Lecture -03

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Paper Name	Analog System and Application
Course & Semester	B.Sc (H) Physics, 4th Semester, Section A
Department	Physics

Numerical Problems

Q1. A transistor used in CE arrangement has the fallowing set of h-parameters when the d.c operating point is $V_{CE} = 10$ Volts, $I_C = 1mA$

$h_{ie} = 2000\,\Omega$, $h_{oe} = 10^{-4}$ mho, $h_{re} = 10^{-8}$, $h_{fe} = 50$

Determin (i) Input impedance, (ii) current gain, (iii) Voltage gain, The d.c load seen by the transistor is $R_L = 600\,\Omega$ What will be the approximate values using resonable approximation?

Q2. A transistor used in CE connection has the following set of h-parameters when at d.c operating point is 5V, 1mA.

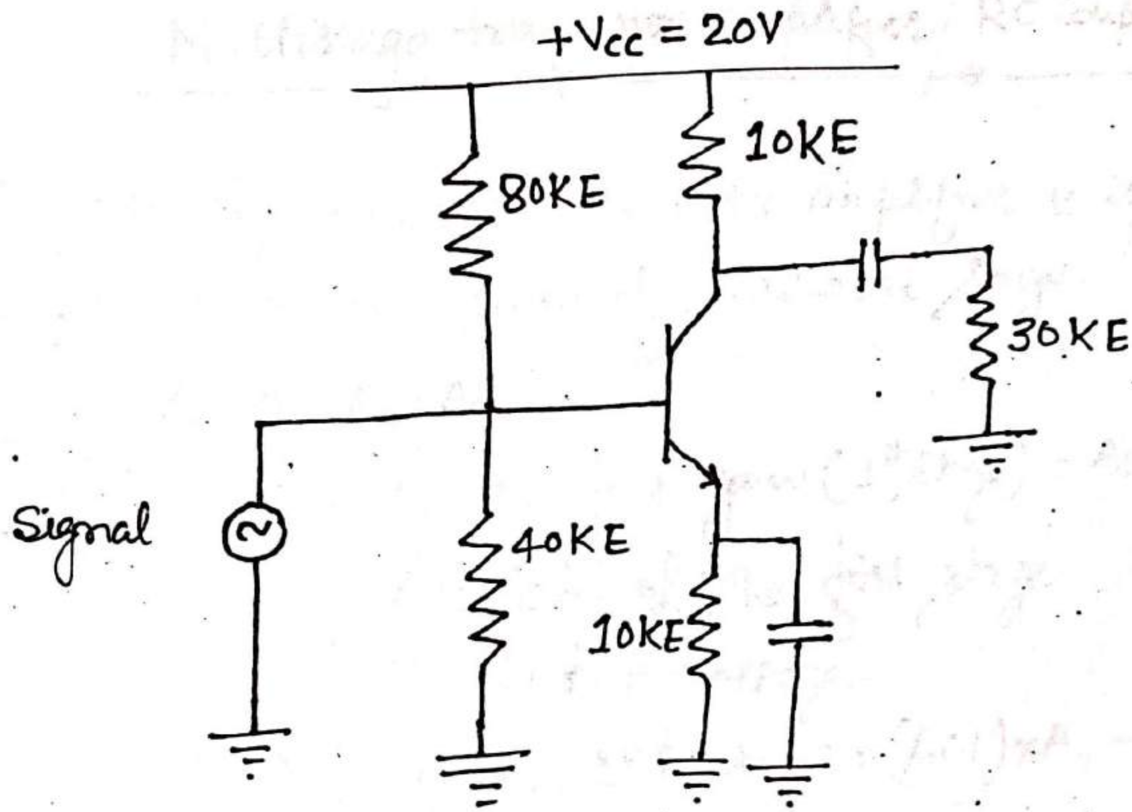
$h_{ie} = 1700\,\Omega$, $h_{re} = 1.3 \times 10^{-4}$, $h_{fe} = 38$, $h_{oe} = 6 \times 10^{-6}\,\Sigma$

if $R_L = 2K\Sigma$, find (i) The input Impedance (ii) current gain (iii) voltage gain.

Q3. In the given figure, the h-parameters of the transistor are -

$h_{ie} = 1500\,\Sigma$, $h_{fe} = 50$, $h_{re} = 4 \times 10^{-4}$, $h_{oe} = 5 \times 10^{-5}\,\Sigma$

find the (i) a.c input Impedance
(ii) Voltage gain
(iii) Output Impedance.



Hints: Here $R_L = \frac{10 \times 30}{10+30} = 7.5K\Omega = 7500\Omega$

* Output Impedance of the stage $= Z_{out} \| R_L \| R_C$
$= Z_{out} \| 30K\Omega \| 10K\Omega$

Multistage transistor amplifier / RC coupled amplifier

§ Gain of multistage transistor amplifier is equal to the product of the gain of individual stage.

$A = A_1 \times A_2 \times A_3 \cdots$

Proof: Output of the first gain (1st stage) = $A_1 V$

A_1 = Gain of the first stage

V = Input voltage.

Output of the 2nd stage $= (A_1 V) \times A_2 = A_1 A_2 V$

Output of the 3rd stage $= (A_1 A_2 V) \times A_3 = A_1 A_2 A_3 V$

$$\text{Total gain } A = \frac{\text{Output of the 3rd stage}}{\text{Input of the first stage}}$$

$$= \frac{(A_1 A_2 A_3)V}{V}$$

$$[A = A_1 \times A_2 \times A_3]$$

However, in actual the total gain A is less than the $A_1 A_2 A_3$ due to loading effect of next stage.

§ Gain in dB:

gain in dB = 1st stage gain in dB + 2nd stage gain in dB.

§ Bandwidth: The range of frequencies over which the voltage gain equal to or grater than 70.7% of max gain known as the bandwidth.

OR

Bandwidth of an amplifier is the range of frequencies at this limit of which its voltage gain falls by 3dB from its max gain.

Proof: let the max voltage gain = 100

and 70.7% ($100/\sqrt{2}$) of 100 = 70.7

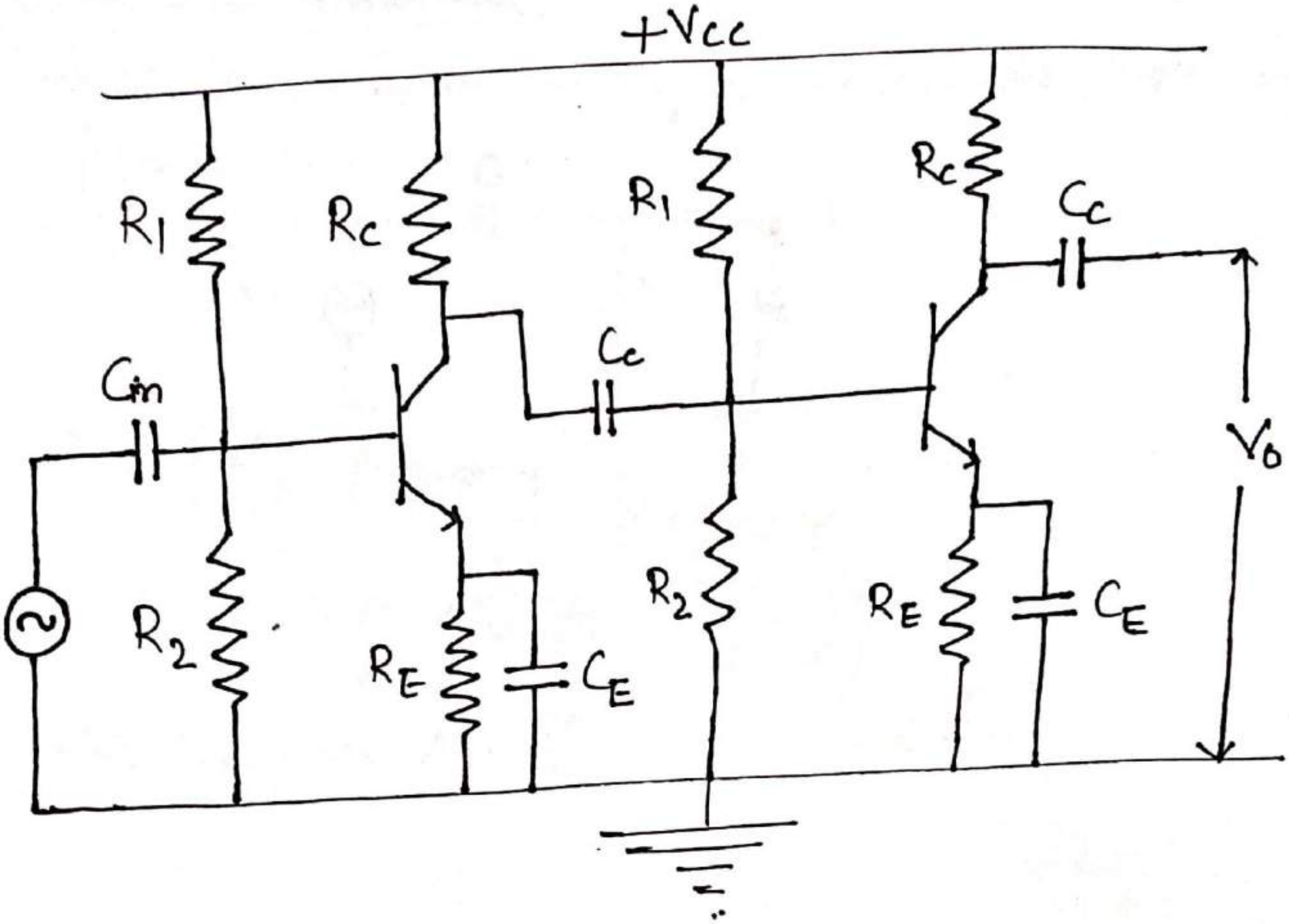
fall in voltage gain from its max gain

$= 20\log_{10}100 - 20\log_{10}70.7$

$= 20\log_{10}\frac{100}{70.7}$ dB

$= 3$ dB

§ R-C Coupled transistor amplifier:



→ Here, R_1, R_2, R_c, and R_E form the biasing and stablisation network.

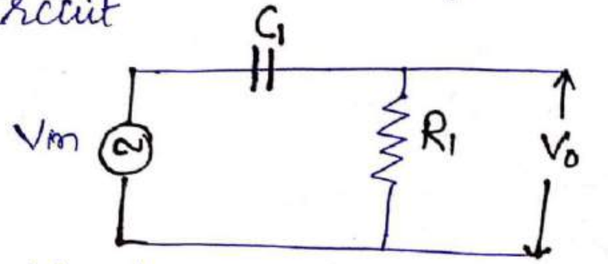
→ Total gain is less than the product of the gain of the individual stage

→ Because the effective load resistance of 1st stage is reduced due to shunting effect of the input-resistance of second stage

§ Frequency Response Curve :

(1) At low frequencies :

→ at low frequencies the stage behave like the simple high pass circuit



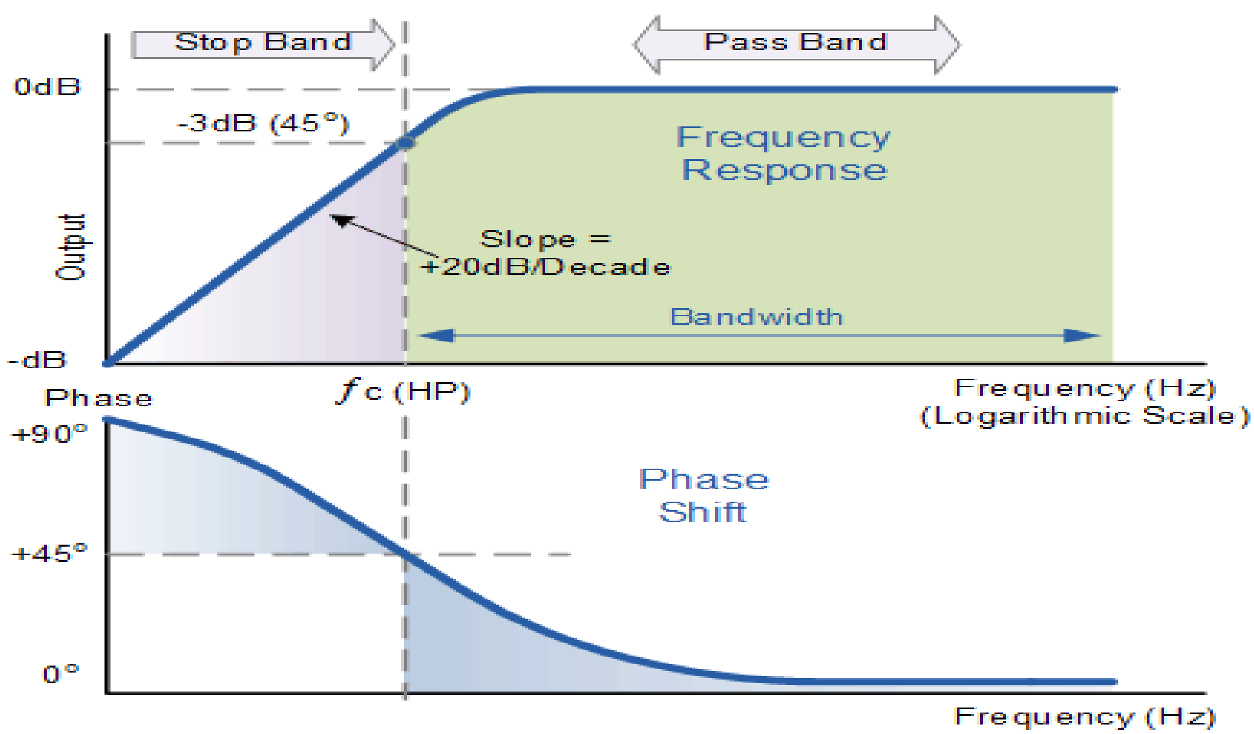
→ Cut-off frequency $f_c = \frac{1}{2\pi R_1 C_1}$

→ Phase shift $\phi = \tan^{-1}\left(\frac{1}{2\pi R_1 C_1}\right)$

→ Voltage gain $A_v = \frac{V_o}{V_{in}} = \frac{R_1}{\sqrt{R_1^2 + X_C^2}} = \frac{R}{Z}$

Frequency Response of a 1st Order High Pass Filter

$$\text{Gain (dB)} = 20 \log \frac{V_{out}}{V_{in}}$$



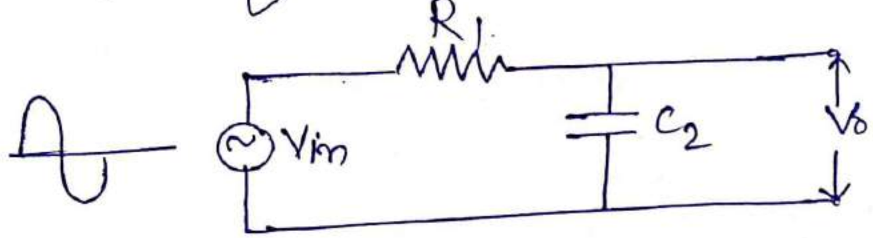
The **Bode Plot** or Frequency Response Curve above for a passive high pass filter is the exact opposite to that of a low pass filter. Here the signal is attenuated or damped at low frequencies with the output increasing at +20dB/Decade (6dB/Octave) until the frequency reaches the cut-off point (fc) where again R = Xc. It has a response curve that extends down from infinity to the cut-off frequency, where the output voltage amplitude is 1/√2 = 70.7% of the input signal value or -3dB (20 log (Vout/Vin)) of the input value.

Also we can see that the phase angle (Φ) of the output signal **LEADS** that of the input and is equal to **+45º** at frequency fc. The frequency response curve for this filter implies that the filter can pass all signals out to infinity. However in practice, the filter response does not extend to infinity but is limited by the electrical characteristics of the components used.

The cut-off frequency point for a first order high pass filter can be found using the same equation as that of the low pass filter, but the equation for the phase shift is modified slightly to account for the positive phase angle as shown below.

2) at high frequency:

→ at high frequency the stage behave like simple low pass filter



$$V_o = V_{in} \times \frac{R_2}{R_1 + X_{C2}} = V_{in} \frac{X_{C2}}{R_1 + X_{C2}}$$

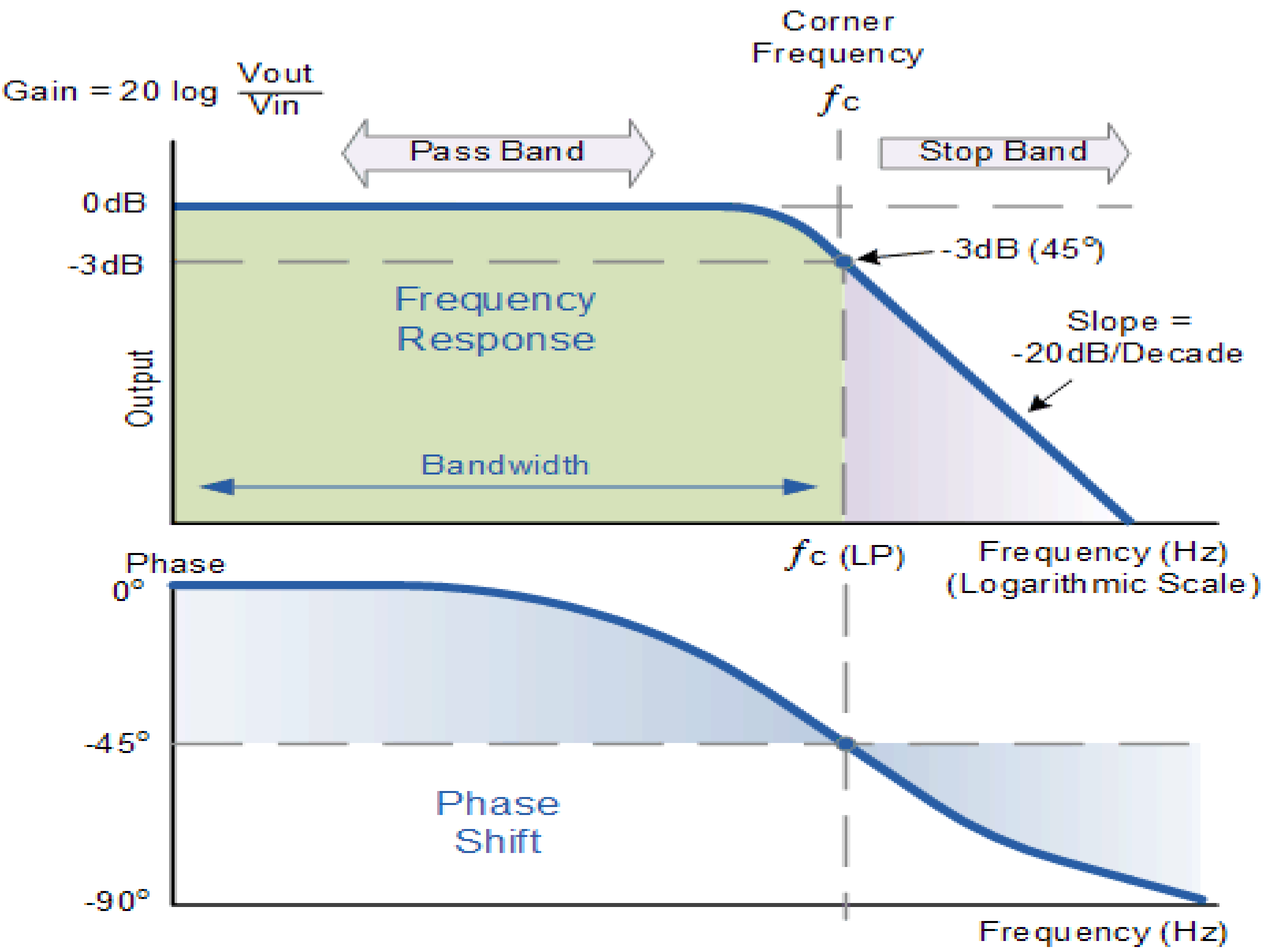
$$X_C = \frac{1}{2\pi f C} \text{ ohm}, \quad Z = \sqrt{R^2 + X_C^2}$$

$$V_o = V_{in} \frac{X_C}{Z}$$

→ Cut-off and phase shift

$$f_c = \frac{1}{2\pi RC}, \quad \phi = -\tan^{-1}(2\pi f RC)$$

Frequency Response of a 1st-order Low Pass Filter



The Bode Plot shows the **Frequency Response** of the filter to be nearly flat for low frequencies and all of the input signal is passed directly to the output, resulting in a gain of nearly 1, called unity, until it reaches its **Cut-off Frequency** point (ƒc). This is because the reactance of the capacitor is high at low frequencies and blocks any current flow through the capacitor.

After this cut-off frequency point the response of the circuit decreases to zero at a slope of -20dB/ Decade or (-6dB/Octave) "roll-off". Note that the angle of the slope, this -20dB/ Decade roll-off will always be the same for any RC combination.

Any high frequency signals applied to the low pass filter circuit above this cut-off frequency point will become greatly attenuated, that is they rapidly decrease. This happens because at very high frequencies the reactance of the capacitor becomes so low that it gives the effect of a short circuit condition on the output terminals resulting in zero output.

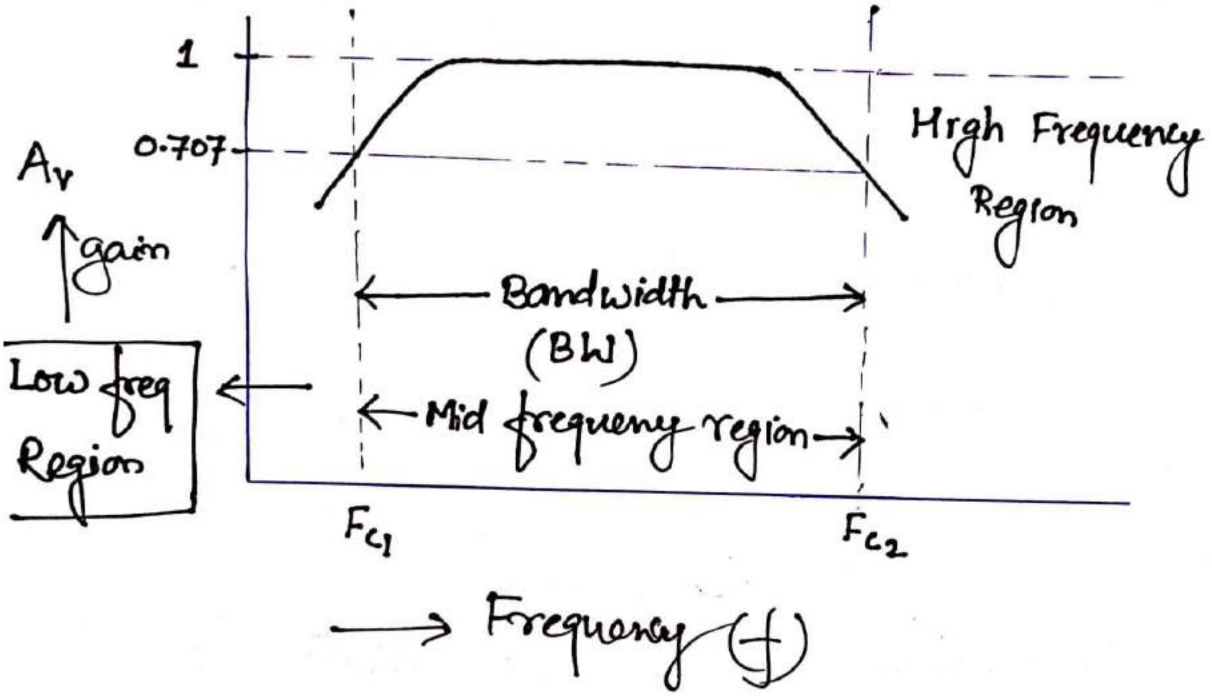
Then by carefully selecting the correct resistor-capacitor combination, we can create a RC circuit that allows a range of frequencies below a certain value to pass through the circuit unaffected while any frequencies applied to the circuit above this cut-off point to be attenuated, creating what is commonly called a **Low Pass Filter**.

For this type of "Low Pass Filter" circuit, all the frequencies below this cut-off, ƒc point that are unaltered with little or no attenuation and are said to be in the filters **Pass band** zone. This pass band zone also represents the **Bandwidth** of the filter. Any signal frequencies above this point cut-off point are generally said to be in the filters **Stop band** zone and they will be greatly attenuated.

This "Cut-off", "Corner" or "Breakpoint" frequency is defined as being the frequency point where the capacitive reactance and resistance are equal, R = Xc = 4k7Ω. When this occurs the output signal is attenuated to 70.7% of the input signal value or **-3dB** (20 log (Vout/Vin)) of the input. Although R = Xc, the output is **not** half of the input signal. This is because it is equal to the vector sum of the two and is therefore 0.707 of the input.

As the filter contains a capacitor, the Phase Angle (Φ) of the output signal **LAGS** behind that of the input and at the -3dB cut-off frequency (*ƒ*c) is -45º out of phase. This is due to the time taken to charge the plates of the capacitor as the input voltage changes, resulting in the output voltage (the voltage across the capacitor) "lagging" behind that of the input signal. The higher the input frequency applied to the filter the more the capacitor lags and the circuit becomes more and more "out of phase".

Frequency response curve of R-C amplifier



Where F_{c1} = Lower cut-off frequency
F_{c2} = Upper Cut-off frequency.

§ Bandwidth: The difference between Upper cut-off and lower cut-off frequency is called the bandwidth $[BW = f_2 - f_1]$

Numerical Prob: H-W