Solution

Part 1a

a. $v_{ret} = \sqrt{v_0^2 - 2(e/m)V} = 1.956 \times 10^6 \, m/s$ (0.5 pts)

$v_{acc} = \sqrt{v_0^2 + 2(e/m)V} = 2.044 \times 10^6 \, m/s$

$x_{ret} = v_{ret} t, \qquad \mathrm{x}_{\mathrm{acc}} = v_{acc}(t - T/2)$ (0.5 pts)

$x_{ret} = x_{acc} \;\rightarrow\; \mathrm{t}_{\mathrm{bunch}} = \dfrac{v_{acc} T}{2(v_{acc} - v_{ret})} = 11.61T$ (0.3 pts)

$b = v_{ret} t_{bunch} = 2.272 \times 10^{-2} \, m.$ (0.2 pts)

b. The phase difference:

$\Delta\varphi = \pm(\frac{t_{bunch}}{T} - n)2\pi = \pm 0.61 \times 2\pi = \pm 220°.$ (1.0 pts)

OR

$\Delta\varphi = \pm 140°$

Part 1b

$\rho_L = n_L \dfrac{M}{N_A}$ (0.3 pts)

where n_L is the number of molecules per cubic meter in the liquid phase

Average distance between the molecules of water in the liquid phase:

$d_L = (n_L)^{-1/3} = (\dfrac{M}{\rho_L N_A})^{\frac{1}{3}}$ (0.2 pts)

$P_a V = nRT$,
where n is the number of moles (0.6 pts)

$$P_a = \frac{nM}{V}\frac{RT}{M} = \rho_V \frac{RT}{M} = \frac{n_V M}{N_A}\frac{RT}{M}$$

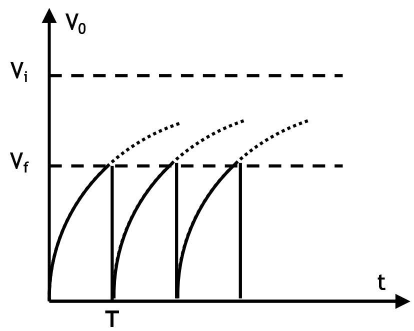
where n_V is the number of molecules per cubic meter in the vapor phase. (0.9 pts)

$d_V = (n_V)^{-1/3} = (\dfrac{RT}{P_a N_A})^{\frac{1}{3}}$ (0.2 pts)

$\dfrac{d_V}{d_L} = (\dfrac{RT\rho_L}{P_a M})^{\frac{1}{3}} = 12$ (0.3 pts)

Part 1c

a. (0.5 pts.)



b. $V_i >> V_f$ (0.2 pts)

c. $V_f = V_i\left(1 - e^{-T/RC}\right)$ (0.2 pts)

If

$V_i >> V_f$, $T/RC << 1$, $e^{-T/RC} \approx 1 - (T/RC)$

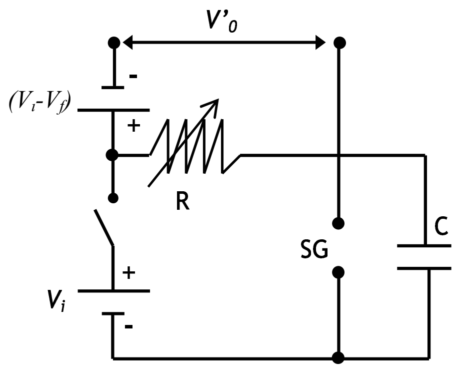
then

$T = (V_f / V_i)\, RC$ (0.2 pts)

d. R (0.2 pts)

e. SG and R (0.2 pts)

f. Correct circuit (0.4 pts)



V_0' (0.3 pts)

$V_i' - V_f$ with the correct polarity (0.3 pts)

Total (1.0 pts)

Part 1d

As the beam passes through a hole of diameter D the resulting uncertainty in the y-component of the momentum;

$$\Delta p_y \approx \frac{\hbar}{D}$$ (0.6 pts)

and the corresponding velocity component;

$$\Delta v_y \approx \frac{\hbar}{MD}$$ (0.4 pts)

Diameter of the beam grows larger than the diameter of the hole by an amount

$\Delta D = \Delta v_y . t$,

where t is the time of travel. (0.2 pts)

If the oven temperature is T, a typical atom leaves the hole with kinetic energy

$$KE = \frac{1}{2}Mv^2 = \frac{3}{2}kT$$ (0.4 pts)

$$v = \sqrt{\frac{3kT}{M}}$$ (0.2 pts)

Beam travels the horizontal distance L at speed v in time

$t = \frac{L}{v}$, so (0.2 pts)

$$\Delta D = t\Delta v_y \approx \frac{L}{v}\frac{\hbar}{MD} = \frac{L\hbar}{MD\sqrt{\frac{3kT}{M}}} = \frac{L\hbar}{D\sqrt{3MkT}}$$ (0.4 pts)

Hence the new diameter after a distance L will be;

$$D_{new} = D + \frac{L\hbar}{D\sqrt{3MkT}}$$ (0.1 pts)