Q: Determine the density of air in grams per liter at a temperature of 20.5 deg. C and a pressure of 755 mmHg. Assume that air is approximately 20% O2 and 80% N2 (i.e. the mole fraction of oxygen is 0.20 and the mole fraction of nitrogen is 0.80)

Solution:

$pV = nRT$, *(eq. 1)*
where P is the pressure of the gas, V is the volume of the gas(755 mmHg), n is the amount of substance of gas, T is the temperature of the gas(in Kelvins T=273+20.5=293.5K) and R is the ideal, or universal, gas constant ($R = 62.364\ L*mmHg*K^{-1}*mol^{-1}$).

$n = m/M$, *(eq. 2)*
where m is the mass of a compound, M is the molar mass of the compound.
$M(O_2) = 32$ g/mol
$M(N_2) = 28$ g/mol

we can rewrite (eq. 1) together (eq. 2):
$pV=mRT/M$
since,
$m_i=pV_iM_i/RT$. *(eq. 3)*
We can determine the density of air as mass of air divided by volume of air:
$d(air) = m(air)/V(air)$ *(eq. 4)*
air mass is sum of oxygen mass and nitrogen mass
$m(air) = m(O_2) + m(N_2)$ *(eq. 5)*
considering (eq. 3) and (eq. 5):
$m(air) = pV_{(O2)}M_{(O2)}/RT + pV_{(N2)}M_{(N2)}/RT$
considering (eq. 4):
$d(air) = (p/RT)*((V_{(O2)}M_{(O2)}/V) + (V_{(N2)}M_{(N2)}/V))$ *(eq. 6)*
the mole fraction of gas is
$\chi_i = V_i/V$ *(eq. 7)*
considering (eq. 6) and (eq. 7):
$d(air) = (p/RT)*(\chi_{(O2)}*M_{(O2)} + \chi_{(N2)}*M_{(N2)})$ *(eq. 6)*

$$d(\text{air}) = \frac{p}{RT} \times \left(\chi_{O_2} M_{O_2} + \chi_{N_2} M_{N_2}\right)$$

$d(air) = ((755\ mmHg/((62.364\ L*mmHg*K^{-1}*mol^{-1})*(293.5K)))*(0.2*32\ g/mol + 0.8*32\ g/mol) = 1.188\ g/L$

Answer: the density of air is 1.188 grams per liter