

Engineering Part IB 2007-08

Numerical Solutions to Paper 1, Section A

1 b)  $\frac{L}{3}$

c)  $-\frac{4FL}{27}$

2 a)  $\frac{\dot{\theta}}{2}, 0$

b)  $-\frac{\dot{\theta}^2}{4}, -\frac{\dot{\theta}^2}{2}$

c)  $-\frac{mL^2\dot{\theta}^2}{4}$

3 a)  $-\frac{3}{2}\Omega^2 \sin \theta$

c)  $0, 4.73m\Omega^2 L$

ENGINEERING TRIPOS PART IB

PAPER 2: STRUCTURES

SECTION A

1 (a) One redundancy from  $s - m = b(3) + r(3 \times 2) - D \cdot j(2 \times 4) = 1$

(b)  $\mathbf{s} = [1 \ 1 \ 1]^T$

(c)  $\mathbf{t} = \mathbf{t}_0 + x\mathbf{s}$ ,  $x = AEe_0/3L - 2F \cos \theta/3$

$$\mathbf{t} = \begin{bmatrix} F \cos \theta/3 - F \sin \theta/\sqrt{3} + AEe_0/3L \\ F \cos \theta/3 + F \sin \theta/\sqrt{3} + AEe_0/3L \\ -2F \cos \theta/3 + AEe_0/3L \end{bmatrix}$$

(d)

$$\delta_v = \frac{2FL}{3AE} \uparrow, \quad \delta_h = \frac{2e_0}{3} \rightarrow$$

2 (a)  $J = I_{xx} + I_{yy}$  by perpendicular axis theorem, equal to  $2\pi R^3 t$

(b.ii)  $\sigma_1 = 27.5$  MPa,  $\sigma_2 = -2.5$  MPa,  $\sigma_3 = 0$  MPa, (b.iii) Factor is 9.54

3 (a) vertical  $V/2$  upwards and horizontal  $V/2$  inwards at both pins; reactions unaffected by temperature change

(b.i) vertical  $V/2$  upwards, horizontal  $V/(3\pi - 8)$  inwards, and moment  $VR(3\pi - 10)/2(3\pi - 8)$  at both feet

(b.ii)  $\Delta T = -VR^2/4EI\alpha$  (arch needs to be cooled to eliminate abutment thrust; moment persists)

SECTION B

4 (b)  $W_{\max} = 2M_p/L$

5 (a)  $V = 16M_p/3L$ , (b)  $H = 20M_p/3L$ , (c)  $H + 7V/4 = 34M_p/3L$

6 (b)  $F_2 = \sqrt{3}kH$ , (c)  $F_3 = 6kb$  smooth,  $F_3 = 6kb(1 + \mu)/(1 - \mu)$  rough

**Question 1:**

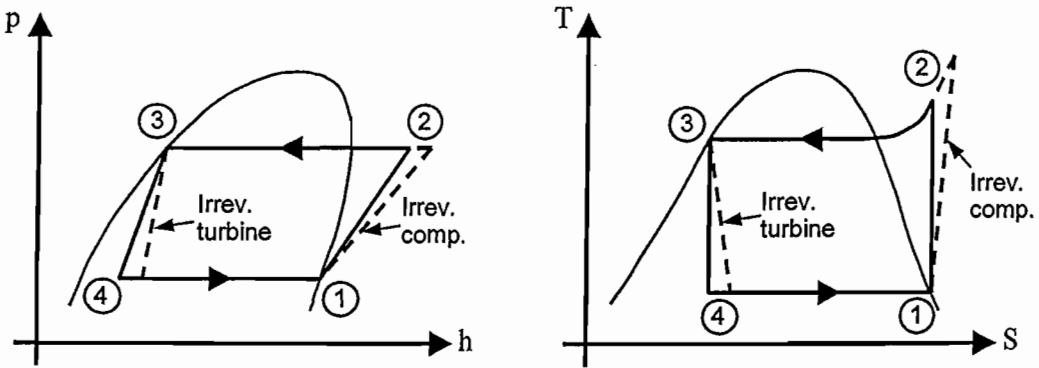
- (a) (ii)  $\dot{Q}/L = 6.713 \text{ Wm}^{-1}$
- (iii)  $\dot{Q}/L = 4.76 \text{ Wm}^{-1}$  (surface temp. of insulation  $T_2 = 17.1 \text{ }^\circ\text{C} = 290.1 \text{ K}$ )
- (b) (ii)  $Re_d = 27281$  so Turbulent flow. ( $V = 3.150 \text{ ms}^{-1}$ )
- (iii)  $Nu_d = 136.4$
- (iv)  $T_0 = 277.5 \text{ }^\circ\text{C}$  ( $h = 17730 \text{ Wm}^{-2}\text{K}^{-1}$ )

**Question 2:**

- (d)  $\dot{m}_{s4} = 0.0851 \text{ kgs}^{-1}$
- (e)  $\dot{Q}_{heater} = 208.87 \text{ kJs}^{-1}$
- (f)  $\dot{m}_{w2} = 0.2274 \text{ kgs}^{-1}$
- (g)  $\dot{Q}_{cooler} = 933.43 \text{ kJs}^{-1}$

**Question 3:**

- (a)  $COP|_{rev} = 3.97$
- (b) Liquid water entering a turbine is likely to cause damage.
- (c)



- (e)  $h_4 = 260.7 \text{ kJ kg}^{-1}$
- (f)  $COP|_{actual} = 3.94$  The mean temperature of heat rejection is slightly large than  $50 \text{ }^\circ\text{C}$ .

**Question 4:**

- (a) Force per unit length:  $C_D = \frac{F}{\frac{1}{2} \rho V^2 d}$  and  $Re = \frac{\rho V d}{\mu} \left[ = \frac{V d}{\nu} \right]$
- (e) (i)  $Force / Length = 55.1 \text{ Nm}^{-1}$  ( $C_D \approx 1$ )
- (ii)  $Force / Length = 1.2 \text{ Nm}^{-1}$  ( $C_D \approx 1$ )

**Question 5:**

- (e)  $\tan \alpha_2 = b \tan \beta$

**Question 6:**

- (e)  $dp/dx = -\rho g H / h$
- (f) Volume flow rate:  $\dot{Q} = \frac{\pi}{128 \mu} \rho g \left( 1 + \frac{H}{h} \right) d^4$

Answers

Q3: b)  $N=2$  for stiff clay and  $N=8.5$  for soft clay

Q4: b) FoS against sliding = 2.5  
d) FoS against sliding = 1.2

Q5: a)  $p = 510 \text{ kN/mm}^2$ ;  $q = 75 \text{ kN/mm}^2$   
b) Max BM = 510 kNm/m; Min BM = -290.4 kNm/m  
c)  $d \geq 337 \text{ mm}$   
d)  $A_s = 3063 \text{ mm}^2/\text{m}$ ; Choose 25 mm bars @ 150 mm spacing  
e) Special rebar needed to deal with concentrated load from anchorage.

**IB Paper 8    Aerothermal Elective 2008    Answers**

9.

b) 792.8 K, 0.401

c) 1247.2 K, 4.24

d) 11

10.

a)  $F_N = F_G - \dot{m}V$

c) (i) 238.3 K, 20.8 kPa    (ii) 206.7 m/s, 9.134 kN

d) 88.3 kg/s, 42.66 kN, 483 m/s

e) 9096 rpm

11.

c) (i) 401 m<sup>2</sup>    (ii) 0.70,  $0.0172 \times 10^{-3} \text{ kg s}^{-1} \text{ N}^{-1}$

paper 8 Section E  
Numerical Answers

12. (c)  $199.98 \text{ fm}$ ,  $200.02 \text{ fm}$

13. (b)  $1.5 \times 10^{-15} \text{ s}$   
(c)  $4.68 \times 10^{23} \text{ m}^{-3}$

14. d (i)  $2 \text{ fm}$ ,  $1.6 \times 10^{-11} \text{ s}$   
(ii)  $2.8 \times 10^{-13} \text{ s}$

*w/a* 11/6/08