ex.

what is the directivity for isotropic antenna?

solution:
$$D_o = \frac{4\pi}{\Omega_A}$$

where $\Omega_A = \iint P_n \, d\Omega$

$\because P_n = \frac{U}{U_{max}} = 1$ (because it radiates equally in all directions)

so,
$$\Omega_A = \iint 1 \, d\Omega = 4\pi$$

$$\Rightarrow D_o = \frac{4\pi}{\Omega_A} = \frac{4\pi}{4\pi} = \boxed{1}$$

or directly,

$$D = D_o = \frac{4\pi}{\Omega} = \frac{4\pi}{4\Omega} = \boxed{1}$$

or $\because$ isotropic antenna radiates equally in all directions, so $U = U_o$

$$\Rightarrow D = \frac{U}{U_o} = \frac{U_o}{U_o} = \boxed{1}$$

Antenna efficiency (e_a):

It is the total antenna efficiency which used to take into account losses at the input terminals & within the structure of the antenna.

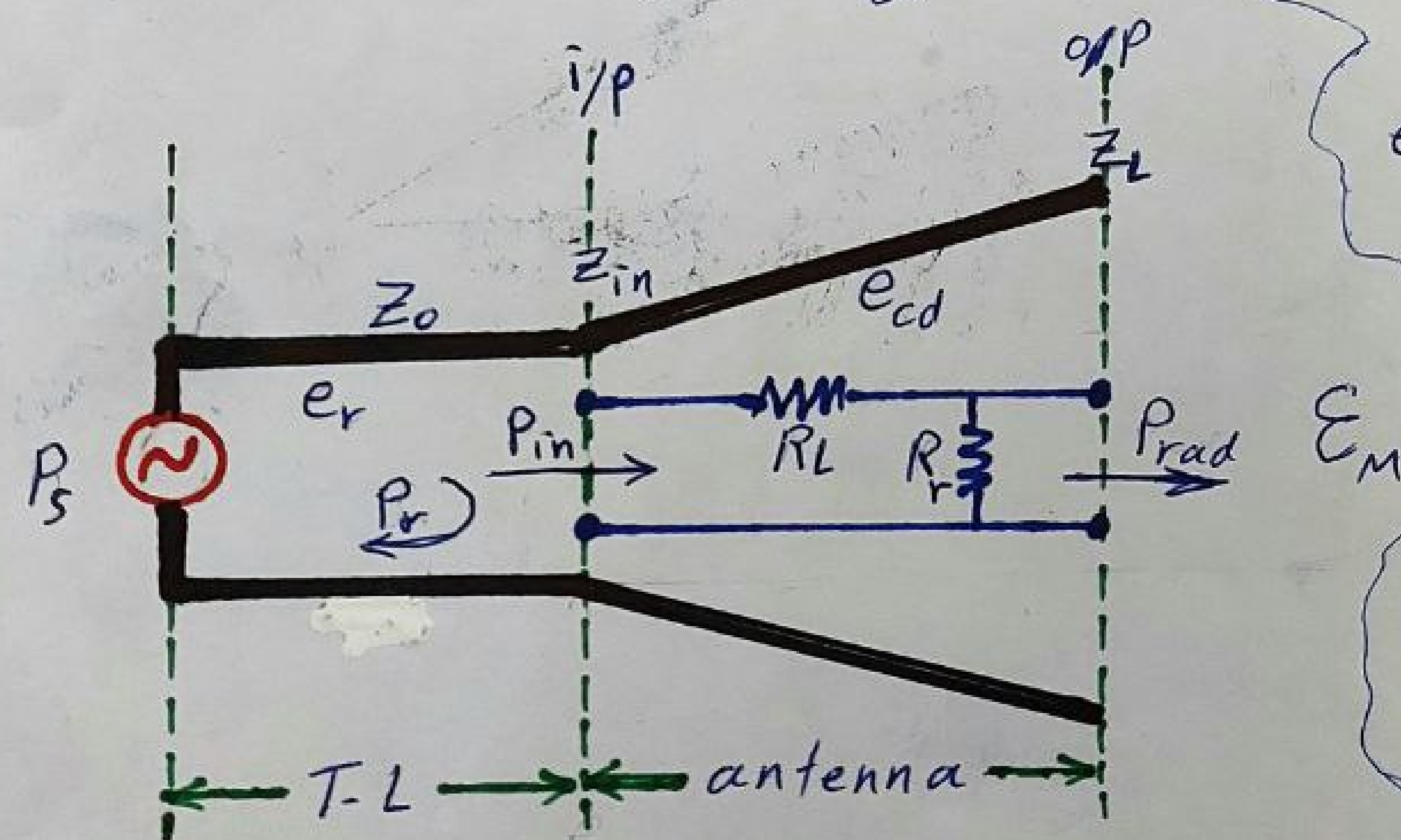
$$e_a = \underbrace{e_r}_{i/p}\ \underbrace{e_{cd}}_{structure} = e_r\, e_c\, e_d$$

where,

- e_r - reflection efficiency (mismatch efficiency),
- e_{cd} - antenna radiation efficiency or conduction dielectric efficiency,
- e_c - Conduction efficiency,
- e_d - dielectric efficiency.

note

- antenna efficiency expressed by % or db
  ex, 100% or 0 db, means there is no losses
- less than 100% means, the value in db will be in minus



e_{cd}: ($e_c\, e_d$): is the ratio of power dielivered to radiation resistance (R_r) to power dielivered to radiation resistance & load resistance ($R_r + R_L$)

$$e_{cd} = P_{rad}/P_{in} = \frac{I^2 R_r}{I^2 (R_L + R_r)} = \frac{R_r}{R_r + R_L}$$

note-1 For ideal antenna (lossless antenna)

$$R_L = 0 \Rightarrow e_{cd} = \frac{R_r}{R_r + R_L} = \frac{R_r}{R_r + 0} = 1$$

that is, $e_c = 1 = e_d \Rightarrow e_a = e_r e_{cd} = e_r * 1 = e_r$

note-2 If antenna is not ideal (lossy), R_L have a value,

$$\Rightarrow R_r + R_L > 1 \Rightarrow e_{cd} = \frac{R_r}{R_r + R_L} < 1$$

e_r is the reflection efficiency $= 1 - |\Gamma|^2$

where Γ = voltage reflection coefficient at the input terminal of the antenna

$$= \frac{Z_{in} - Z_o}{Z_{in} + Z_o}$$

, Z_{in}: antenna i/p impedance
Z_o: char. impedance of T-L

note-1. If antenna is matching, $Z_{in} = Z_o$

$$\Rightarrow |\Gamma| = \frac{Z_{in} - Z_o}{Z_{in} + Z_o} = \frac{0}{0} = 0 \Rightarrow e_r = 1 - |\Gamma|^2 = 1$$

then, $e_a = e_r e_{cd} = 1 * e_{cd} = e_{cd}$

ex Antenna supplied with power of 10 watts. calculate the power radiated when efficiency of this matching antenna is 90% ?

Solution

$P_{in} = 10\,W$

$e_a = 90\% = 0.9$

$\Gamma = 0$

$$\because e_{cd} = \frac{P_{rad}}{P_{in}} \Rightarrow P_{rad} = e_{cd} * P_{in}$$

$$e_a = e_r \, e_{cd}$$

$$\because \Gamma = 0 \Rightarrow e_r = 1 - |\Gamma|^2 = 1 - 0 = 1$$

$$\because e_a = e_r \, e_{cd} \Rightarrow 0.9 = e_{cd}$$

then $P_{rad} = e_{cd} * P_{in} = 0.9 * 10 = 9$ watts.

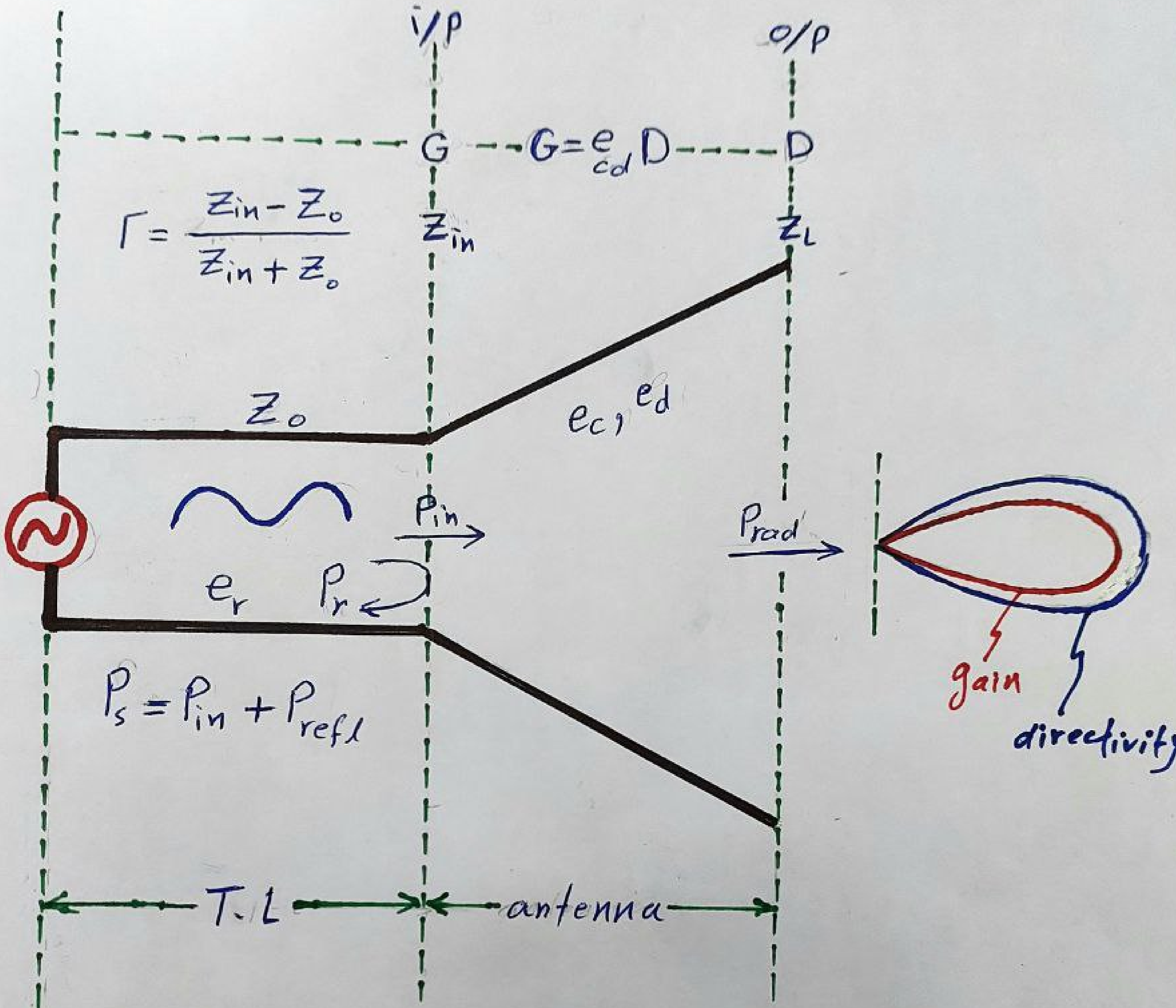
Gain (G) : is the ratio of the radiation intensity in a given direction to the radiation intensity that would be obtained if the power accepted (input) by the antenna were radiated isotropically.

1 - For antenna itself (not connected to T-L) or connected but in matching with T-L ($e_r = 1$)

$$G(\theta,\phi) = \frac{U(\theta,\phi)}{U_o} = \frac{U(\theta,\phi)}{\frac{P_{in}}{\Omega_{iso}}} = \frac{U(\theta,\phi)}{\frac{P_{in}}{4\pi}} = \boxed{\frac{4\pi U(\theta,\phi)}{P_{in}}}$$

$$\because P_{rad} = e_{cd} * P_{in} \Rightarrow P_{in} = \frac{P_{rad}}{e_{cd}}$$

$$\therefore G(\theta,\phi) = \frac{4\pi U(\theta,\phi)}{\frac{P_{rad}}{e_{cd}}} = \frac{e_{cd} * 4\pi U(\theta,\phi)}{P_{rad}} = \boxed{e_{cd} D(\theta,\phi)}$$



P_s = i/P power from source

P_{in} = i/P Power to antenna

P_r = reflected antenna

So, gain is a measure that takes into account the efficiency of the antenna (e_{cd}) as well as its directional capabilities (D).

For max. gain $G_o = e_{cd} D_o$

2- For antenna connected to T-L & there is mismatch (e_r effects),

$$G = e_a D$$

$\because e_a = e_r e_{cd}$

$\therefore G = e_r e_{cd} D$

$$e_r = 1 - |\Gamma|^2$$

$$\Gamma = \frac{Z_{in} - Z_o}{Z_{in} + Z_o}$$

For max. gain, $G_o = e_a D_o$

notes

- when D is max. (D_o) $\Rightarrow$ G is also max. (G_o),
- in isotropic antenna $P_{rad} = P_{in}$ (lossless antenna)
- in ideal antenna (no losses) $\Rightarrow G = D$ (if it matches)
- in lossy antenna & matching with T-L (no reflection), $G = e_{cd} D$
- in lossy antenna & not matching with T-L (there is reflection losses) $\Rightarrow G = e_a D = e_r e_{cd} D = e_{cd}(1 - |\Gamma|^2) * D$
- $G_{db} = 10 \log G$
- gain of isotropic antenna is 0 db (unity)

ex An antenna has a directivity of 20 & radiation efficiency of 90%. compute gain in dB.

solution

$D = 20$

$e_{cd} = 90\% = 0.9$

$$G = e_{cd} D = 0.9 * 20 = 18$$

$$G_{db} = 10 \log 18 = 12.55 \text{ db}$$

note: difference between db, dbi & dbd