UNIVERSITEIT VAN JOHANNESBURG — UNIVERSITY OF JOHANNESBURG

SPECIAL EXAMINATION
13 JANUARY 2015

COURSE:	MECHANICAL ENGINEERING	**TIME:**	180 mins
SUBJECT:	THEORY OF MACHINES MKE3B21	**MARKS:**	90

EXTERNAL EXAMINER: Mr JG Benade PrEng
INTERNAL EXAMINER: Dr CR Bester PrEng

- Formula sheets attached
- No books, lecture notes, self-study-, homework- or practical material allowed
- No cellphone use or communication allowed
- Only UJ approved calculators allowed
- Do not write in pencil or red ink
- Answer all the questions in English
- Smoking is prohibited during the exam

Question 1 **(15 marks)**

(a) A fan delivers a total pressure of 250 Pa and an air flow of 1,5 m^3/s at atmospheric conditions of 101325 Pa and 15°C, when running at nominal (100%) speed. Calculate the fan power. (2)

(b) At what percentage of nominal speed will the same fan run, at atmospheric conditions of 84 kPa and 33°C, if driven by the same power as in (a)? (13)

Question 2 **(20 marks)**

Derive an equation for the power specific speed of a hydraulic turbine. Select the required parameters and then the primary parameters. Determine the dimensions of the parameters and apply Dimensional Analysis to obtain the power specific speed as a dimensionless ratio.

2015-01-09 2015-01-12

Question 3 **(19 marks)**

The six cylinders of a two-stroke Diesel engine are pitched 1 m apart and the cranks are spaced at 60° intervals. The crank length is 300 mm and the connecting rod-to-crank length ratio is 4,5:1. The reciprocating mass per cylinder is 1350 kg and the rotating mass is 1000 kg. The speed is 200 RPM. The firing order is 1-5-3-6-2-4. Take the central plane of the engine as reference. Determine if the engine is balanced wrt secondary forces and moments.

Question 4 **(20 marks)**

Consider the epicyclic gear system shown in Figure 1. A is the annulus, L is the arm, S is the sun wheel and P are the planet wheels. The diameter of S is 300 mm and that of P is 100 mm. If S is the input and A is the output, calculate the overall ratio of the gearbox when L runs at 500 RPM and S runs at 800 RPM.

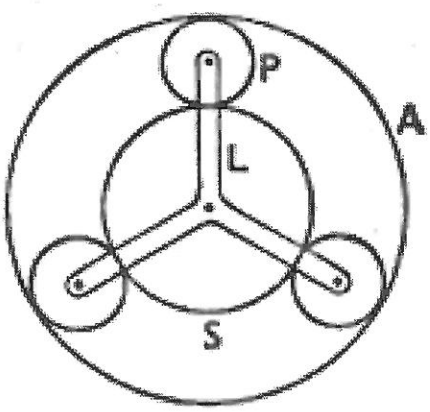

Figure 1: Epicyclic gear system

Question 5 **(16 marks)**

Derive the characteristic equation of a thin linear uniform homogeneous beam with both ends clamped

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Various formulae

$$x = (R + r_0)\sec\theta - (R + r_0)$$
$$f = \ddot{x} = \omega^2 (R + r_0)(2\sec^3\theta - \sec\theta)$$
$$x = \{d\cos\phi + (r + r_0)\cos\gamma\} - (R + r_0)$$
$$\sin\gamma = (\sin\phi)/n$$
$$\cos\gamma = \sqrt{1 - \sin^2\gamma}$$
$$v = -\omega d\left\{\sin\phi + \frac{\sin 2\phi}{2\sqrt{n^2 - \sin^2\phi}}\right\}$$
$$f = -\omega^2 d\{1 + 1/n\}$$
$$v = -\omega d\sin\phi$$
$$f = -\omega^2 d$$
$$v = \omega d\sin\theta$$
$$P = mf$$
$$Fa = \{mf + S(x + y)\}(R + r_0)\sec\theta\tan\theta$$
$$Fa = F(\rho - R)\sin\theta$$
$$F_r = mr\Omega^2$$

$$F_{ix} = m_i r_i \Omega^2 \cos\theta_i$$
$$f = \frac{2gh_L}{V^2}\frac{D}{L}$$
$$Re = \rho DV/\mu$$
$$f = f(Re, \quad \varepsilon/D)$$
$$R = r/a$$
$$\ddot{y}_p \approx a\Omega^2\cos\theta$$
$$\theta_S = -\frac{T_A}{T_S}\theta_A$$
$$m\ddot{y}(t) + c\dot{y}(t) + ky(t) = F(t)$$
$$\omega_n = \sqrt{k/m}$$
$$\tau = \mu\frac{\partial u}{\partial y}$$
$$f(t) = Fe^{j\omega t}$$
$$\dot{y}(t) = j\omega Ye^{j\omega t}$$
$$\left|\frac{Y}{F/m\omega_n^2}\right| = \frac{1}{\sqrt{(1 - r^2)^2 + (2\zeta r)^2}}$$
$$Q = CN^a D^b$$
$$Q/ND^3 = C$$

$$v = \dot{x} = \omega(R + r_0)\sec\theta\tan\theta$$
$$\tan\beta = (d\sin\alpha)/(R + r_0)$$
$$d\sin\phi = (r + r_0)\sin\gamma$$
$$n = (r + r_0)/d$$
$$x = d\left\{\cos\phi + \sqrt{n^2 - \sin^2\phi}\right\} - (R + r_0)$$
$$f = -\omega^2 d\left\{\cos\phi + \frac{\sin^4\phi + n^2\cos 2\phi}{(n^2 - \sin^2\phi)^{3/2}}\right\}$$
$$x = (d\cos\phi + r) - R$$
$$f = -\omega^2 d\cos\phi$$
$$x = d(1 - \cos\theta)$$
$$f = \omega^2 d\cos\theta$$
$$F\cos\theta = mf + S(x + y)$$
$$F = mf + S(x + y)$$
$$Fa = \{mf + S(x + y)\}(\rho - R)\sin\theta$$
$$\ddot{x} \approx a\Omega^2\left(\cos\theta + \frac{\cos 2\theta}{l/r}\right)$$

$$F_{iy} = m_i r_i \Omega^2 \sin\theta_i$$
$$h_L = f\frac{L}{D}\frac{V^2}{2g}$$
$$\ddot{y} \approx a\Omega^2\left(\cos\theta + \frac{\cos 2\theta}{R}\right)$$
$$\Omega = \dot{\theta}$$
$$\ddot{y}_s \approx (a\Omega^2/R)\cos 2\theta$$
$$\theta_P = \frac{T_A}{T_P}\theta_A$$
$$\ddot{y} + 2\zeta\omega_n\dot{y} + \omega_n^2 y = \frac{F}{m}$$
$$\zeta = c/(2m\omega_n) = c/(2\sqrt{km})$$
$$\mu = \frac{\tau}{\partial u/\partial y}$$
$$y(t) = Ye^{j\omega t}$$
$$\ddot{y}(t) = -\omega^2 Ye^{j\omega t}$$
$$\therefore Q = Q(N, \quad D)$$

$$Q = CND^3$$
$$\therefore P = fcn(\rho, \quad N, \quad D)$$

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$$\pi = \frac{P}{\rho N^2 D^2}$$

$$P = \rho g H$$

$$\pi_2 = \frac{H}{D}$$

$$\frac{\pi_1}{\pi} = \frac{P}{\rho N^2 D^2} \Big/ \frac{gH}{N^2 D^2} = \frac{P}{\rho g H}$$

$$k = n - j$$

$$\pi_2 = \pi_P = \frac{P}{\rho N^2 D^2}$$

$$\pi_4 = \frac{\rho N D^2}{\mu}$$

$$Nu = Nu(Re, \quad Pr)$$

$$Re = \rho x V / \mu$$

$$Nu = C Re^m Pr^n$$

$$N_s = \frac{(flow\ coefficient)^{1/2}}{(head\ coefficient)^{3/4}}$$

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

$$C_H = gH / N^2 D^2$$

$$C_{\dot{W}} = \dot{W} / \rho N^3 D^5$$

$$\frac{\dot{W}}{\rho N^3 D^5} = f_5\left(\frac{Q}{ND^3}, \quad \frac{\rho N D^2}{\mu}, \quad \frac{\varepsilon}{D}\right)$$

$$C_{\dot{W}} = \frac{\dot{W}}{\rho N^2 D^2} = C_{\dot{W}}(C_Q)$$

$$\therefore \pi = N^{-c} D^{-c} V^c = \left(\frac{V}{ND}\right)^c$$

$$\frac{\dot{W}}{\rho N^3 D^5} \Big/ \frac{\tau}{\rho N^2 D^5} = \frac{\dot{W}}{\tau N}$$

$$\pi = \pi_F = \frac{F}{\rho N^2 D^4}$$

$$U_2 = r_2 \Omega = \left(\frac{D_2}{2}\right)\left(\frac{2\pi N}{60}\right) = \frac{\pi N D_2}{60}$$

$$A_1 = \pi D_1 t, \quad A_2 = \pi D_2 t$$

$$H = fcn(g, \quad N, \quad D)$$

$$\pi_1 = \frac{g}{N^2 D}$$

$$\pi = \pi_1 \pi_2 = \left(\frac{g}{N^2 D}\right)\left(\frac{H}{D}\right) = \frac{gH}{N^2 D^2}$$

$$\therefore \pi = \frac{gH}{N^2 D^2}$$

$$\pi_1 = \pi_Q = \frac{Q}{ND^3}$$

$$\pi_3 = \pi_{\dot{W}} = \frac{\dot{W}}{\rho N^3 D^5}$$

$$\pi_5 = \frac{\varepsilon}{D}$$

$$Nu = hx/k$$

$$Pr = \mu C_p / k$$

$$C = 0{,}332; \quad m = 1/2; \quad n = 1/3$$

$$N_s = \frac{N\sqrt{Q}}{(gH)^{3/4}}$$

$$\eta = C_H C_Q / C_{\dot{W}}$$

$$C_Q = Q / ND^3$$

$$\frac{gH}{N^2 D^2} = f_1\left(\frac{Q}{ND^3}, \quad \frac{\rho N D^2}{\mu}, \quad \frac{\varepsilon}{D}\right)$$

$$C_H = \frac{gH}{N^2 D^2} = C_H(C_Q)$$

$$\eta = \frac{C_H(C_Q) C_Q}{C_{\dot{W}}(C_Q)}$$

$$\pi = \pi_\tau = \frac{\tau}{\rho N^2 D^5}$$

$$\pi = \frac{\pi_\tau}{\pi_P} = \frac{\tau}{\rho N^2 D^5} \Big/ \frac{P}{\rho N^2 D^2} = \frac{\tau}{D^3 P}$$

$$U_1 = r_1 \Omega = \left(\frac{D_1}{2}\right)\left(\frac{2\pi N}{60}\right) = \frac{\pi N D_1}{60}$$

$$\dot{m}_1 = \rho A_1 c_{r1} = \rho A_2 c_{r2} = \dot{m}_2$$

$$\rho \pi D_1 t c_{r1} = \rho \pi D_2 t c_{r2}$$

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$$\tau_1 = r_1 \underbrace{\underbrace{\frac{d}{dt}\left(\underbrace{mc_{\theta 1}}_{momentum}\right)}_{force}}_{moment} = r_1\left(\dot{m}c_{\theta 1} + m\underbrace{\dot{c}_{\theta 1}}_{=0}\right)$$

$$w_p = U_2 c_{\theta 2} - U_1 c_{\theta 1}$$

$$P_p = \rho\left(U_2 c_{\theta 2} - U_1 c_{\theta 1}\right)$$

$$S = \frac{N\sqrt{Q}}{\left(NPSH_{required}\right)^{3/4}}$$

$$\eta = \frac{Fluid \quad power}{Power \quad input} = \frac{\rho g Q H}{P_{in}} = \frac{\rho g Q H}{T_{in}\Omega}$$

$$H_p = aQ^2 + bQ + c$$

$$H_p = -2{,}55.10^6 Q^2 + 63{,}76\ m \quad water$$

$$U_2 = \left(\frac{D_2}{2}\right)\left(\frac{2\pi N}{60}\right) = \frac{\pi N D_2}{60} = \frac{\pi N D_1}{60} = U_1$$

$$\pi_P = P_t / N^2 D^2$$

$$\phi = Q \Big/ \frac{\pi}{4} D^2 U$$

$$\psi_{st} = P_{st} \Big/ \frac{1}{2}\rho U^2$$

$$\eta_{st} = P_{st} Q / \dot{W}_{in}$$

$$N_s = \frac{N\sqrt{Q}}{P_{st}^{3/4}}$$

$$P_{dyn} = \frac{1}{2}\rho\left(\bar{c}\right)^2$$

$$\eta_t = \left(P_t Q / \dot{W}_{in}\right)$$

$$\Omega_{sp} = \frac{\Omega\sqrt{\dot{W}/\rho}}{\left(gH_E\right)^{5/4}}$$

$$\dot{W} = PQ$$

$$w_T = U_2 c_{\theta 2} - U_3 c_{\theta 3}$$

$$H_p = \dot{W}_T / \dot{m} g = \dot{W}_T / \rho Q g = \frac{U_2 c_{\theta 2} - U_3 c_{\theta 3}}{g}$$

$$H_G = z_R - z_N$$

$$c_0 = \sqrt{2gH_E}$$

$$\eta_N = \frac{c_1^2}{2gH_E} = \frac{H_E - \Delta H_N}{H_E}$$

$$H_p = \dot{W}_p / \dot{m} g = \frac{U_2 c_{\theta 2} - U_1 c_{\theta 1}}{g}$$

$$\dot{W}_p = \tau_A \Omega = \dot{m}\left(U_2 c_{\theta 2} - U_1 c_{\theta 1}\right)$$

$$NPSH_{available} \geq NPSH_{required}$$

$$\frac{NPSH_{required\ 2}}{NPSH_{required\ 1}} = \left(\frac{N_2}{N_1}\right)^2$$

$$h_L = f\frac{L_{eq}}{D}\frac{V^2}{2g} = 0{,}02\frac{L_{eq}}{2gD}\left(\frac{Q}{A}\right)^2$$

$$h_L = f\frac{L}{D}\frac{V^2}{2g} = f\frac{L}{D}\frac{1}{2g}\left(\frac{Q}{A}\right)^2 = f\frac{L}{D}\frac{1}{2g}\frac{Q^2}{\left(\pi D^2/4\right)^2}$$

1 (US gal/min)$^{1/2}$ / (ft)$^{3/4}$ = 1,936.10^{-2} (m^3/s)$^{1/2}$ / (m)$^{3/4}$

$$\pi_Q = Q / ND^3$$

$$\pi_{\dot{W}} = \dot{W} / N^3 D^5$$

$$\psi = P_t \Big/ \frac{1}{2}\rho U^2$$

$$\eta = P_t Q / \dot{W}_{in}$$

$$\pi_{\dot{W}} = \phi\psi / \eta$$

$$\bar{c} = Q / A$$

$$P_t = P_{st} + P_{dyn}$$

$$\eta_{st} = \left(P_{st} Q / \dot{W}_{in}\right)$$

$$\pi_{sp} = \frac{\left(power\ coefficient\right)^{1/2}}{\left(head\ coefficient\right)^{5/4}}$$

$$N_{sp} = \frac{N\sqrt{\dot{W}}}{H^{5/4}}$$

$$\dot{W}_T = \dot{m}\left(U_2 c_{\theta 2} - U_3 c_{\theta 3}\right) = \rho Q\left(U_2 c_{\theta 2} - U_3 c_{\theta 3}\right)$$

$$P_T = \rho\left(U_2 c_{\theta 2} - U_3 c_{\theta 3}\right)$$

$$H_E = H_G - H_f = z_R - z_N - H_f$$

$$K_N = \frac{c_1}{c_0}$$

$$\eta_h = \eta_N \eta_R = \frac{c_1^2}{2gH_E}\frac{w_T}{c_1^2/2} = \frac{w_T}{gH_E}$$

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2015-01-12

$$\eta_o = \eta_N \eta_R \eta_m$$

$$A_j = \frac{Q}{2c_1}$$

$$P \, \alpha \, \rho N^2 D^2; \quad Q \, \alpha \, ND^3$$

$$A_j = \pi \frac{d_j^2}{4}$$

$$\frac{p_a}{\rho g} + H_E = \frac{p_2}{\rho g} + \frac{c_2^2}{2g} + z_2 + \Delta H_N$$

$$\frac{p_a}{\rho g} + H_E = \frac{p_3}{\rho g} + \frac{c_3^2}{2g} + z_3 + \Delta H_N + \Delta H_R + \frac{\dot{W}}{\rho Q g}$$

$$\frac{p_3}{\rho g} + \frac{c_3^2}{2g} + z_3 = \frac{p_a}{\rho g} + \frac{c_4^2}{2g} + \Delta H_{DT}$$

$$\frac{p_2}{\rho g} + \frac{c_2^2}{2g} + z_2 = \frac{p_3}{\rho g} + \frac{c_3^2}{2g} + z_3 + \Delta H_R + \frac{\dot{W}}{\rho Q g}$$

$$\frac{\dot{W}}{\rho Q g} = \frac{p_2 - p_3}{\rho g} + \frac{c_2^2 - c_3^2}{2g} + (z_2 - z_3) - \Delta H_R$$

$$\frac{\dot{W}}{\rho Q g} = \frac{p_{02} - p_{03}}{\rho g} + (z_2 - z_3) - \Delta H_R$$

$$\eta_H = \frac{turbine \;\; work}{g(available \;\; head)} = \frac{w_T}{gH_E}$$

$$\frac{p_3 - p_a}{\rho g} = \frac{c_4^2 - c_3^2}{2g} + \Delta H_{DT} - z_3$$

$$\pi_1 = \eta^{l_1} = \eta$$

$$\pi_2 = \gamma^{k_2} = \gamma$$

$$\pi_3 = P_{02}/P_{01}$$

$$\pi_4 = T_{02}/T_{01}$$

$$\pi_5 = \varepsilon/D$$

$$\pi_6 = ND^2/\nu$$

$$\pi_7 = ND/\sqrt{\gamma R T_{01}}$$

$$\pi_8 = \dot{m}\sqrt{\gamma R T_{01}}/P_{01}D^2$$

$$\eta_C\left(\frac{T_{02}}{T_{01}} - 1\right) = \left(\left(\frac{P_{02}}{P_{01}}\right)^{(\gamma-1)/\gamma} - 1\right)$$

$$\frac{\dot{m}\sqrt{\gamma R T_{01}}}{D^2 P_{01}} \rightarrow \frac{\dot{m}\sqrt{T_{01}}}{P_{01}}; \quad \frac{ND}{\sqrt{\gamma R T_{01}}} \rightarrow \frac{N}{\sqrt{T_{01}}}$$

$$\frac{P_{02}}{P_{01}} = f_1\left(\frac{\dot{m}\sqrt{T_{01}}}{P_{01}}, \quad \frac{N}{\sqrt{T_{01}}}\right) = r_P$$

$$\eta_C = f_2\left(\frac{\dot{m}\sqrt{T_{01}}}{P_{01}}, \quad \frac{N}{\sqrt{T_{01}}}\right)$$

$$\phi = \frac{c}{U} \quad \alpha \quad M_F/M_R$$

$$\psi = \frac{\Delta h_0}{U^2} = \frac{w}{U^2} = \frac{U(c_{\theta 2} - c_{\theta_1})}{U^2} = \frac{\Delta c_0}{U}$$

$$R = \frac{h_2 - h_3}{h_{01} - h_{03}} = -\frac{w_{\theta 2} + w_{\theta 3}}{2U}$$

$$\phi = C_1 \cos \beta x + C_2 \sin \beta x + C_3 \cosh \beta x + C_4 \sinh \beta x$$

$$\omega_i = \beta_i^2 \sqrt{EI/\rho A}$$

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2015-01-12

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SUBJECT:	THERMOMACHINES TRM4A11	**MARKS:**	90

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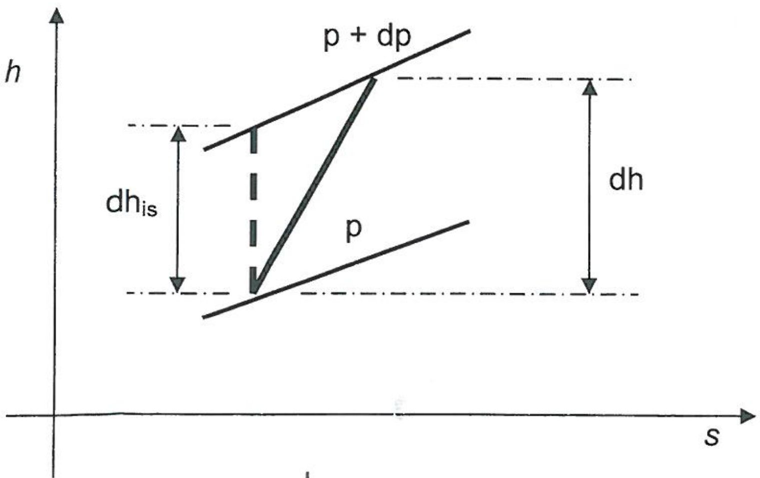
- Only UJ approved calculators allowed
- No answers in pencil or red ink will be accepted
- Answer all the questions in English

Question 1 **(34)**

1a) Starting with the *h*-*s* diagramme shown below, derive an equation for the temperature ratio for a compression process of an ideal gas in terms of pressure ratio, polytropic efficiency and ratio of specific heats γ **(10 marks)**



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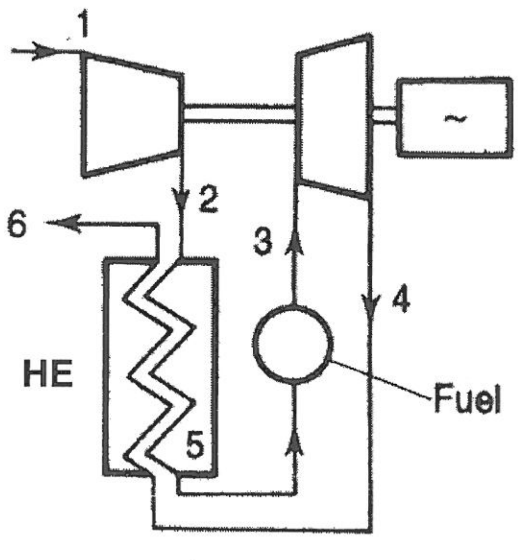
Question 1 (continued)

1b) Starting from the First Law of Thermodynamics, derive an equation for the thermal efficiency of the air-standard Dual cycle in terms of the compression ratio r_v, cutoff ratio c, pressure ratio α and ratio of specific heats γ. Draw *P*-*v*- and *T*-*s*-diagrammes of the cycle to help you with your derivation **(24 marks)**

Question 2 **(25)**

Determine the specific work output, specific fuel consumption and cycle efficiency for a shaft-power heat-exchange (HE) cycle, having the following specification

Compressor pressure ratio	4,0
Turbine inlet temperature	1100 K
Isentropic efficiency η_C of the compressor	85%
Isentropic efficiency η_T of the turbine	87%
Mechanical transmission efficiency η_m	99%
Combustion efficiency η_b	98%
HE effectiveness	80%
Pressure losses	
Combustion chamber ΔP_b	2% of compressor delivery pressure
HE air-side ΔP_{ha}	3% of compressor delivery pressure
HE gas side ΔP_{hg}	0,04 atm
Ambient conditions P_a, T_a	100 kPa, 288 K



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Question 3 **(12)**

Why does the performance of real gas turbine cycles differ from that of ideal cycles?

Question 4 **(14)**

An automobile has a 3,2 l, 5-cylinder four-stroke cycle Diesel engine operating at 2400 RPM. Fuel injection occurs from 20° before top dead centre ("BTDC") to 5° after top dead centre ("ATDC"). The engine has a volumetric efficiency of 95% and operates with a fuel equivalence ratio of 0,8. "Average" Diesel fuel $C_{12}H_{23}$ is used.

Calculate

1. time for one injection
2. fuel flow rate through an injector

Question 5 **(5)**

The Rolls-Royce CV12 turbocharged four-stroke direct injection CI engine has a displacement of 26,1 *l*. The engine has a maximum output of 900 kW at 2300 RPM and is derated to 397,5 kW at 1800 RPM for industrial use. What is the *BMEP* for each of these engine ratings?

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Various formulae

$$\eta = \frac{T'_{01} - T_a}{T_{01} - T_a}$$

$$\eta = \frac{T'_{02} - T_{01}}{T_{02} - T_{01}}$$

$$\eta = \frac{T_{03} - T_{04}}{T_{03} - T'_{04}}$$

$$\eta = \frac{(FA)_{theor}}{(FA)_{actual}}$$

$$\eta = \frac{T_{04} - T_5}{T_{04} - T'_5}$$

$$\eta = \frac{T_{04} - T_c}{T_{04} - T'_c}$$

$$\eta = \frac{P_{01} - P_a}{P_{0a} - P_a}$$

$$\eta = -\frac{w_C}{w_T}$$

$$\eta = \frac{w_{net}}{q_{in}}$$

$$w_T = -\frac{w_C}{\eta} + \frac{w_{net}}{\eta}$$

$$dq = du + dw$$

$$dq = dh - vdP$$

$$dw = Pdv$$

$$q_{in} + q_{out} = w_{net}$$

$$T(h) = T_{SL} - \lambda h$$

$$P(h) = P_{SL}\left(1 - \frac{\lambda}{T_{SL}} h\right)^{g/(\lambda R)}$$

$$\rho(h) = \rho_{SL}\left(1 - \frac{\lambda}{T_{SL}} h\right)^{\left(\frac{g}{\lambda R} - 1\right)}$$

$$P = \rho RT$$

$$C_p T_0 = C_p T + c^2/2$$

$$\frac{T_0}{T} = \left(\frac{P_0}{P}\right)^{(\gamma-1)/\gamma}$$

$$\frac{T_{02}}{T_{01}} = \left(\frac{P_{02}}{P_{01}}\right)^{(n-1)/n}$$

$$c = \sqrt{\gamma RT}$$

$$M_a = c_a / c$$

$$P_{03} = P_{02}\left(1 - \frac{\Delta P_b}{P_{02}} - \frac{\Delta P_{ha}}{P_{02}}\right)$$

$$P_a = P_{04}\left(1 - \frac{\Delta P_{hg}}{P_{04}}\right)$$

$$w = C_p(T_{01} - T_{02})$$

$$w = C_p(T_{03} - T_{04})$$

$$C_p - C_v = R$$

$$\frac{R}{C_p} = \frac{\gamma - 1}{\gamma}$$

$$\frac{n-1}{n} = \frac{\gamma - 1}{\eta_p \gamma}$$

$$\frac{n-1}{n} = \eta_p \frac{\gamma - 1}{\gamma}$$

$$t = T_3 / T_1$$

$$F = \dot{m}(c_j - c_a) + A_j(P_j - P_a)$$

$$F = \dot{m}(c_j - c_a)$$

$$SFC = \frac{3600(FA)}{F_s}$$

$C_p = 1005$ J/kgK

$C_p = 1148$ J/kgK

$R = 287{,}1$ J/kgK

$\gamma = 1{,}4$

$\gamma = 1{,}333$

$\lambda = -0{,}986$ °C/km

$\lambda = 0$ °C/km

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$$\frac{T_{03}}{T_{04}} = \left(\frac{P_{03}}{P_{04}}\right)^{(n-1)/n}$$

$$\frac{T'_{02}}{T_{01}} = \left(\frac{P_{02}}{P_{01}}\right)^{(\gamma-1)/\gamma}$$

$$\frac{T'_{04}}{T_{03}} = \left(\frac{P_{04}}{P_{03}}\right)^{(\gamma-1)/\gamma}$$

$$\frac{T'_{c}}{T_{04}} = \left(\frac{P_{c}}{P_{04}}\right)^{(\gamma-1)/\gamma}$$

$$T_c = \frac{2}{\gamma+1}T_0$$

$$\dot{m} = \dot{m}_h + \dot{m}_c$$

$$B = \frac{\dot{m}_c}{\dot{m}_h}$$

$$F_D = \dot{m}c_a = (\dot{m}_c + \dot{m}_h)c_a$$

$$w_{T\,LP} = -\frac{w_F}{\eta}$$

$$T_{SL} = 288{,}15\ \text{K}$$

$$\dot{m} = \dot{m}_h + \dot{m}_c$$

$$\dot{m}_h = \dot{m}/(1+B)$$

$$F_G = \dot{m}_c c_{jc} + \dot{m}_h c_{jh}$$

$$F_N = (\dot{m}_c c_{jc} + \dot{m}_h c_{jh}) - (\dot{m}_c + \dot{m}_h)c_a$$

$$\dot{W}_{T\,LP} = \dot{m}_h C_{pg}(T_{05} - T_{06})$$

$$TP = \eta_{pr} SP + Fc_a$$

$$EP = \frac{TP}{\eta_{pr}} = SP + \frac{Fc_a}{\eta_{pr}}$$

$$EP_{take\,off} = \frac{TP}{\eta_{pr}} = SP + \frac{F}{8{,}5}$$

$$\eta_{T\,Diesel} > \eta_{T\,Dual} > \eta_{T\,Otto}$$

$$y = (r+a) - (a\cos\theta + r\cos\phi)$$

$$\dot{y} = a\dot{\theta}\sin\theta\left(1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right)$$

$$\overline{\dot{y}} = 2S\frac{N}{60}$$

$$\lambda = 6{,}5\ ^\circ\text{C/km}$$

$$g = 9{,}81\ \text{m/s}^2$$

$$\dot{m}_{fuel} = (FA)\dot{m}_a$$

$$\dot{m} = \frac{\dot{W}}{w}$$

$$\dot{m} = \rho c A$$

$$\dot{m} = F/F_s$$

$$F_G = \dot{m}_c c_{jc} + \dot{m}_h c_{jh}$$

$$F_N = F_G - F_D$$

$$T_{05} - T_{06} = (1+B)\frac{C_{pa}}{\eta_m C_{pg}}(T_{02} - T_{01})$$

$$P_{SL} = 101{,}325\ \text{kPa}$$

$$B = \dot{m}_c/\dot{m}_h$$

$$\dot{m}_c = \dot{m}B/(1+B)$$

$$F_D = \dot{m}c_a = (\dot{m}_c + \dot{m}_h)c_a$$

$$\dot{W}_F = \dot{m}C_{pa}(T_{01} - T_{02})$$

$$\dot{W}_{T\,LP} = -\dot{W}_F/\eta_m$$

$$c = v_3/v_x$$

$$c = v_3/v_2$$

$$\alpha = P_x/P_2$$

$$s = a\cos\theta + \sqrt{r^2 - a^2\sin^2\theta}$$

$$R = r/a$$

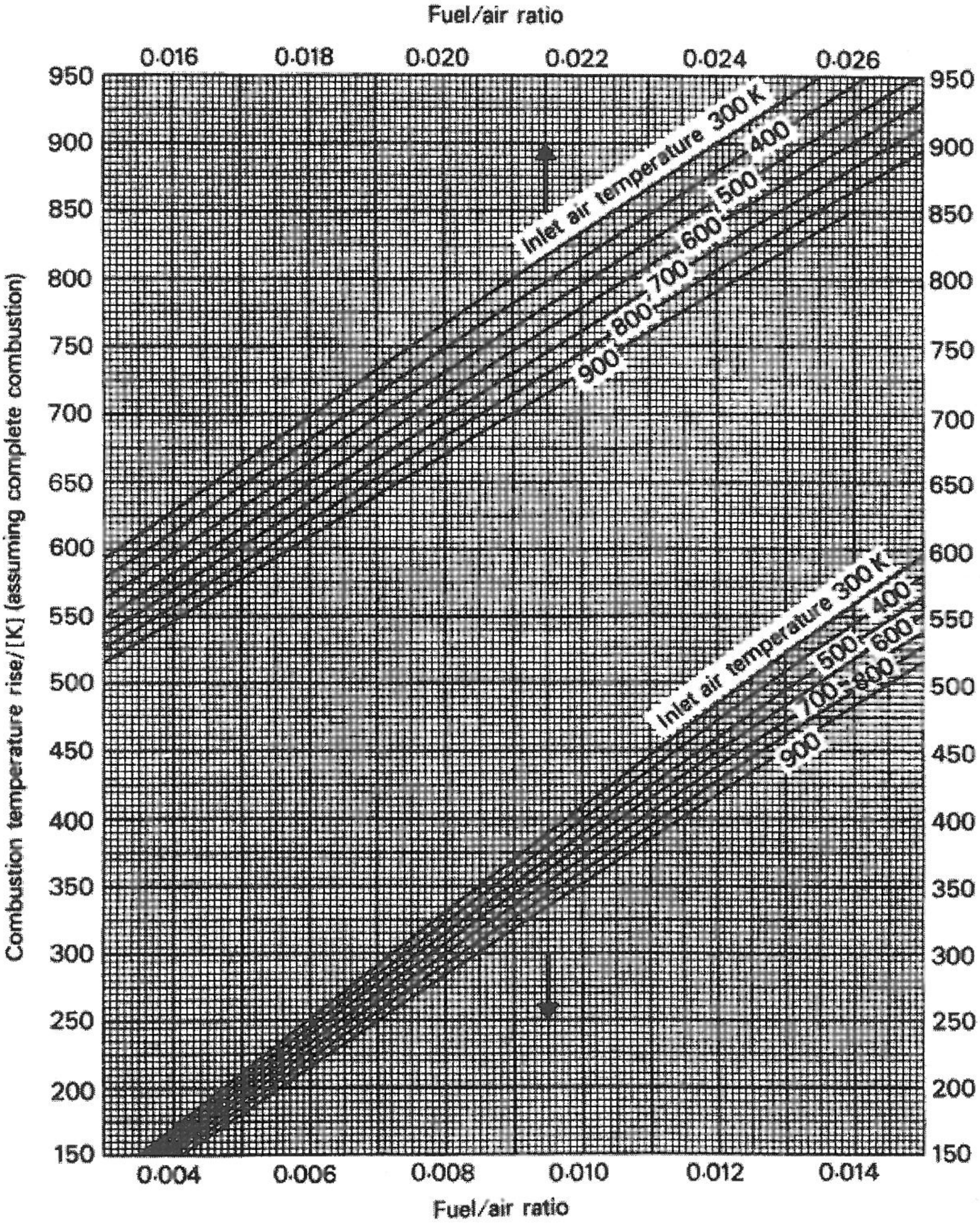
$$\dot{y} \approx a\Omega\left(\sin\theta + \frac{\sin 2\theta}{2R}\right)$$

$$\frac{\dot{y}}{\overline{\dot{y}}} \approx \frac{\pi}{2}\left(\sin\theta + \frac{\sin 2\theta}{2R}\right)$$

2015-01-09

2015-01-12

Fuel chart



2015 - 01 - 09

2015 - 01 - 12