453592)(9.800665(kg)(m/s^2) = 4.445(kg)(m/s^2)\right]$

10: $(1lb = 0.453592kg)$ of steam at $(21^o F = -6.11^o C)$ and $(14.7\,lb/in^2 = 101352.932\ (kg)(m/s^2)/m^2)$ occupies $(26.8\,ft^3 = 0.7589m^3)$.

(a) What fraction of the observed heat of vaporization of water $[970\,Btu/lb =]$ at $(212^o F = 100^o C)$ and $(14.7\,lb/in^2 = 101352.932\ (kg)(m/s^2)/m^2)$ is accounted for by the external $(M\vec{a}d)$ done in expanding water into steam at $(212^o F = 100^o C)$ against atmospheric pressure of $(14.7\,lb/in^2 = 101352.932\ (kg)(m/s^2)/m^2)$?

A: $(1lb)$ of water occupies $\left[(1lb/60\,lb/ft^3) = 0.02\,ft^3\right]$ and expands to $(26.8\,ft^3)$ of steam under the conditions stated. The $(M\vec{a}d)$ done in expanding $(1lb)$ of water to steam at constant $(P\Delta V = 1atm)$ is: (using *Btu* and *ftlb*)

$$\left[P\Delta V = (14.7\,lb/in^2)(144\,in^2/ft^2)(26.8\,ft^3 - 0.02\,ft^3) = 56700\,ftlb\right]$$

Heat equivalent of $\left[(56700\,ft \cdot lb)(1Btu/778\,ft \cdot lb) = 73Btu\right]$

Fraction of heat of vaporization: $\left[73Btu/970Btu = 0.075 = 7.5\%\right]$

A: $(0.453592kg)$ of water occupies $(0.453592kg/961.1kg/m^3 = 0.000472m^3)$ and expands to $(0.7589m^3)$ of steam under the conditions stated. The $(M\vec{a}d)$ done in expanding $(0.453592kg)$ of water to steam at constant $(M\vec{a}/A \text{ at } 1atm)$ is: (using SI units)

$$\begin{bmatrix} (M\vec{a}/A)(\Delta V) = (101352.932\ (kg)(m/s^2)/m^2)(0.7589m^3 - 0.00057m^3) \\ = 76916.7(\text{kg})(m/s^2)(m) \end{bmatrix}$$

Heat equivalent of $\left[76916.7(\text{kg})(m/s^2)(m)\right]$: NOTE: no conversion in SI units.

Fraction of heat of vaporization:

$$\begin{bmatrix} 76916.7(\text{kg})(m/s^2)(m)/\left[(1054)(\text{kg})(m/s^2)(m)/Btu\right]\left[(970)Btu\right] \\ 76916.7(\text{kg})(m/s^2)(m)(/1022380(\text{kg})(m/s^2)(m) = 0.075 = 7.5\% \end{bmatrix}$$

(b) Determine the increase in internal $(M\vec{a}d)$ when $(1lb)$ of steam is formed at $(212^o F = 100^o C)$?

A: $\left[\Delta U = \Delta Q - \Delta W = 970Btu - 73Btu = 897Btu\right]$ (using *Btu* and *ftlb*)

A: $$\begin{bmatrix} \varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out} \\ 1022380(\text{kg})(m/s^2)(m) - 76916.7(\text{kg})(m/s^2)(m) = 945463.3(\text{kg})(m/s^2)(m) \end{bmatrix}$$ (SI units)

11: The temperature of $(5kg = 5000g)$ of (N_2) gas is raised from $(10^oC = 283^oT)$ to $(130^oC = 403^oT)$.

?: If this is done at constant pressure, find the increase in $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$.

- For (N_2) gas, $(H^s_{cV} = 0.177\, cal/g \cdot^o C)$
- For (N_2) gas, $(H^s_{cP} = 0.248\, cal/g \cdot^o C)$

A: In this problem, the 1st equation is: $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{ab}\vec{a}d)_{in} - (M_{em}\vec{a}d)_{out}]$

In this problem, $\left[[(M_{em}\vec{a}d)_{out}]_{H^s_c} = 0\right]$.

Under constant pressure, the equation reduces to:

$$\begin{bmatrix} \left((M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}\right)_P = \left((M_{ab}\vec{a}d)_{in}\right)_P \\ \left((M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}\right)_P = (M)(H^s_{cP})(\Delta T) \end{bmatrix}$$

For the same temperature increase at constant volume.

$$\begin{bmatrix} [(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]_V = [(M_{ab}\vec{a}d)_{in}]_V \\ [(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]_V = (M)(H^s_{cV})(\Delta T) \end{bmatrix}$$

For the same change in temperature at constant pressure, the increase in volume equals $((M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha})_P$: $\left[[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]_P = [(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]_V\right]$

Subtracting the two equations yields the $(M_{ab}\vec{a}d)_{in}$:

$$\left[(M)(H^s_{cP} - H^s_{cV})(\Delta T) = f(5000g)(0.248 - 0.177\, cal/g \cdot^o C)(120oC) = 43 > 3cal\right]$$

The increase in $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ at constant pressure or volume is:

$$\begin{bmatrix} [(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]_P = [(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]_V = (M)(H^s_{cV})(\Delta T) \\ = (5000g)(0.177\, cal/g \cdot^o C)(120oC) = 106 > 3cal \end{bmatrix}$$

12: For (N_2) gas, find its specific heat (H^s_{cP}) at constant pressure.

- $(H^s_{cV} = 0.177\, cal/g \cdot^o C)$
- $(W = 28.0\, kg/kmol)$
- $\left[R = 8314 \frac{(kg)(m/s^2)(m)}{(kmol)(T)}\right]$

A: Method 1

$$\left[\begin{aligned}&(H^s_{cP}) = (H^s_{cV}) + \frac{R}{W}\\ &= (0.177\frac{cal}{g \cdot^o C}) + \left(\frac{8314\frac{(kg)(m/s^2)(m)}{(kmol)(T)}}{28\frac{kg}{kmol}}\right)\left(\frac{1cal}{4.184(kg)(m/s^2)(m)}\right)\left(\frac{1kg}{1000g}\right)\\ &= 0.177\frac{cal}{g \cdot^o C} + 0.071\frac{cal}{g \cdot^o C} = 0.248\frac{cal}{g \cdot^o C}\end{aligned}\right]$$

Method 2

Since (N_2) is a diatomic gas and since $\left(\frac{H^s_{cP}}{H^s_{cV}} \approx 1.40\right)$ for such a gas,

$$\left[H^s_{cP} = (1.400(H^s_{cV}) = (1.40)\left(0.177\frac{cal}{g \cdot^o C}\right) = 0.248\frac{cal}{g \cdot^o C}\right]$$

13: How much $(M_{ab}\vec{a}d)_{in}$ is done by an ideal gas in expanding, under constant temperature, from an initial volume of $(3liters = 3 < 3m^3)$ at $\left(20atm = 20.2 > 5\frac{(kg)(m/s^2)}{m^2}\right)$ to a final volume of $(24liters)$.

A:

$$\left[\begin{aligned}&(M_{ab}\vec{a}d)_{in} = 2.3P_1V_1\log(\frac{V_2}{V_1})\\ &= (2.3)\left(20.2 > 5\frac{(kg)(m/s^2)}{m^2}\right)\left(3 < 3m^3\right)\left(\log\left(\frac{24}{3}\right)\right)\\ &= 1.26 > 4(kg)(m/s^2)(m)\end{aligned}\right]$$

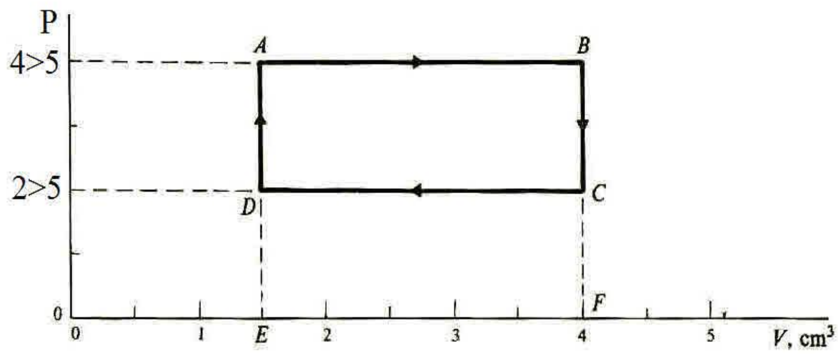
14: The (PV) diagram applies to a cyclic change in a piston-cylinder arrangement. What is the $(M\vec{a}d)$ done by the gas in portion:

a) AB?

b) BC?

c) CD?

d) DA?



A: In expansion, the $[(M_{ab}\vec{a}d)_{in}]$ is equal to the area under ABFEA of the (PV) curve. In contracting, the $[(M_{em}\vec{a}d)_{out}]$ is equal to the same area.

a) Expansion; Photon absorption.

$$\left[(M_{ab}\vec{a}d)_{in} = PV = \left((4-1.5)<6m^3\right)\left(4>5(kg)(m/s^2)/m^2\right) = 1.0(kg)(m/s^2)(m)\right]$$

b) $[(M_{ab}\vec{a}d)_{in} - (M_{em}\vec{a}d)_{out} = area\ under\ BC = 0]$ In portion BC, the volume does not change, therefore $(P\Delta V = 0)$.

c) Contraction; Photon emission.

$$\left[(M_{em}\vec{a}d)_{out} = PV = \left((4-1.5)<6m^3\right)\left(2>5(kg)(m/s^2)/m^2\right) = 0.5(kg)(m/s^2)(m)\right]$$

d) $[(M_{ab}\vec{a}d)_{in} - (M_{em}\vec{a}d)_{out} = area\ under\ \mathrm{DA} = 0]$ In portion DA, the volume does not change, therefore $(P\Delta V = 0)$.

NOTE: Schaum's labels contraction as something called a negative (whatever that could be). In a correct interpretation of the experiment, photons are absorbed and emitted. There is nothing positive or negative in the experiment.

In Symmetry-Math, there are no negatives or positives. In Symmetry-Math's explanation of physics and chemistry experiments, these misleading concepts of dashes(-) and crosses(+) to describe processes are removed.

15: For the cycle shown in problem-14, find

a) net output $(M\vec{a}d)$ of the gas during the cycle.

b) net heat flow into the gas per cycle.

A: a) Method-1

$$\left[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (M_{ab}\vec{a}d)_{in} - (M_{em}\vec{a}d)_{out} = (1-0.5) = 0.5(kg)(m/s^2)(m)\right]$$

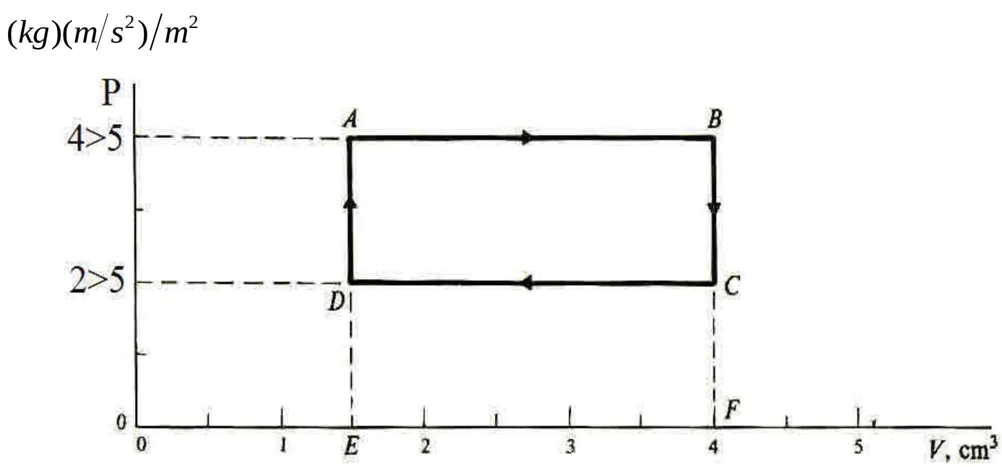
a) Method-2

The net $(M\vec{a}d)$ done is equal to the area enclosed by the (PV) diagram.

$$\left[M\vec{a}d = area\ ABCDA = \left(2 > 5(kg)(m/s^2)/m^2\right)\left(2.5 < 6m^3\right) = 0.5(kg)(m/s^2)(m)\right]$$

b) Suppose the cycle starts at point A. The gas returns to this point at the end of the cycle, so there is no difference in the gas at its start and the end point. For one compete cycle, $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ is equal to zero. Applying the first equation to a complete cycle:

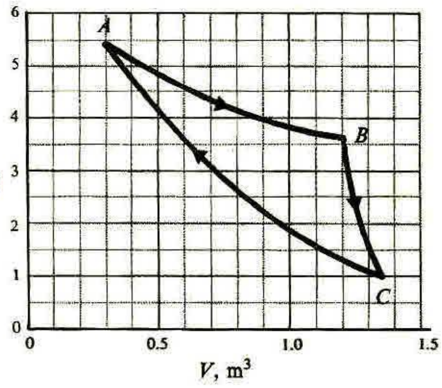
$$\begin{bmatrix} \varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out} \\ \varepsilon\alpha = (0) + (1.0) - (0.5) = 0.5(kg)(m/s^2)(m) = 0.120cal \end{bmatrix}$$



16: What is the net output $(M\vec{a}d)$ per cycle for the cycle shown?

$P\ units = (kg)(m/s^2)/m^2$

P>5



A: We know that the net output $(M\vec{a}d)$ per cycle is the area enclosed by the (PV) diagram. We estimate that in area ABCA there are approximately 22 squares.

Each square has an area of:

$$\left[\left(0.5 > 5(kg)(m/s^2)/m^2\right)(0.1m^3) = 5 > 3(kg)(m/s^2)(m)\right]$$

The area enclosed by cycle:

$$\left[Area\ enclosed \approx (22)(5 > 3(kg)(m/s^2)(m)) = 110 > 3(kg)(m/s^2)(m)\right]$$

17: $(20cm^3)$ of monatomic gas at $(12^oC = 285^oT)$ and $\left(100 > 3(kg)(m/s^2)/m^2\right)$ is suddenly (with no absorption or emission of photons $(\Delta\varepsilon\alpha = 0)$) compressed to $(0.5cm^3)$.

?” What is the new pressure and temperature?

- For single-atom gases (such as He, Ne, Ar), $\left[(H^s_{cP})/(H^s_{cV}) = 1.67\right]$.

A: Pressure:

For an ideal gas changing from conditions (P_1,V_1,T_1) to (P_2,V_2,T_2) when $(\Delta\varepsilon\alpha = 0)$, then: $\left[P_1(V_1^{H^s_{cP}/H^s_{cV}}) = P_2(V_2^{H^s_{cP}/H^s_{cV}})\right]$ and $\left[T_1V_1^{(H^s_{cP}/H^s_{cV})-1} = T_2V_2^{(H^s_{cP}/H^s_{cV})-1}\right]$

$$\left[(p_2 = P_1\left(\frac{V_1}{V_2}\right)^{H^s_{cP}/H^s_{cV}} = (1 > 5(kg)(m/s^2)/m^2)\left(\frac{20}{0.5}\right)^{1.67} = 4.74 > 7(kg)(m/s^2)/m^2\right]$$

Temperature:

$$\left[\begin{array}{l} T_2 = T_1\left(\frac{V_1}{V_2}\right)^{(H^s_{cP}/H^s_{cV})-1} = (285^oT)\left(\frac{20}{0.5}\right)^{1.67-1} = (285^oT)\left(\frac{20}{0.5}\right)^{0.67} \\ \quad = (285^oT)\left(40\right)^{0.67} = (285^oT)\left(11.84\right) = 3370^oT \end{array}\right]$$

As a check:

$$\left[\begin{array}{ccc} \frac{P_1V_1}{T_1} & = & \frac{P_2V_2}{T_2} \\ \frac{(1 > 5)(20)}{285} & = & \frac{(4.74 > 7)(0.5)}{3370} \\ 7000 & = & 7000 \end{array}\right]$$

18: Calculate the maximum efficiency of a heat engine operating between the temperatures of $(100^o C = 373^o T)$ and $(400^o C = 673^o T)$.

A: $$\left[eff_{\max} = 1 - \frac{T_c}{T_h} = 1 - \frac{373}{673} = 1 - 0.55 = 0.45 = 45\% \right]$$ Absolute T must be used

19: A steam engine operating between a boiler temperature of $(220^o C = 493^o T)$ and a condenser temperature of $(35^o C = 308^o T)$ delivers $(8hp)$.

?: If the efficiency is 30%:

a) How many calories are absorbed each second by the boiler?

b) How many calories are exhausted to the condenser each second?

A: $$\left[actual\ efficiency = (0.30)(eff_{\max}) = (0.30)\left(1 - \frac{T_c}{T_h}\right) = (0.30)\left(1 - \frac{308}{673}\right) = 0.113 \right]$$

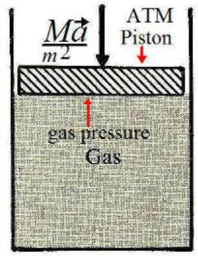
$$\left[eff = \frac{(M\vec{a}d)output}{(M\vec{a}d)input} = \frac{(8hp)(746W/hp)(\frac{1cal/s}{4.184W})}{0.113} = 12700\,cal/s \right]$$

To find the $(M\vec{a}d)$ input to the condenser, we use the conservation of $(M\vec{a}d)$.

$$\left[\begin{aligned} \frac{(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}}{s} &= \frac{(M_{ab}\vec{a}d)_{in}}{s} - \frac{(M_{em}\vec{a}d)_{out}}{s} \\ &= \frac{(M_{ab}\vec{a}d)_{in}}{s} - (1 - eff) \\ &= (12700\,cal/s)(1 - 0.113) = 11300\,cal/s \end{aligned} \right]$$

20: A cylinder of ideal gas is closed by an $(8kg)$ moveable piston with an area of $(60cm^2 = 60 < 4m^2)$. Atmospheric pressure is $\left(100 > 3(kg)(m/s^2)/m^2\right)$.

When the gas is heated from (30^oC) to (100^oC), the piston rises $(20cm = 0.02m)$.



The piston is then fastened into place and the gas is cooled back to (30^oC).

Calling $(\varepsilon\alpha)_1$ the heat absorbed by the gas in the heating process and $(\varepsilon\alpha)_2$ the heat emitted during the cooling,

? Find the difference between $(\varepsilon\alpha)_1$ and $(\varepsilon\alpha)_2$?

A: $[\varepsilon\alpha = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} + (M_{ab}\vec{a}d)_{in} + (M_{em}\vec{a}d)_{out}]$

During the heating process (photon absorption), the $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ changed and $[(M_{ab}\vec{a}d)_{in}]$ was done. The gas pressure is:

$$\left[\begin{array}{l} P = \overbrace{\left(\frac{M\vec{a}}{m^2}\right)}^{\text{gas against piston up}} + \overbrace{\left(\frac{M\vec{a}}{m^2}\right)}^{\text{atm against top of piston down}} = \frac{(8kg)(9.8m/s^2)}{60 < 4m^2} + \left(1 > 5(kg)(m/s^2)/m^2\right) \\ = 1.13 > 5(kg)(m/s^2)/m^2 \end{array}\right]$$

Volume of a cylinder is $\left[\Delta V = (area)(height) = (60 < 4m^2)(0.2m) = 12 < 4m^3\right]$

Therefore:
$$\left[\begin{array}{l} (\varepsilon\alpha)_1 = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = (P\Delta V)_{in} \\ \quad = (M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha} = ((1.13 > 5)\left((0.20)(60 < 4)\right) \\ \quad = \Delta(M\vec{a}d)_{\text{internal}} = 136(kg)(m/s^2)(m) \end{array}\right]$$

During the cooling process (photon emission), the $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ changed and $[(M_{em}\vec{a}d)_{out}]$ was done. Since the Volume is locked in and cannot change, the pressure must decrease during the photon emission and the product of (PV) must equal the $[(M\vec{a}d)_{\text{initial-internal-}\varepsilon\alpha}]$ due to returning to the initial temperature.

Therefore $(\varepsilon\alpha)_1$ exceeds $(\Delta\varepsilon\alpha)_2$ by $136(kg)(m/s^2)(m)$