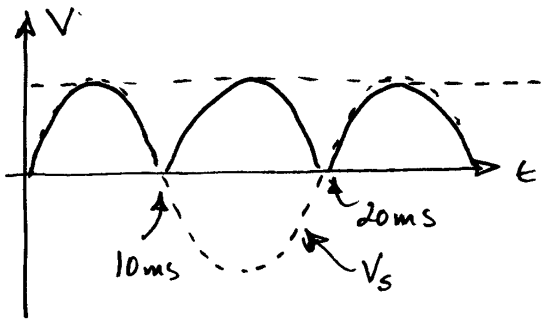
Q1 (i) B, F, E, A.

(ii)



* this can be neglected providing an appropriate statement is made.

(iii) Average of half wave rectified sinusoid
$= V_P/\pi$ (given in "useful information")

$$\therefore \text{Average of F.W.} = 2\frac{V_p}{\pi} \approx 2\frac{(20\sqrt{2} - 1.4^{*})}{\pi} = \underline{17.1\ V.}$$

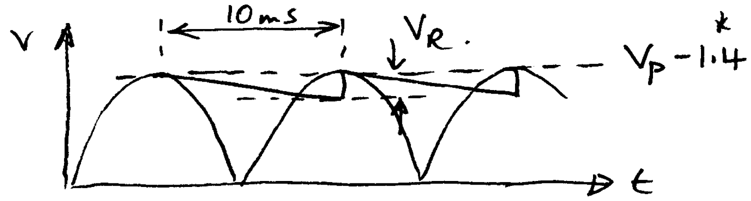
(iv) $$I_{max} = \frac{V_p - 1.4^{*}}{R}$$

assume C discharges at I_{max} for full 10 ms

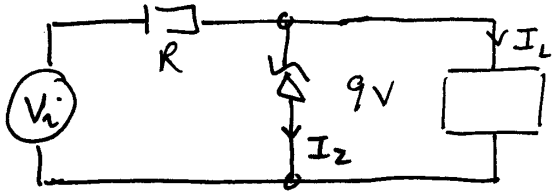
$$I_{max} = C\frac{\Delta V}{\Delta t} = C\frac{V_R}{10ms}$$

$$\therefore C = \frac{I_{max} \times 10ms}{V_R} = \frac{(V_p - 1.4^{*}) \times 10ms}{R\, V_R}$$

$$= \underline{\underline{6.7 \times 10^{-3}\ F.}}$$



(v)



$I_{L\,min} = 5\,mA$
$I_{L\,max} = 10\,mA$
$I_{Z\,min} = 2\,mA.$

$V_{i\,max} - V_{i\,min} = 2V.$

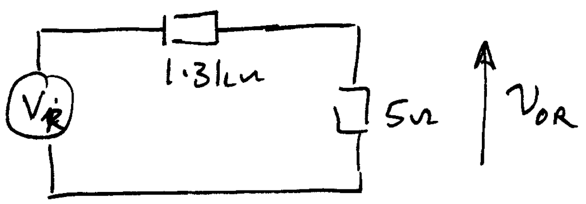
$V_{i\,min} = 20\sqrt{2} - \overset{*}{1.4} - 2 = 24.9V.$

$$R_{max} = \frac{V_{i\,min} - 9V}{I_{L\,max} + I_{Z\,min}} = \frac{24.9 - 9}{10\,mA + 2\,mA}.$$

$$= \underline{\underline{1.3k\Omega}}.$$

(1.4kΩ if the 1.4V diode drop is neglected).

(vi) ripple equivalent circuit ...

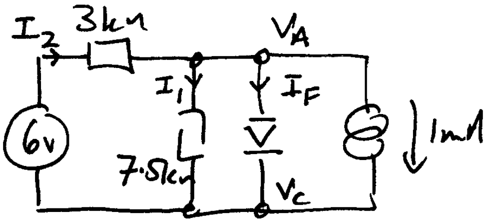


$$v_{oR} = V_R \cdot \frac{5\Omega}{5 + 1.3k\Omega} = 2 \times \frac{5}{1305}$$

$$= \underline{7.6\,mV} \text{ pk-pk}$$

Q2(a)(i) Try a test ....

Assume diode not conducting ..... diode is open cct



by superposition, V_A w.r.t. V_c is

$$V_A - V_c = 6 \times \frac{7.5}{3+7.5} - 1mA \times \frac{3k\Omega \times 7.5k\Omega}{3k\Omega + 7.5k\Omega}$$

$$= 6 \times \frac{7.5}{10.5} - \frac{22.5}{10.5}$$

$$= \frac{45 - 22.5}{10.5} = \frac{22.5}{10.5} = 2.14V.$$

so guess is wrong, diode conducts.

replace diode with $V_A - V_c = 0.7V$ and work out I_F ...

$$I_2 = \frac{6 - 0.7}{3k\Omega} = \frac{5.3}{3k\Omega} = 1.77 mA.$$

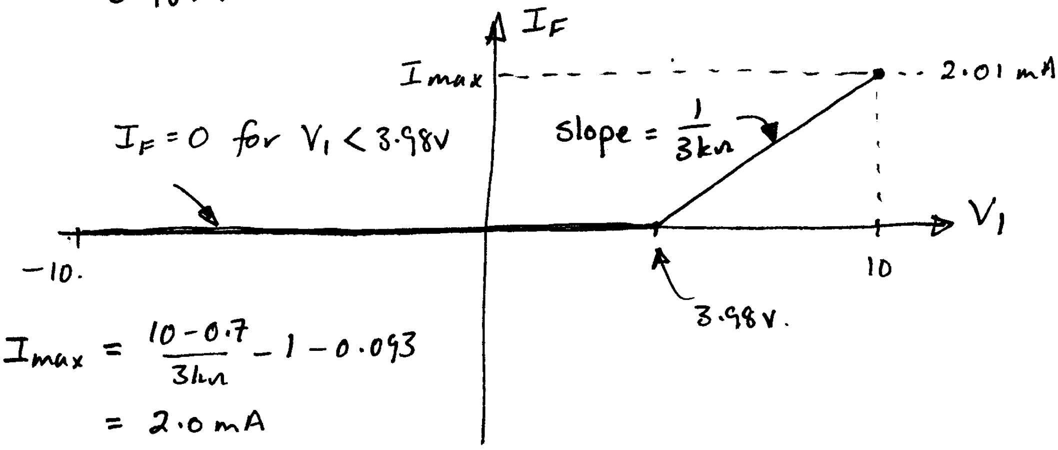
$$I_1 = 0.7/7.5k\Omega = 0.093 mA.$$

sum currents at V_A node

$$I_2 = I_1 + I_F + 1mA$$

$$\therefore I_F = 1.77 - 0.093 - 1 = \underline{\underline{677\mu A}}.$$

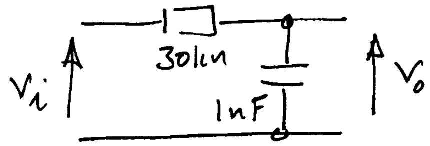
(ii) diode on point of changing state when $I_F = 0$ and $V_A - V_c = 0.7$ .... ie when $I_2 = 1.093$ mA ..... ie when $V_{3k\Omega} = 3 \times 1.093 = 3.28V$ $\therefore V_1 = 3.28 + 0.7 = 3.98V$.

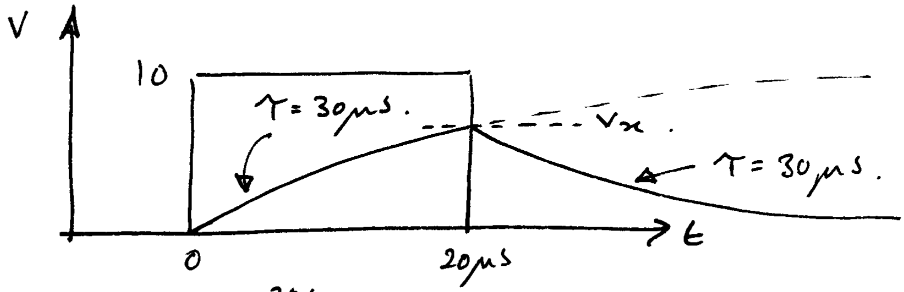


$$I_{max} = \frac{10 - 0.7}{3k\Omega} - 1 - 0.093$$

$$= 2.0 mA$$

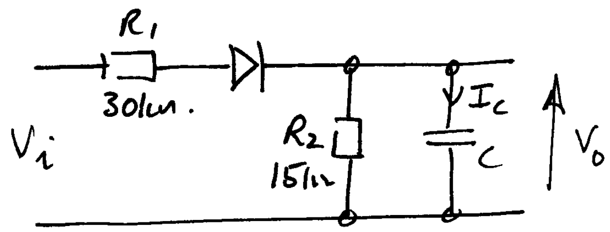
Q2 b (i)

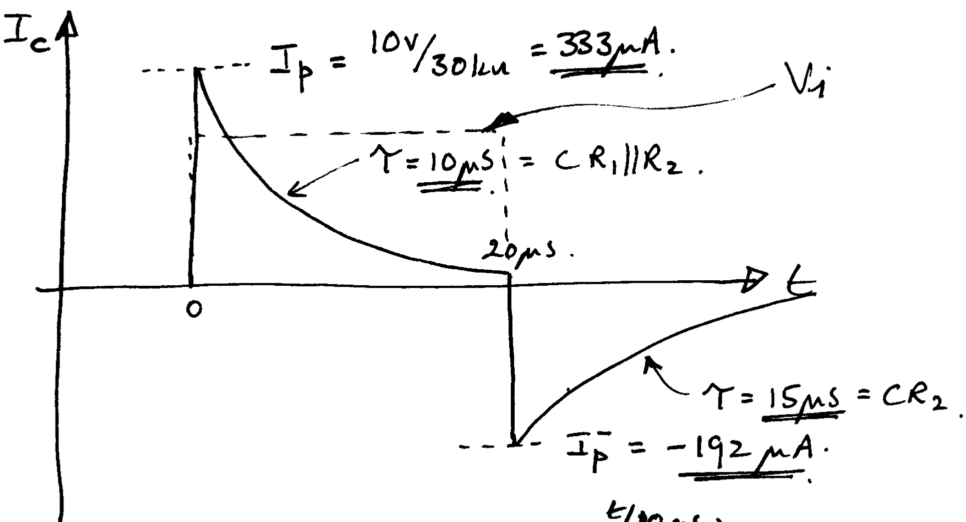




$$V_x = 10\left(1 - e^{-20/30}\right) = 4.87\,V.$$

(ii).





between 0 + 20μs $V(t) = 3.33\left(1 - e^{-t/10\mu s}\right)$.

so at 20μs $V_o = 3.33\left(1 - e^{-2}\right) = 2.88\,V$.

$$I_p^- = -\frac{2.88}{15k\Omega} = -192\,\mu A.$$

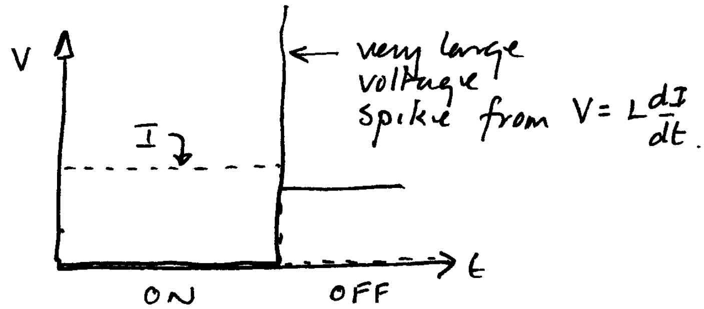
Q3 (a) (i) $I_{CON} = \frac{24}{200} = \underline{\underline{120\,mA}}$ (ignores V_{CESAT}).

(ii) To support $I_{C(ON)} = 120\,mA$, $I_{B(ON)}$ must be at least $\frac{I_{C(ON)}}{h_{FE}} = \frac{120\,mA}{35} = 3.43\,mA$.

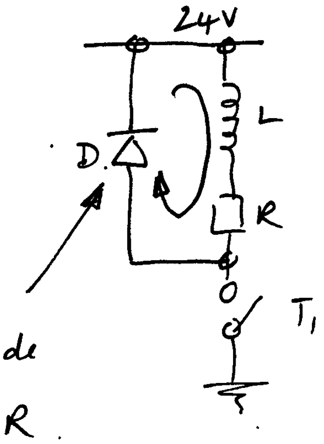
If $V_i = 5V$ and $V_{BE} = 0.7V$,

R_B given by $R_B = \frac{5-0.7}{3.43\,mA} = \underline{\underline{1.25\,k\Omega}}$.

(iii) L stores energy while T_1 is on. When T_1 tries to turn off, the stored energy in the inductor tries to keep the current flowing into what suddenly becomes a high impedance node. Hence, V_{CE} rises rapidly as the current seeks a circuit through which it can pass..... this high voltage can damage T_1.



Problem can be eased by providing a path for the inductor current by using an idling or freewheeling diode ....→



Current circulates as shown and stored energy is lost as heat in D and R.

Q3 b (i) V_B given by potential division of V_{cc} (18V)

$$V_B = V_{cc}\frac{R_2}{R_1+R_2} = 18\,\frac{68k\Omega}{188k\Omega} = \underline{\underline{6.5V}}.$$

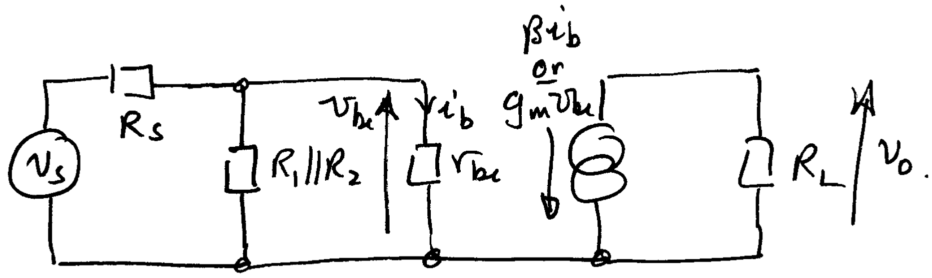
$$\therefore\ V_E = V_B - 0.7 = 5.8\,V. \quad \text{so} \quad I_E \approx I_C = \frac{5.8}{R_E} = \underline{\underline{1.93\,mA}}.$$

$$V_C = V_{cc} - I_C R_L = 18 - 1.93 \times 3k\Omega = 18 - 5.8V = \underline{\underline{12.2V}}$$

$$g_m = \frac{eI_C}{kT}\ (\text{given}) = \frac{1.93\times10^{-3}}{.026} = \underline{0.074}\ A/V = \underline{\underline{74\ mA/V}}.$$

$$r_{be} = \beta/g_m\ (\text{given}) = \frac{400}{.074} = \underline{\underline{5.4k\Omega}}.$$

(ii)



— 1 mark per error.

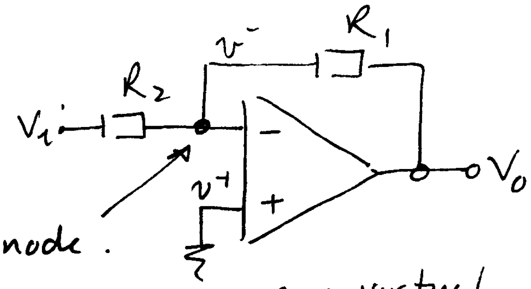
(iii).

$$\frac{v_o}{v_{be}} = -g_m R_L. \quad (\text{from o/p side}) = -222$$

$$\frac{v_{be}}{v_s} = \frac{r_{be}\|R_1\|R_2}{R_s + r_{be}\|R_1\|R_2} = \frac{4.8k\Omega}{2.2k\Omega + 4.8k\Omega} = 0.69$$

$$\therefore\ \frac{v_o}{v_s} = 0.69 \times (-222) = \underline{\underline{-153}}\ V/V.$$

Q4 (a)



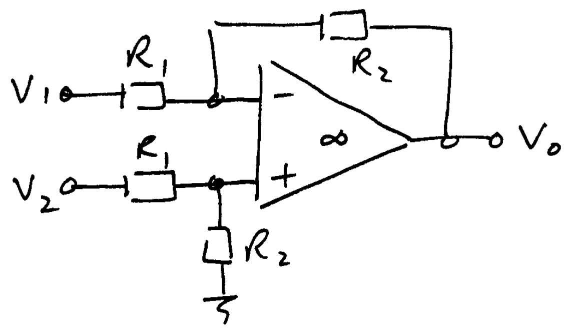
any virtual earth circuit will do.

The virtual earth is a point that is maintained at earth (ground) potential, even though it isn't actually connected to ground.

It exists in the cct above because of the very high gain of the op-amp.

$$V_0 = A_v(v^+ - v^-)$$ where A_v is very large. If V_0 is finite (say somewhere between +15V and −15V) and A_v is somewhere in the region of 10^6 V/V, then v^+ and v^- must be very close in potential (within 15µV of each other in this example). Thus if v^+ is connected to ground, v^- will always be close to ground potential.

(b) can either use superposition or work out v^+ & v^- and equate them.



superposition ...

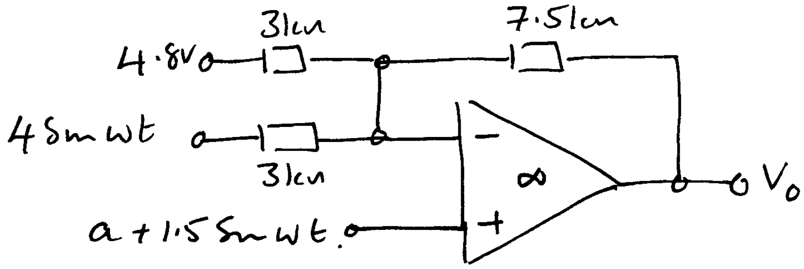
$$V_0 = V_0\Big|_{V_1} + V_0\Big|_{V_2}$$

$$= -\frac{R_2}{R_1}V_1 + \underbrace{V_2\frac{R_2}{R_1+R_2}}_{v^+} \cdot \underbrace{\frac{R_1+R_2}{R_1}}_{\text{non-inv. gain acting on } v^+}$$

$$= -\frac{R_2}{R_1}V_1 + \frac{R_2}{R_1}V_2$$

or $$\frac{V_0}{V_2 - V_1} = \frac{R_2}{R_1}$$

(c)



(i) Considering ac ....

$$V_o\Big|_{4\sin\omega t} = -2.5 \times 4 \sin\omega t = -10 \sin\omega t$$

$$V_o\Big|_{1.5\sin\omega t} = 1.5 \sin\omega t \times \frac{7.5 + 3\|3}{3\|3}$$

$$= 1.5 \sin\omega t \times \frac{9}{1.5} = 9 \sin\omega t$$

$$\therefore V_{oT} = \sin\omega t\,(-10 + 9) = -\sin\omega t$$

$$= \sin(\omega t + \pi)$$

ie magnitude $\underline{\underline{= 1}}$, $\phi = \underline{\underline{\pm 180}}$.

(ii) considering d.c. ....

$$V_o\Big|_{4.8V} = -2.5 \times 4.8V$$

$$V_o\Big|_{a} = a \cdot \frac{7.5 + 3\|3}{3\|3} = 6a.$$

$$V_{oT} = -2.5 \times 4.8 + 6a = 0.$$

$$\text{or } a = \frac{2.5 \times 4.8}{6} = 2.5 \times 0.8 = \underline{\underline{2V}}$$