1B Paper 8 - Section H. ~ Civil + Structural Eng.

Q. 1 Solution

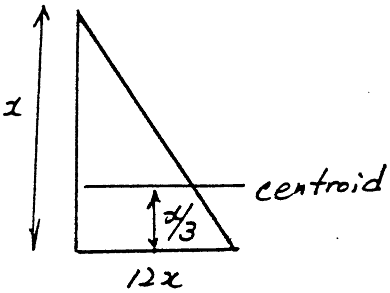
(a) Since the slab's own weight is ignored, the loading on the underside of the slab should be full hydrostatic pressure with no soil pressure $\therefore \; \underline{\underline{\omega = 40 \text{ KN/m}^2}}$ //

[2]

(b) In the side walls

$$\text{Moment} = \frac{12x \cdot x}{2} \cdot \frac{x}{3} = 2x^3$$

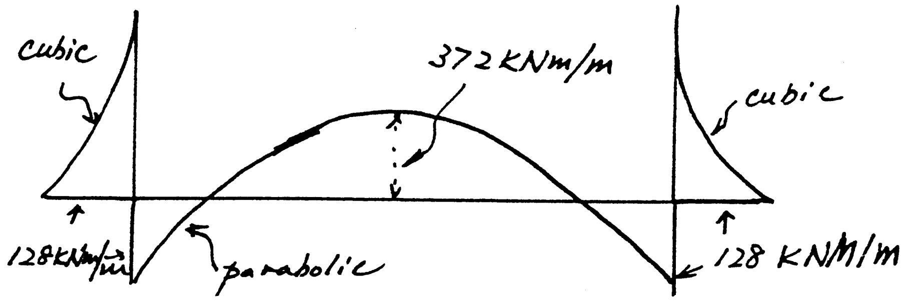
when $x = 4$. Moment $= 2 \cdot 4^3 = 128$ KNm/m



In the slab, free bending moment

$$= \frac{\omega L^2}{8} = \frac{40 \times 10^2}{8} = 500 \text{ kNm/m at the centre.}$$

Net moment at the centre $= 500 - 128 = \underline{\underline{372 \text{ KN M/m}}}$ //



Bending moment diagram

[6]

(c) Maximum moment to be resisted = 372 kNm/m

$M = 0.15 f_{cu} b d^2$ (from data sheet)

$b = 1000$ mm $\qquad f_{cu} = 40 \text{ N/mm}^2$

$$372 \cdot 10^6 = 0.15 \cdot 40 \cdot 1000 \cdot d^2$$

$\underline{\underline{d = 249 \text{ mm}}}$ Say 250 mm //

[4]

(d) • At the centre of the slab

If the slab is minimum thickness, then neutral axis will be at $d/2$: $n = 1/2$

$$\therefore \quad M = 0.87\, f_y\, A_s\, d\,(1 - \tfrac{n}{2}) \qquad \text{(data book)}$$

$$372 \cdot 10^6 = 0.87 \cdot 460 \cdot A_s \cdot 250\,(1 - \tfrac{1}{4})$$

$$A_s = 4957 \text{ mm}^2/\text{m}$$

from Data book, 32 mm bar is 804mm^2

Could use 32 mm bar at 160 mm centre-to-centre spacing (c.

• At the corners, moment applied is less than the maximum the section can accomodate $\therefore$ neutral axis will be at $< d/2$ and need to iterate to find the neutral axis.

Guess that the neutral axis is at $\frac{128}{372} \cdot 0.5d = 0.17d$

[students do not need to start with this value, any reasonable starting point will do.]

$$128 \cdot 10^6 = 0.87 \cdot 460 \cdot A_s \cdot 250\,(1 - \tfrac{0.17}{2}) \qquad \text{(data book)}$$

$$\Rightarrow A_s = 1398 \text{ mm}^2/\text{m}$$

Find new position of the neutral axis.

$$x = 2.175 \cdot (f_y / f_{cu})(A_s / bd) \qquad \text{(data book)}$$

$$= 2.175 \cdot (460/40) \cdot (1398/(1000 \cdot 250))$$

$$= 0.14$$

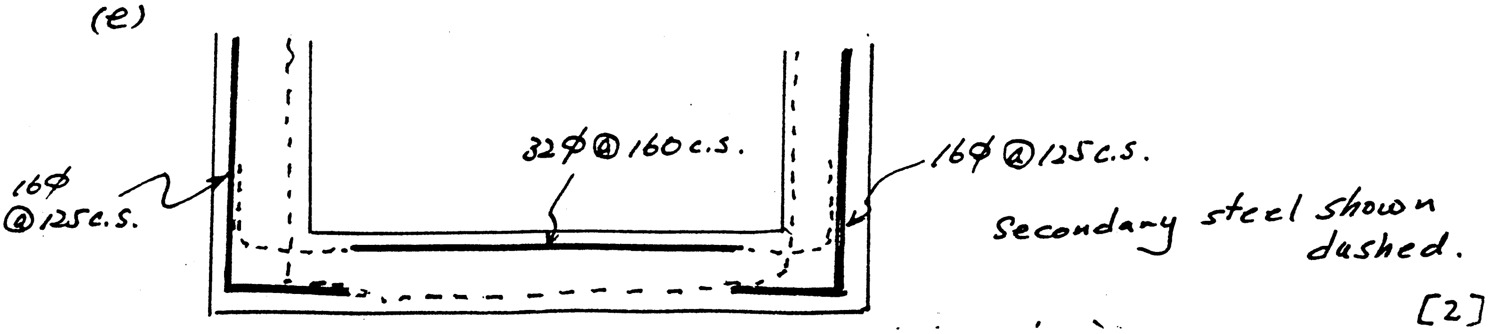
New value of $A_s = 1375 \text{ mm}^2/\text{m}$

from Data book. 16 mm bar is 201 mm^2

16 mm bar at 146 mm centre-to centre spacing (c.

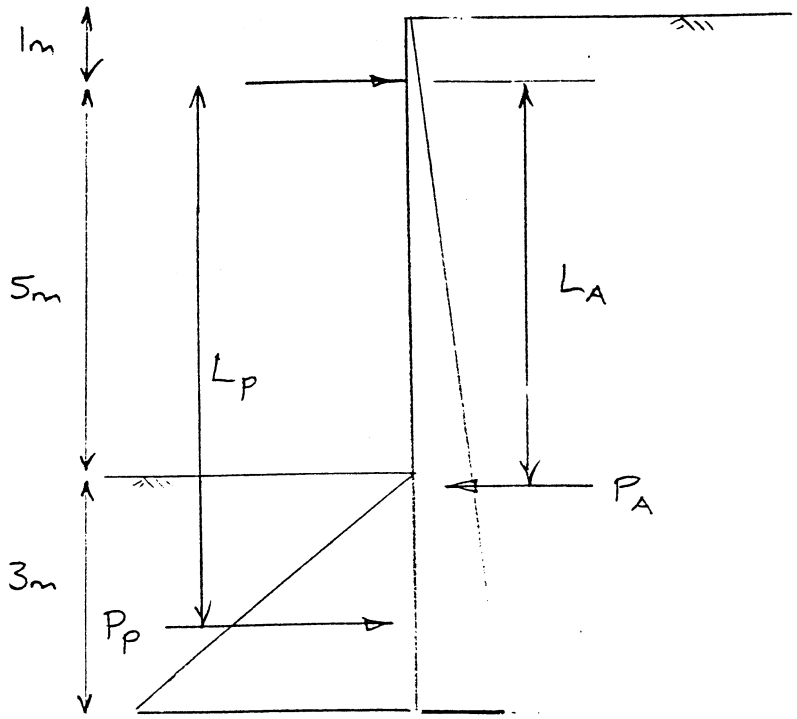
needed. could use 16mm bar at 125 c.s. " [6]

(e)



(2) [2]

Question 2. Solution



$\gamma = 17\ \text{kN/m}^3$

$\phi' = 35°$ $\quad K_a = \dfrac{1-\sin\phi'}{1+\sin\phi'} = 0.27$

$K_p = 1/K_a = 3.68$

Factor of safety against rotational failure

$$F = \frac{P_p . L_p}{P_A . L_A}$$

$P_A = \frac{1}{2} \times 0.27 \times 17 \times 9^2 = 186\ \text{kN/m}$

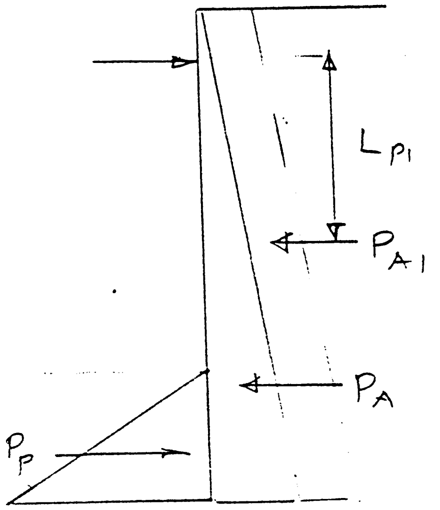
$L_A = 5\text{m}$

$P_p = \frac{1}{2} \times 3.68 \times 17 \times 3^2 = 281\ \text{kN/m}$

$L_p = 7\text{m}$

$\therefore\ F = \dfrac{281 \times 7}{186 \times 5} = \underline{\underline{2.1}}$ [8]

(i) Effect of 2m surcharge



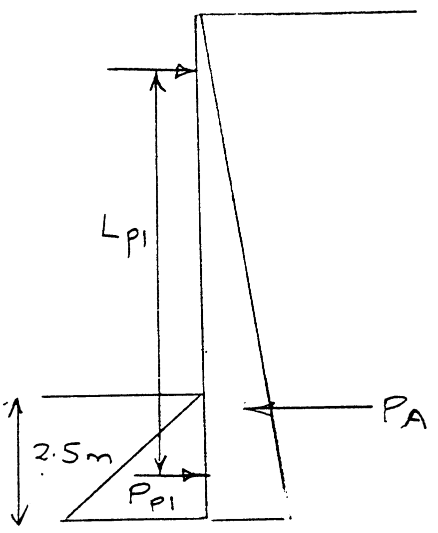
P_A, P_p, L_A, L_p as before
but additional force P_{A1}
and lever arm L_{p1}

$P_{A1} = 0.27 \times 17 \times 2 \times 9 = 82.6$ kN/m
$L_{A1} = 3.5$m

$$\therefore F = \frac{281 \times 7}{(186 \times 5) + (82.6 \times 3.5)} = \frac{1967}{930 + 289}$$

$$= \underline{\underline{1.61}}$$ [4]

(ii) Effect of 0.5m overdig

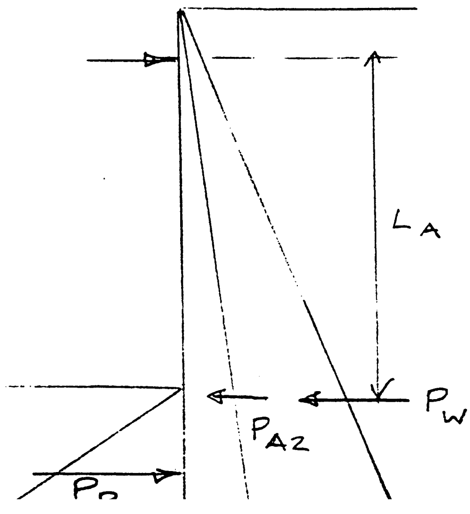


P_A, L_A as before

$P_{p1} = \frac{1}{2} \times 3.68 \times 17 \times 2.5^2 = 195$ kN/m
$L_{p1} = \left(\frac{2}{3} \times 2.5\right) + 5.5 = 7.17$m

$$\therefore F = \frac{195 \times 7.17}{186 \times 5} = \underline{\underline{1.50}}$$ [4]

(iii) Effect of burst water main $\gamma = 20$ kN/m³ behind wall



P_p, L_p as for 1st case
$P_{A2} = \frac{1}{2} \times 0.27 \times (20-10) \times 9^2 = 109$ kN/m
$P_W = \frac{1}{2} \times 10 \times 9^2 = 405$ kN/m
$L_A = 5$m (as before)

$$F = \frac{281 \times 7}{(109 + 405)5} = \underline{\underline{0.76}}$$ [4]

Question 3 Solution

Stability

The choice of tunnel excavation method must be such that the tunnel heading will remain stable during construction. Key factors affecting stability are:

- Ground conditions – permeable or impermeable (ie sands, gravels or clays)
- Groundwater conditions – is tunnel above or below water table?
- Depth of tunnel – this affects stability ratio in clays (ratio of total vertical stress at tunnel axis level to undrained shear strength of clay)

If tunnel is to be in impermeable ground, i.e. clays, and if the clay has sufficient undrained shear strength (stability ratio less than about 5), tunnel can be constructed in open face mode – i.e. no face support would be needed.

If the tunnel is to be in permeable ground, i.e. sands, gravels, or in soft clay where the stability ratio would be too high without face support (greater than about 5), then the tunnel must be constructed in closed face mode. This means a slurry or earth pressure balance machine.

An alternative to a closed face machine would be to use ground treatment to deal with the problem of water, either by grouting (if feasible) or by ground water lowering. [4]

Ground movements

Ground movements are inevitably caused by tunnelling in soft ground. Beneath cities this potentially could be a problem if there are buildings, structures or services (including existing tunnels) which may be damaged by movements.

Particularly vulnerable are old masonry buildings on shallow foundations. These are more prone to damage to differential settlement in the hogging mode. The key factor leading to damage is the magnitude of tensile strain induced in the building. The stiffness of the building is often significant in reducing differential settlement; overall tilt of a building is not generally damaging. Old services such as cast-iron water or gas mains are also vulnerable to differential settlement. [3]

Tunnel lining

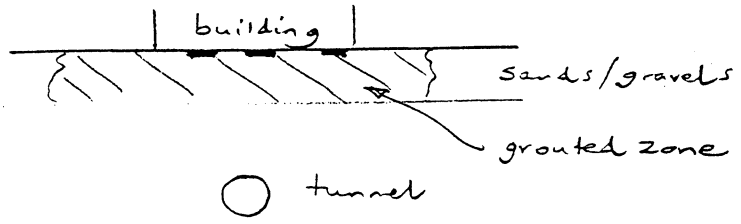
Tunnel linings can be precast segmental concrete (bolted or unbolted), segmental cast iron or sprayed concrete followed by cast in-situ concrete. In high speed construction, such as in running tunnels for a metro, segmental linings are usually selected. If the ground is low permeability stiff clay (eg London Clay) unbolted expanded linings are used. In other ground conditions the segments are always bolted. Sprayed concrete is generally only used for larger size tunnels (eg for station tunnels). [2]

(2)

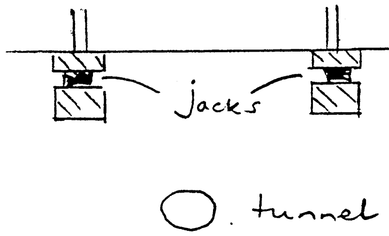
Possible protective measures

1. Tie rods can be used to strengthen weak masonry buildings.

2. Where the ground conditions allow, chemical grouting of sands or gravels beneath buildings on shallow foundations results in the building effectively being founded on a stiff raft. It is therefore able to withstand differential settlement of the ground by responding in a much more rigid mode.

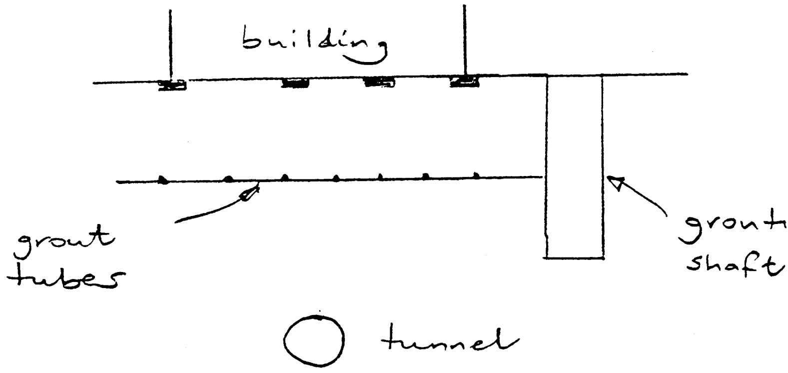


3. Positive jacking can be used. This involves cutting of a foundation, inserting hydraulic jacks and then jacking in response to measurements of movements so that the building is maintained at the same level.



4. Compensation grouting comprises the injection of grout (usually cementitious) into the ground between the tunnel and the building to be protected in such a way that the volume of grout injected compensates for the volume of ground "lost" into the tunnel. Grout tubes must be installed before tunnelling commences. Instrumentation must be installed on the building and in the ground to monitor carefully the movements, so that grouting can be undertaken at the right time and in the right quantities.

[6]



Instrumentation

Typical instrumentation:

Settlement monitoring stations, on the ground surface, and on buildings to allow precise levelling. Stations on ground surface to be along centre line of tunnel and also, at intervals, to be along transverse sections.

In special circumstances, for example where buildings are especially sensitive and/or compensation grouting is being used as a protective measure, they might also have electrolevels installed on them, so that differential settlements are monitored automatically.

Also in special cases, instruments to measure horizontal strain induced in buildings can be useful.

Subsurface instrumentation in the ground: vertical movements by rod extensometers or magnetic rings or by horizontal (or near horizontal) boreholes with electrolevels; horizontal movements by vertical inclinometers installed in boreholes.

In soft clays, piezometers to measure pore pressure changes.

In closed face tunnelling machines, pressure gauges to monitor pressure of slurry in the case of slurry machines or of spoil in the case of EPB machines.

[5]

IB Paper 8 - Section B Mechanical Engineering

4 (a) A = spanning pipe - most displacement - least stiffness
B = exposed pipe
C = buried pipe - least displacement - most stiffness

Type of excitation is likely to be a shaker, finite displacement at low frequency, displacement reduces to zero at high frequency. (Shaker force to drive mass is independent of frequency).

(b) Response is data-book case (a).

From data-book peak occurs at $\omega/\omega_n = \sqrt{1-2c^2}$ when

$$\frac{X_{max}}{KY} = \frac{1}{2c\sqrt{1-c^2}}$$

at lower frequencies $\frac{X}{KY} \rightarrow 1$

hence $\frac{X_{max}}{X_o} = \frac{1}{2c\sqrt{1-c^2}} = 1.75$ (from plot)

this leads to a quartic in c (quadratic in c^2) and values for c of ± 0.954 and ± 0.3.

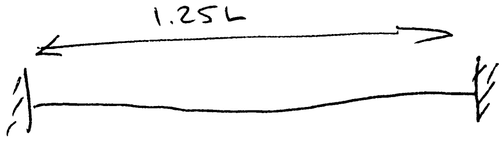
The only sensible answer is $c = 0.3$.

From the plot (with care of log scale) peak is at 4.5 Hz

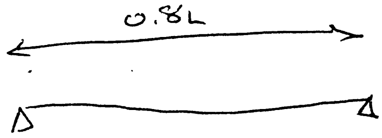
Hence $\omega_n = \frac{\omega}{\sqrt{1-2c^2}}$

$\therefore f_n \approx 5$ Hz

4(c) Spanning pipe may be modelled as:



or



where $k = \frac{192 EI}{(1.25L)^3} \approx \frac{94EI}{L^3}$ $\qquad k = \frac{48EI}{(0.8L)^3} \approx \frac{98EI}{L^3}$

$\therefore k \approx \frac{100 EI}{L^3}$

assuming equivalent mass = ½ span mass at centre span:

$$\omega_n \approx \sqrt{\frac{k}{m}}$$

$$\therefore (2\pi \times 5)^2 \approx \frac{100 EI}{L^3} \cdot \frac{1}{\pi d t \rho L/2} \qquad \text{where } I = \frac{\pi d^3 t}{8}$$

$$(2\pi \times 5)^2 \approx \frac{100 \times 210 \times 10^9}{L^3} \quad \frac{4.8 \times 10^{-3}}{\pi \times 0.8 \times 0.024 \times 7800 \times L/2}$$

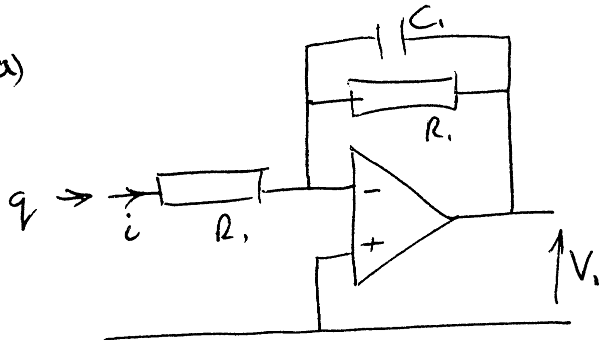
$$\therefore L^4 \approx 436 \times 10^3$$

$$L \approx 26 \text{ m}$$

(d) Measuring the displacement vs. frequency response requires a lot of data and multiple excitation frequencies. A shaker could be driven by a sweeping frequency and the resultant displacement measured. However, transients will effect the result.

Better to measure at one frequency (or two) to discriminate types of burial.

5 (a)



$$i = \frac{dq}{dt}$$

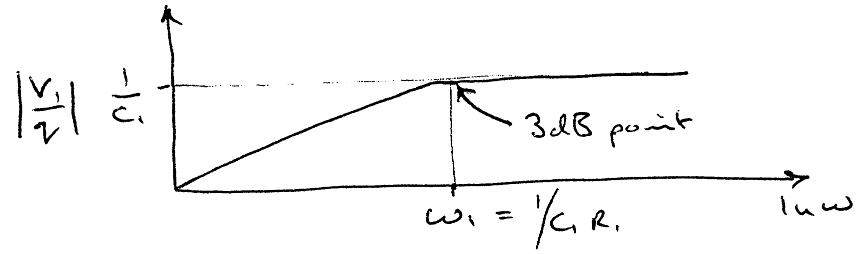
at -ve terminal:

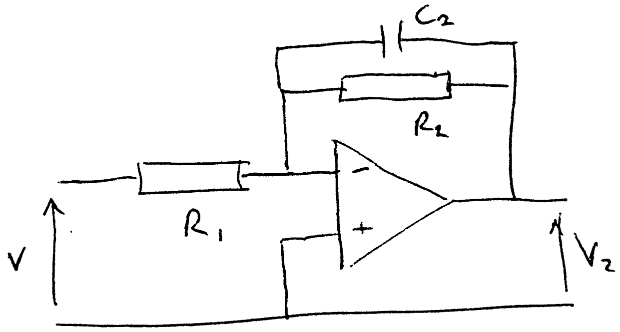
$$\frac{dq}{dt} + \frac{V_1}{R_1} + V_1 j\omega C_1 = 0$$

For harmonic input : $j\omega q + \frac{V_1}{R_1} + V_1 j\omega C_1 = 0$

$$\therefore \frac{V_1}{q} = \frac{j\omega R_1}{1 + j\omega C_1 R_1}$$

high-pass filter



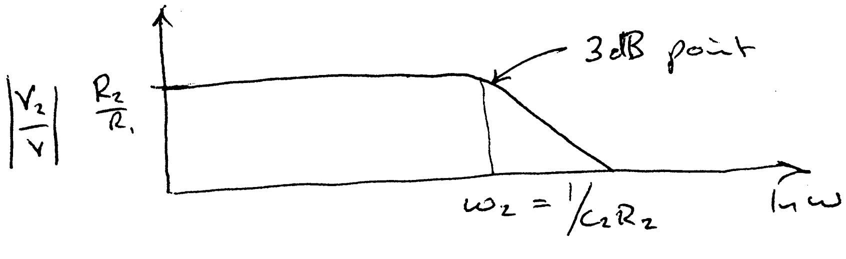


at -ve terminal:

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + V_2 j\omega C_2 = 0$$

$$\therefore \frac{V_2}{V} = \frac{R_2/R_1}{1 + j\omega C_2 R_2}$$

low-pass filter

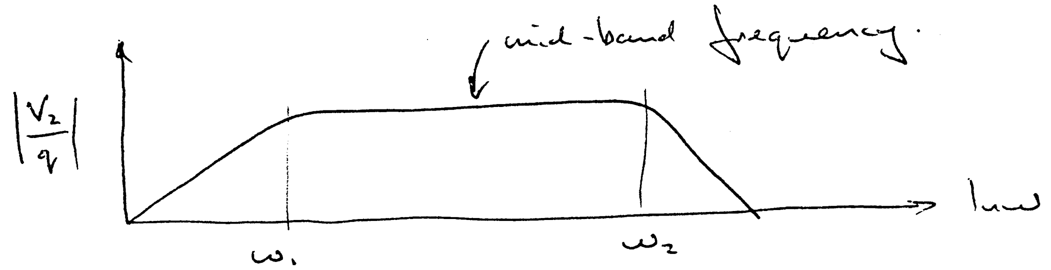


5 (b) The two circuits may be combined serially with V_1 connected to V.

The resultant gain is given by: $\frac{V_2}{q} = \frac{j\omega R_1}{1+j\omega C_1 R_1} \cdot \frac{R_2/R_1}{1+j\omega C_2 R_2}$

For a band-pass filter $\omega_2 \gg \omega_1$, hence $1/C_2R_2 \gg 1/C_1R_1$

$\therefore C_2R_2 \ll C_1R_1$



In addition for practical circuits choose all resistances to be less than 100MΩ. (less than op-amp input impedance).

(c) For a mid-band frequency, ω_0, of 15 Hz:

$$\frac{\omega_0}{\omega_1} = \frac{\omega_2}{\omega_0}$$

$$\therefore \omega_1\omega_2 = \omega_0^2$$

$$1/C_1R_1 \cdot 1/C_2R_2 = \omega_0^2$$

now $R_2 = 10R_1$ and $C_2 = 10^{-3}C_1$, hence on substitution and rearrangement: $1/C_1R_1 = \omega_0/10 = 9.4$

5 (c) If the gain is also fixed at mid-band:

Mid-band gain $\approx \frac{1}{C_1} \cdot \frac{R_2}{R_1}$ where $R_2 = 10R$.

$\therefore \frac{1}{C_1} \cdot 10 = 100 \times 10^{-6}$ and $C_1 = 0.1 \mu F$

then $R_1 = 1.1 M\Omega$ $R_2 = 10.1 M\Omega$
$C_1 = 0.1 \mu F$ $C_2 = 0.1 nF$

(d) Sampling frequency = 2 × maximum frequency of interest.
Set maximum frequency at higher 3dB point to ensure mid-band is included.

$\therefore$ Sampling frequency = 2 × 150 = 300 Hz

(e) Dynamic range of 60 dB in the voltage signal represents a 1000 to 1 range.
To capture this range in digital form 10 bits are required since $2^{10} = 1024$

Hence, 4 signals at 300 Hz of 10 bits for 20 hours

$= 4 \times 300 \times 10 \times 20 \times 60 \times 60$
$= 864$ Mbits
$= 108$ Mbytes.

6 (a) Specification should include reference to force requirement, size, frequency range, stroke. Estimates for values are required also.

Include reference to geographical market, maintenance, control requirements etc.

Identify demands and wishes in the specification.

(b) Highest risk? increasing force limit?
product support?

(c) Follow stages of BS7000
motivation/need – planning, feasibility
Creation – design development, production.

(d) FMEA – look at effect of individual component failures and look for reason of failure to identify actions to reduce chances of failure.

Apply to shaker at conceptual design stage when the system architecture is known. Continue to apply throughout the subsequent development.

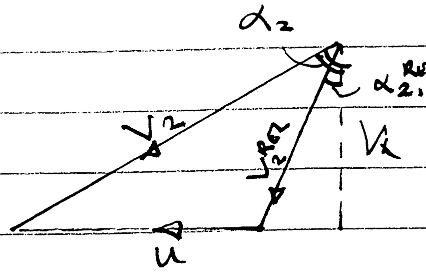
SECTION C AEROTHERMAL ENGINEERING.

Q7 (a) In the stator, the stagnation P & T are essentially constant, the velocity increases and so the pressure falls.

In the rotor, if the radius is constant, the relative stagnation P & T are essentially constant, the relative velocity increases and so the pressure falls.

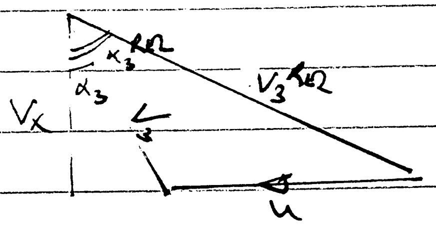
(b)

Stator Exit / Rotor Inlet



Rotor Exit / Stator Inlet

③ = ①



(c) $\alpha_2 = 60.3°$ $\quad \alpha_2^{REL} = 36.8°$ $\quad U = 156$ m/s

$\therefore \; V_x(\tan\alpha_2 - \tan\alpha_2^{REL}) = U \Rightarrow V_x = \underline{\underline{155.21 \text{ m/s}}}$

(d) $W_x = U(V_{\theta 2} - V_{\theta 3})$; $U = 156$ m/s

$V_{\theta 2} = V_x \tan\alpha_2$; $\alpha_2 = 60.3°$

$V_{\theta 3} = V_x \tan\alpha_3$; $\alpha_1 = \alpha_3 = -36.8°$ (Note -ve)

$\therefore \; \underline{\underline{W_x = 60562 \text{ W/kgs}^{-1}}}$ $\quad \Delta T_0 = \dfrac{W_x}{c_p} = \underline{\underline{59.96}}$

(e) $T_{045} = 950$ K $\quad \dot{m} = 400$ kgs^{-1}

$\dot{W}_x = 145$ MW

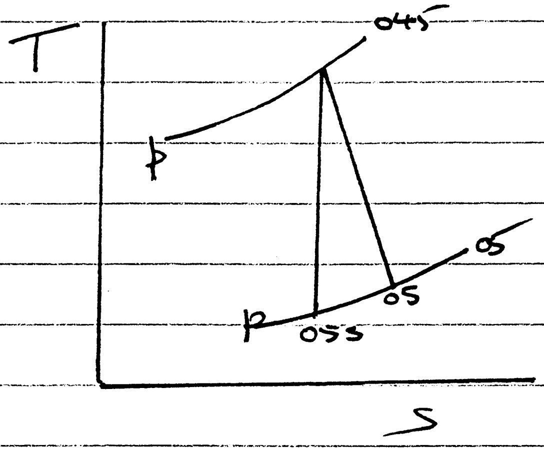
Q7
Cont

$$\# \text{ stages} = \frac{\dot{W}_x}{\dot{m}\, w_x} = \frac{145\times10^6}{400\times60562} = 5.96 = \underline{\underline{6}}$$

$$T_{05} = T_{045} - 6\times\Delta T_{0,\text{stage}}$$

$$= 950 - 6\times59.96$$

$$= 590.24$$



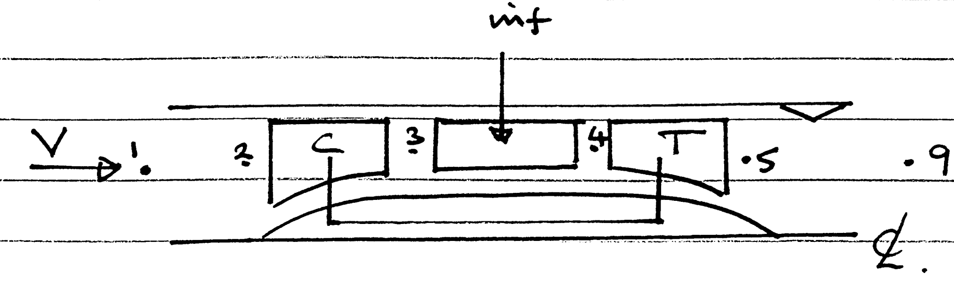
$$\therefore \frac{T_{045}-T_{05}}{T_{045}-T_{05s}} = 0.92$$

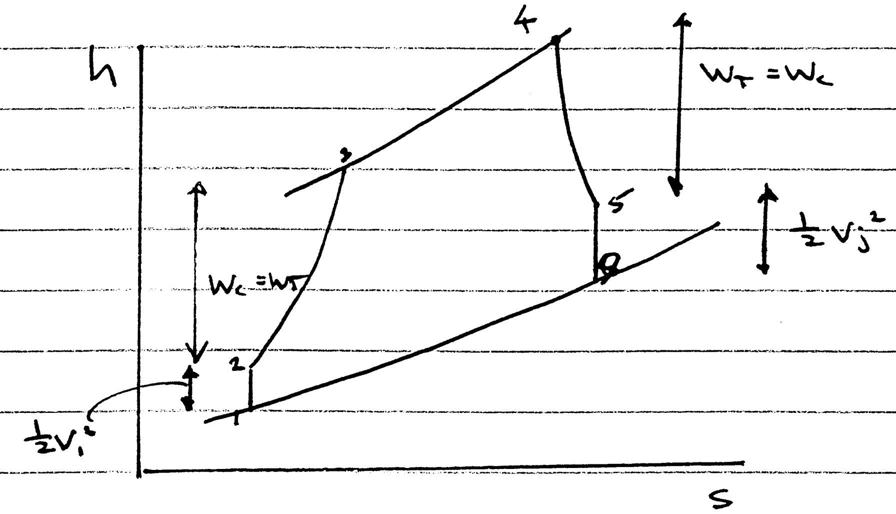
$$\therefore T_{05s} = 558.96\ \text{K}$$

$$\therefore \frac{P_{05}}{P_{045}} = \left(\frac{T_{05s}}{T_{045}}\right)^{\gamma/\gamma-1} = \underline{\underline{0.156 = \frac{1}{6.4}}}$$

(f) Normally, we expect a few turbine stages to drive many compressor stages. In this case, the fan power for 1 stage requires 6 LP turbine stages because (i) the blade speed of the fan is much higher due to its large radius and most importantly (ii) it has a much higher mass flow rate. Note that the stage loading of a fan ($=\Delta h_0/U^2$) will be lower than that of the turbine due to the presence of adverse pressure gradients in the fan which limits the max. pressure rise.

Q8 (a)





(b) (i) $T_{04c} = T_{04g} \times \frac{T_{01c}}{T_{01g}} = 1200 \times \frac{248}{288} = \underline{\underline{1033\,K}}$

because same compressor PR's, η's, $W_c = W_T$ etc

(ii) $\frac{\dot m \sqrt{c_p T_0}}{D^2 P_0}$ = const ie $\dot m_c = \dot m_g \sqrt{\frac{T_{0g}}{T_{0c}}}\,\frac{P_{0c}}{P_{0g}}$

$= 5\sqrt{\frac{288}{248}}\,\frac{36}{101} = \underline{\underline{1.92\ kg/s}}$

(c) $P_{03c} = P_{02c} \times PR = P_{01c} \times PR = \underline{\underline{360\ kPa}}$

$\eta_c = \frac{T_{03cs} - T_{02c}}{T_{03c} - T_{02c}} = 0.8$ ~~&~~ $T_{03cs} = T_{02c} \times PR^{\frac{\gamma-1}{\gamma}}$

$= 478.8\,K$

$\therefore T_{03c} = \underline{\underline{536.5\,K}}$

(16)

Q8 cont (d) $\eta_T = 0.85 = \frac{T_{04c} - T_{05c}}{T_{04c} - T_{05cs}}$

$T_{04} = 1033.3\ k$ $\quad c_p = 1010$

$W_T = W_C \Rightarrow T_{05} = T_{04} - [T_{03} - T_{02}]$
$= 1033.3 - [536.5 - 248]$
$= \underline{\underline{744.7\ k}}$

$\therefore T_{05s} = 693.8$

$\therefore P_{05} = P_{04}\left(\frac{T_{05s}}{T_{04}}\right)^{\gamma/\gamma-1} = \underline{\underline{89.32\ kPa}}$

(e) Isentropic $\therefore \frac{T_9}{T_{05}} = \left(\frac{p_9}{p_{05}}\right)^{\gamma-1/\gamma} = \left(\frac{22.5}{89.32}\right)^{1/3.5} = 0.6744$

$\therefore T_9 = 502.23\ k$

SFEE: $c_p T_9 + \frac{1}{2} V_9^2 = c_p T_{05}$

$\Rightarrow V_g = 699\ m/s$

$M = \frac{V_g}{\sqrt{\gamma R T_9}} = \frac{699}{\sqrt{1.4 \times 287 \times 502}} = 1.56 > 1\ \therefore$ choke

$X_g = \dot{m} V_9 = 1.92 \times 699 = \underline{\underline{1.34\ kN}}$

(f) $V_1 = \sqrt{2c_p(T_{01} - T_1)} = 252.2\ m/s$

$\therefore X_n = \dot{m}(V_g - V_1) = \underline{\underline{0.86\ kN}}$

Q9 (a) $\eta_p = \dfrac{\text{Power to aircraft}}{\text{Power to Jet}}$.

$$= \frac{V\left((\dot{m}_a + \dot{m}_f)V_j - \dot{m}_a V\right)}{\frac{1}{2}\left((\dot{m}_a + \dot{m}_f)V_j^2 - \dot{m}_a V^2\right)}$$

Neglecting $\dot{m}_f$: $\eta_p = \dfrac{V(V_j - V)}{\frac{1}{2}(V_j^2 - V^2)} = \dfrac{2V}{V + V_j}$

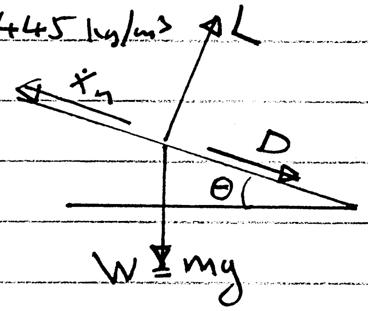
High η_p implies that "it is better to accelerate a large mass of air a little rather that vice versa" Hence the use of the bypass engine.

(b) The two most important reasons are the tyres and the length of the runway. A high speed is needed because of the limits on C_L.

(c) $C_L = \dfrac{mg}{\frac{1}{2}\rho V^2 A} = \dfrac{620 \times 10^3 \times 9.81}{\frac{1}{2} \times 1.225 \times 90^2 \times 766} = \underline{\underline{1.60}}$

(d)

(e) $\left.\begin{array}{l} P_a = 29\,kPa \\ T_a = 227K \end{array}\right\} \therefore \rho_a = \dfrac{p}{RT} = 0.445\,kg/m^3$



From vector diagram,

$L = W\cos\theta$

$X_n - D = W\sin\theta$

Q9 cont

$$\frac{L}{D} = 20 \Rightarrow D = \frac{L}{20} = \frac{W\cos\theta}{20}$$

$$\therefore X_n = W\sin\theta + \frac{W\cos\theta}{20} \quad ; \quad W = mg$$

To find θ: $M = 0.85$ $\therefore V_H = 0.85\sqrt{\gamma RT}$

$$= 0.85\sqrt{1.4\times 287\times 227}$$

$$= 256.7$$

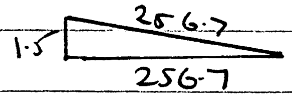
$$\theta = \tan^{-1}\left(\frac{V_V}{V_H}\right) = \tan^{-1}\left(\frac{1.5}{256.7}\right) = 0.3348^\circ$$

$$\therefore X_n = 620\times 10^3 \times 9.81\left[\sin 0.3348 + \frac{\cos 0.3348}{20}\right]$$

$$= 339.644 \text{ kN}$$

$\therefore X_n$/Engine = 84.911kN

(f) $\dot{m} = 510$ kg/s per engine



$$84911 = X_n \approx \dot{m}(V_j - V_1) = 510\,(V_j - 256.7)$$

$$\Rightarrow \underline{\underline{V_j = 423.2 \text{ m/s}}}$$

$$\eta_p = \frac{2\times 256.7}{423.2+256.7} = \underline{\underline{0.755}}$$

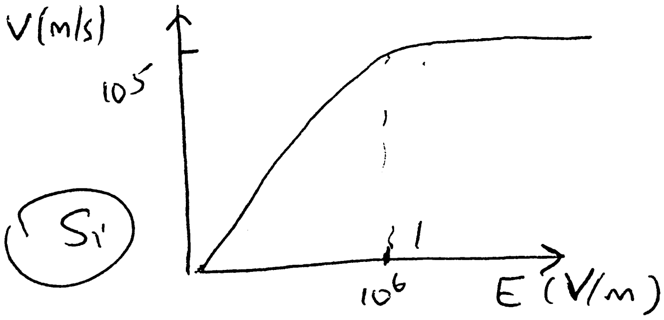
1B. Paper 8 - Section D - Electrical Engineering

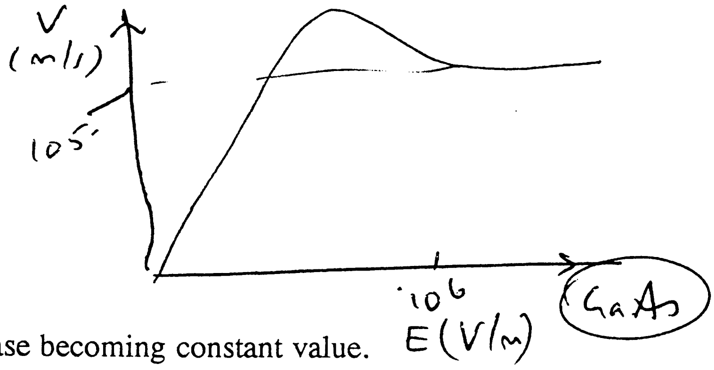
⑩

FCC has 4 sites per cell.
Electron concentration $= 4/(3.61 \,.\, 10^{-10})^3 = 8.5 \,.10^{28}$ m^{-3}.

$\sigma = Ne\mu$,
so $e\mu = 6 \,.10^7 / 8.5 \,.10^{28} = 7.06 \,.10^{-22}$ $[\mu = 0.0044\ m^2/V.s\,]$
$\sigma = 7.06.10^{-22} \,.10^{21} =$ **0.7 ohm^{-1} m^{-1}.**

Scattering limited velocity is when the maximum electron velocity is limited by phonon scattering, in which an electron loses all its KE in each collision with a phonon.





Show diagram of v vs. E, with linear increase becoming constant value.

Thus, $U_{ph} = 0.5mv^2 = 0.5 \,.9.1.10^{-31} \,.\, (5.10^4)^2 = 1.14.10^{-21}$ J = **0.0071 eV.**

Critical field $E_s = v_s/\mu = 5.10^4/0.0044 = 1.14.10^7$ V/m.

$L = V/E_s = 2\,/1.14.10^7 = 1.76\,.10^{-7}$ m = **0.176 μm.** W/L not relevant.

$\tau = L/v = 1.76.10^{-7}\,/5.10^4 = 3.52.10^{-12}$ s.

$\omega\tau = 1$, so $f_T = 1/2\pi\tau =$ **4.5. 10^{10} Hz.**

⑪

The gate drive must satify 2 conditions, $V_g < 2V$ and $E_{max} < E_{breakdown}$.

$V_g = [eND^2]/[2\varepsilon]$ and (1)
$E_{max} = [eND]/\varepsilon$, (2)
where D is the layer thickness.

Breakdown is the more critical limit.
Dividing these equations gives
$D = 2V_g/E_{max} = 2 \text{ x}2/2.10^7 = 2.10^{-7}$ m.

substitute for N into (2),
$N = \varepsilon E/eD = 10^{-10} .2.10^7 / 1.6.10^{-19}\, 2.10^{-7} = 6.25.10^{22}\ m^{-3}. << N_{max}$.

Use saturated electron velocity for fastest transit time
transit time $\tau = L/v_s = 0.3.10^{-6}/10^5 = 3.10^{-12} = 3$ ps.

Min field E needed for v_s is, $E = v_s/\mu = 10^5/0.01 = 10^7$ V/m. This is just less than breakdown field. This field gives the minimum source-drain voltage.

$V_{ds} = E.L = 10^7.0.3.10^{-6} = 3V$.

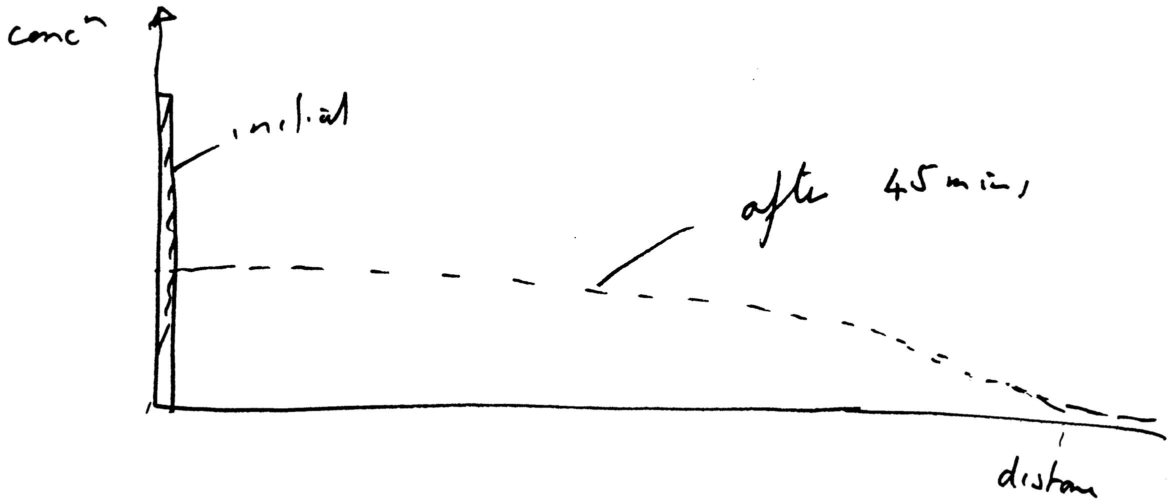
$I_{sat} = eNWDv_s = 1.6.10^{-19} .6.25.10^{22} .10x0.3.10^{-6} .2.10^{-7} .10^5 = 6.10^{-4}$ A

Q 12. Solution

① Diffusion etc

② Ion Implantation etc

for small features I.I best ∴ of lower anneal temp + ∴ shorter diffⁿ lengths, etc.



$$D \frac{\partial^2 c}{\partial x^2} = \frac{\partial c}{\partial t} \quad \ldots\ldots \quad (1)$$

show that $C = \frac{A}{\sqrt{t}} \exp\left[-\frac{Bx^2}{t}\right]$

is a solution

(2) + $\frac{\partial c}{\partial t} = -\frac{1}{2} A t^{-3/2} \exp\left(-Bx^2 t^{-1}\right) + Bx^2 t^{-2} A t^{-1/2} \exp[-Bx$

$$\frac{\partial c}{\partial x} = -2At^{-1/2} Bx\, t^{-1} \exp\left(-Bx^2 t^{-1}\right)$$

$$= -2ABt^{-3/2} x \exp\left(-Bx^2 t^{-1}\right)$$

$$\frac{\partial^2 c}{\partial x^2} = -2ABt^{-3/2} \exp -\left(Bx^2 t^{-1}\right) + 2Bxt^{-1}\, 2ABt^{-3/2} x \exp\left[-Bx^2 t^{-1}\right.$$

$$= \left[-2ABt^{-3/2} + 4AB^2 t^{-5/2} x^2\right] \exp\left[-Bx^2 t^{-1}\right] \quad (3)$$

sub. ② + ③ into ①

$$\Rightarrow \quad D\frac{\partial^2 c}{\partial x^2} - \frac{\partial c}{\partial t} = \left[-2ABt^{-3/2}D + 4AB^2t^{-5/2}x^2D + \tfrac{1}{2}At^{-3/2} - ABt^{-5/2}x^2\right]\exp\left[-Bx^2t\right.$$

$$= \left[\left(-2BD + \tfrac{1}{2}\right)t^{-3/2} + (4BD-1)Bt^{-5/2}x^2\right]A\exp\left(-Bx^2t^{-1}\right)$$

ie solⁿ if $D = \dfrac{1}{4B}$

$$D = D_0 \exp\left(\frac{-E_A}{kT}\right)$$

$$\frac{D(T_1 = 1273)}{D(T_2 = 1173)} = \frac{\exp\left(-\frac{E_A}{kT_1}\right)}{\exp\left(-\frac{E_A}{kT_2}\right)}$$

$$= \exp\left(E_A\left[-\frac{1}{kT_1} + \frac{1}{kT_2}\right]\right)$$

$k = 1.4\times10^{-23}$

$E_A = 1.1 \times 1.6\times10^{-19}$ J

$$\frac{D(1273)}{D(1173)} = \exp\left[1.1\times1.6\times10^{-19}\left[-\frac{1}{1.4\times10^{-23}\times1273} + \frac{1}{1.4\times10^{-23}\,1173}\right]\right.$$

$$\doteqdot 2.36$$

i.e diffⁿ. coeff at 900°C is 2.36 smaller ~~that~~ that at 1000°C

etc. for answer

~~etc~~

1B Paper 8.

SECTION E - INFORMATION ENGINEERING

Answer 13

(a) Light enough to wear. Probably have a wireless network. Use little power so as to last a year or more without user recharging. Probably have some simple user I/O and simple automatic sensor and configuration systems. Look smart.

(b) The Active Badge is a wearable computer used primarily for location purposes. It transmits an infra-red identification pulses every 15 seconds or so. The transmissions are diffuse and are picked up by receivers within a confined physical space. Infra-red radiation does not go through walls so the location of an Active Badge can be associated with a particular physical space. If attached to a thing an Active Badge provides a strong hint of where the thing is.

(c) Deep sleep mode based on simple RC timeout.
Sleep mode based on synchronised low-power accurate clocks.
Don't have receiver on all the time, only switch it on just after a transmission.
Use efficient scheme for transmissions (eg pulse position modulation).
Design overall system so as to bias power use to the backbone.
Use solar, piezo, mechanical, or some other continous recharger.
Use low-power semiconduinctor process in implementation.
Use fancy architectural approach in design (eg asynchronous).

Answer- 14.

(a) The operating system keeps process state in data structures called *process descriptors*. Each descriptor contains all the state information associated with a process, typically:

- Process ID
- Address space information
- File descriptors (and other I/O handles)
- Thread Information
    - Thread ID
    - State {blocked, running, runnable}
    - Program counter and register state
    - Stack information
    - Thread priority
    - Timeslice information

If the process is multi-threaded, then multiple thread descriptors are notionally attached to a process.

Process descriptors are stored in a process table. Multiple run queues are implemented by chaining together process threads for scheduling purposes.

(b) In accessing the file system, a *system call*, such as `read` or `write`, is used. A system call is a privileged instruction, executed in the context of the operating system. The filing system call manages the taking of data from memory/putting data into memory to/from disk, using the lower layers of I/O management and the relevant device driver. The system call will also mark the process as *blocked*, by executing a WAIT operation. The event to be waited for is the event that the disk operation has been completed. The thread will also be moved from its current queue to a blocked queue.

The WAIT operation affects the process descriptor by saving the current program counter, registers and stack, as well as marking the process state as blocked.

Other events that might cause the thread to block are other types of device access system calls or the thread running out of time in its timeslice.

(c) Two stages are involved in the thread recommencing running:

- The thread must be unblocked and marked as runnable

This occurs if the device operation requested has completed. An interrupt signalling this is handled by the relevant interrupt service routine. The SIGNAL operation is then invoked for the event in question thus unblocking the blocked process.

This affects the process descriptor by changing the state from *blocked* to *runnable.*

- The thread must be scheduled to run

The thread is now added to a runnable process queue. When it is eventually scheduled, the PC, registers, stack, address space information etc. are set up in hardware to allow the thread to run.

This affects the process descriptor by changing the state from *runnable* to *running*.

Answer , 15

(a) The IDL is processed by an *IDL interface compiler* to generate *stubs* and *skeletons*. Stubs and skeletons are used to *marshal* the data associated with an object operation invocation into a form that can be transmitted over a network.

The stubs forms part of a client-side proxy version of the PLS object. If an operation invocation occurs and the proxy detects, by looking at the PLS service's object reference, that the PLS service is on another machine, then it will use the stubs. The stubs communicate with the CORBA ORB (linked as a library or running as another local process). The stub calls operations to marshal the data into a transmittable form, and the ORB communicates with an ORB on the target machine (using IIOP - connecting to a internet address and port, extracted from the object reference) and transmits the relevant information (object reference, operation and marshalled parameters). An object adaptor is used to locate the relevant object within the service address space. For the PLS service this is easy, as there is just one.

The skeletons form part of the server-side PLS object implementation. They interact with the ORB to enable the receipt of the operation name and the unmarshalling of the operation parameters.

It is also possible to perform dynamic invocations, i.e. without compiling the IDL interface. In the context of this question, this information is not necessary. Full marks are obtainable without it. It is included for completeness.

To use dynamic invocation, IDL interfaces are stored in an *interface repository*. A dynamic invocation interface (equivalent of stub) accesses the interface representation from the repository, providing it with the information needed to transmit the operation invocation over the network. At the other end, a dynamic skeleton interface, also having accessed the interface repository, is able to decode the operation.

(b) To initially locate and bind to a distributed object like the PLS service, an *object reference* is required. This is an opaque encoding of an object's location: host, port (and thus process) and object within the process.

In order to obtain initially an object reference for the PLS service, a distributed client can contact a *naming service*. A naming service is a distributed object with a well-publicised object reference. The naming service stores mappings between object name and object reference. A request to the naming service includes the name of the object in question and returns the relevant object reference(s).

(c) To extend your architecture to deliver notification immediately it is detected that a pet has gone out requires a *callback* architecture.

A callback involves setting up an additional interface in the client process, something like the following:

```
interface PLSclient {
     void PetGoneOut(in string PetName)
}
```

This can then be called by the PLS service when a pet goes out, thus alerting the client.

The PLS service interface also has to be extended thus:

```
interface PLS {
     void InterestedClient(in PLSclient client);
     string PetLocation(in string PetName)
}
```

This extra operation allows clients that want to be informed to submit a reference to their callback interface. The PLS service stored such references and invoke the `PetGoneOut` operation on them as soon as it detects a pet has gone out.