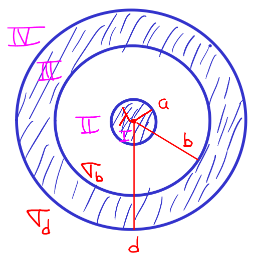
1 Cross secton of the infinite system




cylindrical conductor with line charge λ inside a cylindrical conducting shell, that was initially uncharged

we can use some of the results from Problem 3 of set 10, where the Gauß law was used to derive

$$\bar{E} = \frac{\lambda \hat{r}}{2\pi\epsilon_0 r} \quad \text{in II and IV}$$

$$\bar{E} = 0 \quad \text{in I and III}$$

The total charge of the cylindrical "wire" inside the shell is $Q = \lambda L$ where L is the length of the cylinder (we do not worry about that $L \to \infty$ that only guarantees the cylindrical symmetry of the system

a) The same amount of opposite charge must reside on the inner surface of the cylinder $\to \sigma_b = -\frac{Q}{A_b} = -\frac{\lambda L}{2\pi b L} = -\frac{\lambda}{2\pi b}$

and notice that the dimension of $\sigma_b$ must be correct, $[\sigma_b] = \frac{Q}{L^2}$

The cylinder shell was initially without charge --> $Q_b + Q_d = 0$

$$\to \sigma_d = +\frac{Q}{A_d} = +\frac{\lambda L}{2\pi d L} = +\frac{\lambda}{2\pi d}$$

b) $V_b - V_a = -\int_a^b \bar{E}\cdot d\bar{l}$, where we choose $d\bar{l} = d\bar{r}$

$$= -\int_a^b \frac{\lambda}{2\pi\epsilon_0}\frac{dr}{r} = -\frac{\lambda}{2\pi\epsilon_0}\ln(r)\Big|_a^b = -\frac{\lambda}{2\pi\epsilon_0}\ln\left(\frac{b}{a}\right)$$

$$\to V_b - V_a = -\frac{\lambda}{2\pi\epsilon_0}\ln\left(\frac{b}{a}\right)$$

c) $V_d - V_b = -\int_b^d \bar{E}\cdot d\bar{r} = 0$ as in equilibrium the electrical field is o inside a conductor



2 Dilute gas --> assume an ideal gas

$$pV = nRT$$

work done by the gas

as T = Const.

a) $$W = \int_{V_i}^{V_f} p\,dV = \int_{V_i}^{V_f} \frac{nRT}{V}dV = nRT\int_{V_i}^{V_f}\frac{dV}{V}$$

$$= nRT\ln\left(\frac{V_f}{V_i}\right) \to n = \frac{W}{RT\ln\left(\frac{V_f}{V_i}\right)}$$

$$n = \frac{100\,J}{8.31\frac{J}{mol\cdot K}\cdot 300K\,\ln\left(\frac{4.0}{1.0}\right)} = 0.029 \text{ mole}$$

b) we assume the dilute gas can be considered an ideal gas to obtain the necessary equation of state needed to calculate the work by the gas



3 $H_2O$ $\underbrace{T_i = 25°C \to 100°C}_{\text{step 1}} \to \underbrace{\text{vapor}}_{\text{step 2}}$

a) $\Delta S = \int_A^B \frac{dQ}{T}$, $m = 150g = 0{,}150$ kg

heating process at constant p, we assume we can use the information from chapter 1, Table 1.3

$$Q = m c_{H_2O}\Delta T, \quad c_{H_2O} \approx 4186 \frac{J}{kg\cdot K}$$

$$\Delta S_1 = \int_{298}^{373} m c_{H_2O}\frac{dT}{T} = m c_{H_2O}\ln\left(\frac{373}{298}\right)$$

$$= 0.150\,kg\cdot 4186\frac{J}{kg\cdot K}\cdot\ln\left(\frac{373}{298}\right)$$

$$\approx 141\frac{J}{K}$$

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b) Step 2

$$\Delta S_2 = \int_A^B \frac{dQ}{T} \quad \text{at constant } T$$

$$= \frac{1}{T}\Delta Q = \frac{1}{T} m (L_v)_{H_2O} , \quad (L_v)_{H_2O} = 2256 \frac{kJ}{kg}$$

$$= \frac{1}{373K} \, 0.150\,kg \cdot 2256 \cdot 10^3 \frac{J}{kg}$$

$$\simeq 907 \frac{J}{kg}$$

c) The entropy increase in the vaporization process is almost 6.5 times larger as the phase change from a liquid to a gas state requires a large amount of energy. The liquid has much less entropy than the gas

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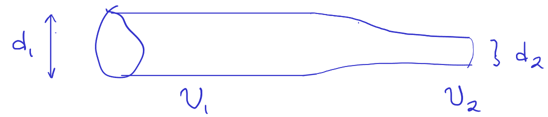


incompressible fluid

a) we use the equation of continuity

$$A_1 v_1 = A_2 v_2$$

$$\rightarrow \pi d_1^2 v_1 = \pi d_2^2 v_2$$

$$\rightarrow v_2 = v_1 \frac{d_1^2}{d_2^2}$$

b) The equation of continuity can be used as the fluid is incompressible and we have for the flow

$$Q_1 = A_1 v_1 = A_2 v_2 = Q_2 = Q$$

so, as the diameter of the pipe changes the speed has to change in order to satisfy the equation of continuity, no mass is lost in the flow

c) For a viscous fluid the type of flow might get more tubulent as the speed increases

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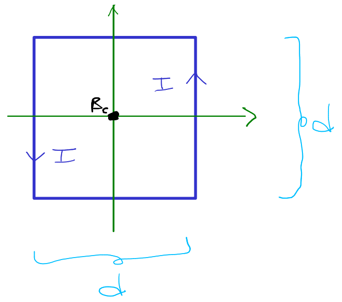


a)

Use section 12.2 in the book to calculate the intensity of the magnetic field at a distance d/2 from the center of a wire segment of length d

$$B = \frac{\mu_0 I}{2\pi} \int_0^{d/2} \frac{d/2 \cdot dx}{\left(x^2 + \left(\frac{d}{2}\right)^2\right)^{3/2}}$$

$$= \frac{\mu_0 I d}{4\pi} \int_0^{d/2} \frac{dx}{\left(x^2 + \left(\frac{d}{2}\right)^2\right)^{3/2}}$$

$$= \frac{\mu_0 I d}{4\pi} \frac{2^{3/2}}{d^2} = \frac{2^{3/2} \mu_0 I}{4\pi d}$$

the r.h.r tells us that for each side of the rectangular loop we get the same contribution and they all add up such that the total field at the center is out of the page

$$\rightarrow \boxed{B_c = \frac{2^{3/2} \mu_0 I}{\pi d}}$$

b) and the r.h.r. giving us the direction out of the page has been mentioned

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c) we can use Eq. (12.7) with the substitution: R --> d/2

$$\rightarrow B_c^{\text{circ loop}} = \frac{\mu_0 I}{d}$$

and we had $B_c^{\text{sq. loop}} = \frac{2^{3/2}}{\pi} \frac{\mu_0 I}{d} \approx 0,900 \cdot \frac{\mu_0 I}{d}$

So, the strength of B in the center of the square loop is about 90% of the strength of B in the circular loop. In the square loop the current, I, is most often at a longer distance than d from the center of the loop. This must lead to a weaker B for the square loop