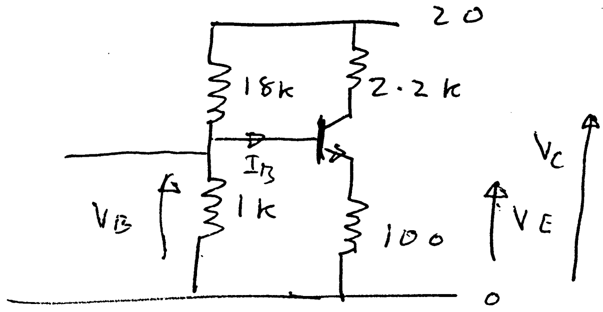
1 (a) $h_{FE} = \infty$, $I_B = 0$



$V_B = 1.0526$

$V_E = .352\ V$

$I_E = I_c = 3.52\ mA$

$V_c = 20 - 2.2 \times 3.52$

$= \underline{\underline{12.256\ V}}$

(b) $V_B = 1.0526 - 18k \| 1k \cdot I_B = 1.0526 - .9474\, I_B$ (I_B in mA).

I_E / mA $= 10 V_E$, $I_B = \frac{V_E}{10} = \frac{10 V_E}{101}$

$V_E = 1.0526 - \frac{.9474\, V_E \times 10}{101} - 0.7$

$V_E = \frac{.352}{1 + 0.9474 \frac{\times 10}{101}}$ $V_E = \underline{\underline{.3218\ V}}$

$V_c = 20 - 2.2 \times 3.218 = \underline{\underline{12.920}}$

(c). The maximum gain available (modulus) if R_E is not bypassed is 22 ($h_{fe} = \infty$)/. With a bypass capacitor (not shown in original!) the gain ~~can~~ will be much higher at m.f. i.e. $h_{ie} f.b.$

(d). With R_E bypassed, $i_b = \frac{v_1}{h_{ie}} = \frac{v_1}{.200}$ mA

$\frac{v_2}{v_1} = \frac{-2.2\, v_1}{.2} \times 150$

$= \underline{\underline{-1.65 \times 10^3}} = \underline{\underline{64\ dB}}$

2 (a). Strictly depends on f.b. used. Ideal(?) answer:

i/. Gain made independent of exact parameters of transistor / Op amp.

ii/. Non linearity ~~greatly~~ reduced.

iii/. Bandwidth extended.

iv/. Affects input + output impedance.

Voltage f.b. at input — R_{in} High

Voltage f.b. at output — R_o Low

Current f.b. at input — R_{in} Low

Current f.b. at output — R_o High

(b). 3dB point when $\omega T = 1$, $\omega = 1/T$

$\therefore$ 3dB b.w. is $\dfrac{1}{2\pi f T}$.

(c) Gen xpression for gain with f.b. is

$$G = \frac{A}{1+\beta A} = \frac{A_0/(1+j\omega T)}{1+\beta A_0/(1+j\omega T)}$$

$$= \frac{A_0}{1+j\omega T+\beta A_0} = \frac{A_0/(1+\beta A_0)}{1+\dfrac{j\omega T}{1+\beta A_0}}$$

$$= \frac{G_0}{1+j\omega T/(1+\beta A_0)}.$$

$\therefore$ B.w. increased by a factor of $1+\beta A_0$.

$1/2\pi T = 10$ Hz

Ans(1). 10 m 0.0001) kHz

Ans(2). 1.01 kHz

2 cont – (d)

(1). $\beta = 0{\cdot}1$; gain at 3dB point $= 7{\cdot}07$

With amplitude v_1 at 100 kHz (approx),

output slew rate $= 7{\cdot}07 \times 2\pi \times v_1 \times 100{,}000 = 10^5$

$\therefore v_1 = 22{\cdot}5\,mV$. Gain $\times\ 22{\cdot}5\,mV \ll 15\ V$

$\therefore$ slew-rate limited + max input signal is $\simeq$ 45 mV p-p

(2) $\beta = {\cdot}001$; gain at 3dB point $= 707$

slew rate limitation has same p-p input voltage as

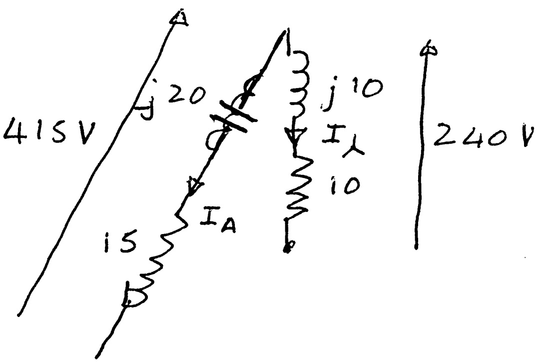
above but ~~gain~~ ~~is~~ ~~not~~ output is now $\simeq 32\ V$

p-p + $\therefore$ slew rate unimportant. Maximum p-p

input is $\therefore < \dfrac{20}{707}\ V$, i.e. $<$ 28 mV p-p

3 (a) i. Lots of room for 3 sets of coils in a generator. Power required over a cycle constant. Smooth running.
ii. Since most loads are approximately balance can get away with 3 heavy cables + one lighter one. c.f. 6 heavy cables for 3× single phase supplies.

(b).



$$I_\Delta = \frac{415}{15+j20} \; ; \; |I_\Delta|^2 = 276\,A^2$$

$$I_\lambda = \frac{240}{10+10j} \; ; \; |I_\lambda|^2 = 288\,A^2$$

Evaluate Power + VARs for each.

	P	VARs
Δ	4140 W	− 5520 VARs
λ	2880 W	+ 2880 VARs
	7020 W	− 2640 VARs

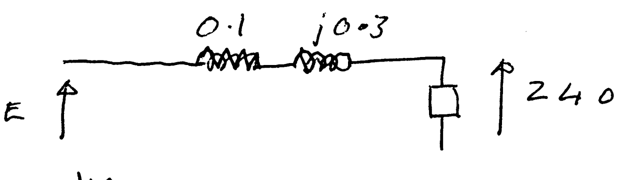
$\therefore$ Total power = 3 × 7020 = $\underline{\underline{21.06 \text{ kW}}}$

Per phase, VA = $\sqrt{P^2+Q^2}$ = 7500 VA.

Line current = $\frac{7500}{240}$ = $\underline{\underline{31.25 \text{ A}}}$.

P.F. = $\cos \tan^{-1} \frac{2640}{7020}$ = $\underline{\underline{0.936}}$

(c).



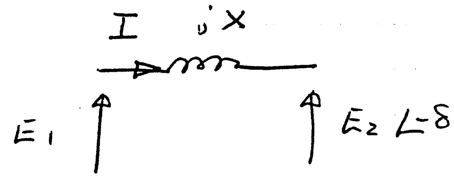
From conservation of Watts + VArs:

$$(E \times 31.25)^2 = (7020 + 31.25^2)^2 + (-2640 + (3\times 31.25^2))^2$$

$$E \times 31.25 = 7999.6, \quad E = 256 \text{ V}$$

$\therefore$ Line voltage = $\underline{443}$ V

4 (a). Bookwork, but



$$I = \frac{E_1 - E_2(\cos\delta - j\sin\delta)}{jX}$$

Power <u>to</u> E_2 = power <u>from</u> E_1 - pure reactance.

Power from E_1 = $\mathrm{Re}\{E_1 I^*\} = \mathrm{Re}\left\{\frac{E_1^2 - E_1E_2(\cos\delta + j\sin\delta)}{-jX}\right\}$

Only R.P. from 2nd term in brackets

$$= \underline{\underline{\frac{E_1 E_2 \sin\delta}{X}}}.$$

(b). Per phase: $100\ MW$; $\frac{33}{\sqrt{3}}\ kV$ at unity p.f. $\Rightarrow$

$|I| = 4249\ A.$

$E = 19.05\ kV + j\ 4249$; $|E| = \underline{\underline{19.52\ kV}}$

$\sin\delta$ ~~from~~ $\frac{19.52 \times 19.05 \times 10^6 \times \sin\delta}{1} = 10^8$

[redacted] $\underline{\underline{\delta = 15.6^\circ}}$

(c). New $E = 19.52 \times 1.15 = 22.45\ kV.$

New $\sin\delta$ from $\frac{22.45 \times 19.05 \times 10^6}{1} = 120 \times 10^6$

$\underline{\underline{\delta = 16.3^\circ}}.$

From (a), $I = \frac{22.45 - 19.05(\cos 16.3 - j\sin 16.3)}{j}\ kA$

$|I| = |4.165 + j\ 5.345| = \underline{\underline{6776\ \ A}}$

New p.f. $= \frac{120\ MW}{19.05\ kV \times 6776\ A} = 0.9296.$

Bonus*: From above, I lags E by $52.1^\circ - 90^\circ = 37.9^\circ$.
V lags E by 16.3° ∴ I lags V by 21.6° – $\cos\phi = .9296$ lag.

5/ a) The table giving V_a (V) vs I_f (A) is the open-circuit characteristic of the motor, and enables $K\phi(I_f)$ to be found:-

On open-circuit $e_a = V_a = K\phi\omega$

$\Rightarrow K\phi = V_a/\omega$ where ω is the speed at which the test was carried out $= 1200 \times 2\pi/60 = 125.7$ rad s^{-1}.

$\therefore$ With $I_f = 4$ A, $K\phi = 300/125.7 = 2.39$ Vs.

$e_a = K\phi\omega = 300$ V at 1200 rpm

$\therefore \; i_a = \dfrac{V_a - e_a}{r_a} = \dfrac{350-300}{1} = 50$ A.

$T = K\phi i_a = 2.39 \times 50 = \underline{119.4 \text{ Nm}}$

b) Use linear interpolation to find V_a at $I_f = 7$ A from o.c. data

$$V_a = 420 + \frac{510-420}{2} = 465 \text{ V}$$

$\therefore K\phi = 465/\cancel{2.39}\ 125.7 = 3.70$

$T = K\phi i_a = 119.4$ (same as part a)

$$\Rightarrow i_a = \frac{119.4}{3.7} = 32.3 \text{ A}$$

$$e_a = V_a - i_a r_a = 350 - 1 \times 32.3$$
$$= 317.7$$

$$e_a = K\phi\omega \Rightarrow \omega = \frac{317.7}{3.70} = 85.9 \text{ rad s}^{-1} = \underline{820 \text{ r}}$$

) To reduce speed increase I_f. However, $K\phi$ is limited by saturation to approx $600/125.7 = 4.77$ (taking maximum I_f from o.c. characteristic). - other answers possible e.g. use $K\phi = \frac{615}{125.7}$ at $I_f = 14$ A $= 4.89$

$$i_a = T/K\phi = 119.4/4.77 = 25.0$$

$$e_a = 350 - 25 \times 1 = 325 = K\phi\omega$$

$$\Rightarrow \omega = \frac{325}{4.77} = 68.1 \text{ rad s}^{-1} = 651 \text{ rpm.}$$

To reduce speed further use armature voltage control ie reduce armature voltage.

6 (a). $v = \dfrac{1}{\sqrt{LC}} = \underline{\underline{2 \cdot 11 \times 10^{8} \text{ m/s}}}$

$Z = \sqrt{\dfrac{L}{C}} = \underline{\underline{63 \cdot 2 \ \Omega}}$

$\sqrt{\epsilon_r} = 3/2 \cdot 11$ $\underline{\text{assuming } \mu_r = 1}$

$\therefore \underline{\underline{\epsilon_r = 2 \cdot 02}}$

(b). A length of line of $\lambda/4$ will present an open circuit

At 300 MHz, $\lambda = 703$ mm

$\therefore$ (1) $\underline{\underline{175 \cdot 8 \text{ mm}}}$

A length of line of $\lambda/2$ will present a s/c (ignore the trivial case of $l = 0$)

$\therefore$ (2) $\underline{\underline{351 \cdot 7}}$ mm.

(c). The length of line beyond the resistor looks like an o.c. so the load looks like a $\lambda/4$ section terminated in 100 Ω.

$\rho = \dfrac{100 - 63 \cdot 2}{100 + 63 \cdot 2} = \cdot 2255$, real.

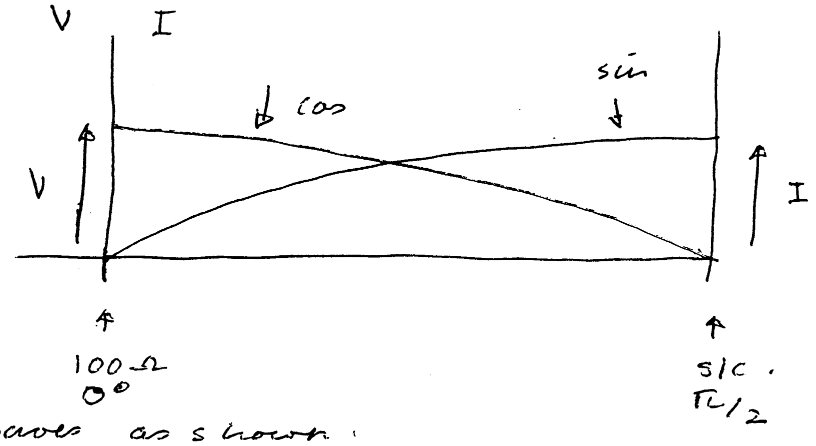
The V.S.W.R. $= \dfrac{1 + \cdot 2255}{1 - \cdot 2555} = \dfrac{100}{63 \cdot 2} = \underline{\underline{1 \cdot 582.}}$

(d). The input resistance of the line is $\dfrac{63 \cdot 2^2}{100} = 39 \cdot 9 \ \Omega$

$\therefore$ Input voltage $= \dfrac{100 \times 39 \cdot 9}{63 \cdot 2 + 39 \cdot 9} = 38 \cdot 7$ V.

$\therefore$ Power to line and also load $= \dfrac{38 \cdot 7^2}{63 \cdot 2}$ W $= \underline{\underline{23 \cdot 7 \text{ W}}}$

6 e



Standing waves as shown.

For a bonus, $V = \sqrt{23.7 \times 100} = \underline{\underline{48.7V}}$

$I = \dfrac{48.7}{63.2} = \underline{\underline{.77\ A}}$

7 (a) From $\nabla \times \underline{E} = -\frac{\partial \underline{B}}{\partial t} = -j\omega\mu_0 \underline{H}$

$\nabla \times \underline{E}$ has only one component, $-\underline{i} \cdot \frac{dE_y}{dz}$; in x direction

$\therefore -j\omega\mu_0 \underline{H} = -\underline{i} \cdot -j\beta E_0 \exp j(\omega t - \beta z)$

$\therefore H_x = -\frac{1}{\mu_0 c} E_0 \exp j(\omega t - \beta z) = -\frac{E_0}{Z_0} \exp j(\omega t - \beta z)$

where $Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$.

Mean power flux: $Re\{\underline{E} \times \underline{H}^*\} = -\frac{E_0^2}{Z_0} \cdot \underline{j} \times \underline{i} = \frac{E_0^2}{Z_0} \underline{k}$ $\{\underline{j} \times \underline{i} = -\underline{k}$

(b) Loop in $\perp$ to direction of H & $\therefore$ |flux| through loop

$= \frac{\pi a^2}{4} \cdot \frac{\mu_0 E_0}{Z_0}$ & $|E_{mf}| = \frac{\pi a^2 E_0}{4} \frac{\omega \mu_0}{Z_0}$

$= \frac{\pi a^2}{4} E_0 \omega \sqrt{\mu_0 \epsilon_0} = \frac{\pi^2 a^2}{2\lambda} E_0.$

P is peak!

(c) Power density at a distance $r = \frac{P}{2\pi r^2} = \frac{E_0^2}{Z_0} = \frac{E_0^2}{120\pi}$

$\therefore E_0^2 = \frac{60P}{r^2}$.

Induced e.m.f. must be, in absence of receiver, given by

$\frac{V_0^2}{4 \times 75} = 4 \times 10^{-9}$; $V_0^2 = 1.2 \times 10^{-6}$ $V^2 = \left(\frac{\pi^2 a^2}{2\lambda}\right)^2 \cdot \frac{60P}{r^2}$

$2\lambda = 1m$, $a = 0.15m$, $P = 1kW$

$\therefore r^2 = \left(\frac{\pi^2 a^2}{2\lambda^2}\right)^2 \cdot \frac{6 \times 10^4}{1.2 \times 10^{-6}}$, $r = \underline{\underline{49.6 \text{ km}}}$.

(d) Can reduce induced e.m.f. by 2 $\therefore$ can tilt by 60°.