

Answer Key

Diesel Electric Power Plant

Time of operation : 24 hrs

$\dot{V} = 230$ gal of fuel at 30°C

EP = 4200 Kw-hr

Fuel = 28°API

cost = ₱16.20/L @ 15.6°C

Required: cost of fuel per Kw-hr

$$\dot{V}_{28^\circ} = \frac{230 \text{ gal}}{24 \text{ hrs}} \left(\frac{3.78 \text{ L}}{1 \text{ gal}} \right) \left(\frac{1 \text{ m}^3}{1000 \text{ L}} \right) = 0.03603 \text{ m}^3/\text{hr}$$

$$SG_{15.6} = \frac{141.5}{\text{API} + 131.5} = \frac{141.5}{28 + 131.5} = 0.8871$$

and;

$$SG_{\text{corrected @ } 30^\circ\text{C}} = SG_{15.6^\circ\text{C}} \left[1 - 0.0007 (t_0 - 15.6) \right]$$

$$= 0.8871 \left[1 - 0.0007 (30 - 15.6) \right]$$

$$SG_{\text{corrected @ } 30^\circ\text{C}} = 0.8782$$

for the density of fuel @ 30°C

$$SG_{@ 30^\circ\text{C}} = \frac{\rho_F}{\rho_W}$$

$$0.8782 = \frac{\rho_F}{1000 \text{ kg/m}^3}$$

$$\rho_F = 878.2 \text{ kg/m}^3$$

Analyze:

$$\text{from; } SG = \frac{\rho_F}{\rho_W}$$

$$\rho_W = \frac{\rho_F}{SG} = \frac{m_F}{\dot{V}} \left(\frac{1}{SG} \right)$$

$$\dot{V} SG = \left(\frac{m_F}{\rho_W} \right) \rightarrow \text{constant}$$

Therefore;

$$\frac{m_F @ 15.6^\circ\text{C}}{\rho_W} = \frac{m_F @ 30^\circ\text{C}}{\rho_W}$$

or

$$\dot{V}_{F@ 15.6^\circ\text{C}} SG_{15.6^\circ\text{C}} = \dot{V}_{F@ 30^\circ\text{C}} SG_{30^\circ\text{C}}$$

$$\dot{V}_{F@ 15.6^\circ\text{C}} (0.8871) = (0.03603 \text{ m}^3/\text{hr}) (0.8782)$$

$$\dot{V}_{F@ 15.6^\circ\text{C}} = 0.03567 \text{ m}^3/\text{hr} = 35.67 \frac{\text{L}}{\text{hr}}$$

Hence;

The cost of fuel @ 15.6°C in ₱/Kw-hr

$$\text{cost} = \frac{\left(\text{₱} \frac{16.20}{\text{L}} \right) \left(35.67 \frac{\text{L}}{\text{hr}} \right)}{\left(4200 \text{ Kw-hr} \right) \left(\frac{1 \text{ day}}{24 \text{ hrs}} \right)}$$

$$\text{Cost} = \text{₱ } 3.3020 / \text{Kw-hr}$$

$$BP = 800 \text{ Bhp}$$

$$\text{Fuel} = 30^\circ \text{API}$$

$$\text{BSFC} = 0.82 \text{ lb/bhp-hr}$$

$$\text{Cost of fuel} = \$18.34/\text{L}$$

$$\text{ambient temp. } 38^\circ \text{C}$$

Required: minimum volume of cubical day tank, in m^3

$$\rho_F = \frac{M_F}{V_F} ; SG_{@115.6^\circ \text{C}} = \frac{141.5}{9API + 131.5} = \frac{141.5}{30API + 131.5}$$

$$SG_{@115.6^\circ \text{C}} = 0.8762$$

$$SG_{\text{corrected}@38^\circ \text{C}} = SG_{@115.6^\circ \text{C}} [1 - 0.0007(t - 15.6)]$$

$$SG_{\text{corrected}@38^\circ \text{C}} = 0.8762 [1 - 0.0007(38 - 15.6)]$$

$$SG_{\text{corrected}@38^\circ \text{C}} = 0.8625$$

For density of fuel:

$$SG_{@45^\circ \text{C}} = \frac{\rho_F}{\rho_W}$$

$$0.8625 = \frac{\rho_F}{1 \text{ kg/L}}$$

$$\rho_F = 0.8625 \text{ kg/L}$$

For the mass of fuel;

$$\text{BSFC} = \frac{M_F}{\text{Bhp}}$$

$$0.82 \text{ lb/bhp-hr} = \frac{M_F}{800 \text{ bhp}}$$

$$M_F = \left(656 \frac{\text{lb}}{\text{hr}} \right) \left(\frac{1 \text{ kg}}{2.2 \text{ lb}} \right) = 298.1818 \text{ kg/hr}$$

Subst, to solve for the value of fuel, V_F

$$0.8625 \text{ kg/L} = \frac{298.1818 \text{ kg/hr}}{V_F}$$

$$V_F = (345.7161 \text{ L/hr}) \left(\frac{1 \text{ m}^3}{1000 \text{ L}} \right) = 0.3457 \text{ m}^3/\text{hr}$$

Therefore; the minimum volume of cubical day tank

$$\dot{V}_F = (0.3457 \text{ m}^3/\text{hr}) \left(\frac{24 \text{ hrs}}{1 \text{ day}} \right)$$

$$\dot{V}_F = 8.2968 \text{ m}^3$$

$$\rho_F = 895.32 \text{ kg/m}^3 @ 15.6^\circ\text{C}$$

for the Heating value

$$\text{HHV} = 41130 + 139.6 (^{\circ}\text{API}) ; \text{ kJ/kg}$$

$$\text{SG}_F = \frac{\rho_F}{\rho_W} = \frac{895.32 \text{ kg/m}^3}{1000 \text{ kg/m}^3} = 0.89532$$

from;

$$\begin{aligned} ^{\circ}\text{API} &= \frac{141.5}{\text{SG}_{F@15.6^\circ\text{C}}} - 131.5 \\ &= \frac{141.5}{0.89532} - 131.5 \end{aligned}$$

$$^{\circ}\text{API} = 26.5441$$

then;

$$\text{HHV} = 41130 + 139.6 (26.5441)$$

$$\text{HHV} = (44835.5564 \text{ kJ/kg}) \left(\frac{1 \text{ Btu}}{1.055 \text{ kJ}} \right) \left(\frac{1 \text{ kg}}{2.216 \text{ lb}} \right)$$

$$\text{HHV} = 19317.3444 \text{ Btu/lb}$$

$$V_f = 950 \text{ L/day @ } 28^\circ\text{C}$$

Fuel purchased @ 15.6°C and 32°API at $\text{P}4.35/\text{L}$

Required cost of fuel to operate the engine per day

$$\text{From; } V_{f@15.6^\circ\text{C}} SG_{f@15.6^\circ\text{C}} = V_{f@28^\circ\text{C}} SG_{f@28^\circ\text{C}}$$

Solving for $SG_{f@15.6^\circ\text{C}}$;

$$SG_{f@15.6^\circ\text{C}} = \frac{141.5}{\text{API} + 131.5} = \frac{141.5}{32 + 131.5} = 0.8654$$

Solving for $SG_{f@28^\circ\text{C}}$;

$$\begin{aligned} SG_{corrected@28^\circ\text{C}} &= SG_{f@15.6^\circ\text{C}} [1 - 0.0007(t - 15.6)] \\ &= 0.8654 [1 - 0.0007(28 - 15.6)] \end{aligned}$$

$$SG_{corrected@28^\circ\text{C}} = 0.85793$$

Subst;

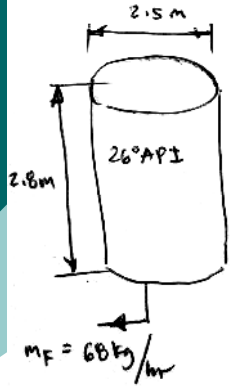
$$V_{f@15.6^\circ\text{C}} (0.8654) = (950 \text{ L/day}) (0.85793)$$

$$V_{f@15.6^\circ\text{C}} = 941.7997 \text{ L/day}$$

Hence;

$$\text{Cost of fuel to operate per day} = (941.7997 \text{ L/day}) (\text{P}4.35/\text{L})$$

$$\text{Cost} = \text{P}4096.8289/\text{day}$$



Solving for the density of fuel;

$$\rho_F = \frac{m_F}{V_F} ; SG_{F@15.6^\circ C} = \frac{141.5}{API + 131.5} = \frac{141.5}{26 + 131.5} = 0.8984$$

$$\text{then; } SG_F = \frac{\rho_F}{\rho_W}$$

$$0.8984 = \frac{\rho_F}{1000 \text{ kg/m}^3}$$

$$\rho_F = 898.4 \text{ kg/m}^3$$

subst;

$$898.4 \text{ kg/m}^3 = \frac{68 \text{ kg/hr}}{V_{F@15.6^\circ C}}$$

$$V_{F@15.6^\circ C} = 0.07569 \text{ m}^3/\text{hr}$$

Solving for the number of days;

$$\# \text{ of days} = \frac{\frac{\pi (2.5 \text{ m})^2}{4} (2.8 \text{ m})}{0.07569 \text{ m}^3/\text{hr}}$$

$$\# \text{ of days} = (181.5887 \text{ hr}) \left(\frac{1 \text{ day}}{24 \text{ hr}} \right)$$

$$\# \text{ of days} = 7.5662 \text{ days}$$

$$HHV = 41130 + 139.6^\circ \text{API}$$

$$44900.3 \text{ kJ/kg} = 41130 + 139.6^\circ \text{API}$$

$$^\circ \text{API} = 27$$

$$\text{and; } ^\circ \text{API} = \frac{141.5}{SG_{@15.6^\circ}} - 131.5$$

$$27 = \frac{141.5}{SG_{@15.6^\circ}} - 131.5$$

$$SG_{@15.6^\circ} = 0.8927$$

$$e_o = \frac{BP}{m_{FHHV}} \times 100\%$$

$$BP = \frac{2\pi TN}{60} = \frac{2\pi (3.2 \text{ kN-m})(580 \text{ rpm})}{60} = 194.3599 \text{ kW}$$

Hence;

$$e_o = \frac{194.3599 \text{ kW}}{\left(\frac{45 \text{ kg}}{3600 \text{ s}}\right)(43500 \text{ kJ/kg})} \times 100\%$$

$$e_o = 35.74\%$$

$$BP = 3.2 \text{ MW}$$

Fuel: 250 L of 26°API

$$EP = 950 \text{ kW-hr}$$

Required: Rate of fuel consumption

$$SG_{@15.16^\circ C} = \frac{141.5}{^\circ API + 131.5} = \frac{141.5}{26 + 131.5} = 0.8984$$

$$\rho_F = SG_{@15.16} \rho_w = (0.8984)(1 \text{ kg/L}) = 0.8984 \text{ kg/L}$$

for the mass of fuel;

$$m_F = \rho_F V_F = (0.8984 \text{ kg/L})(250 \text{ L}) = 224.6032 \text{ kg}$$

for the time of operation;

$$\text{time of operation} = \frac{(950 \text{ kW-hr})}{3200 \text{ kW}} = 0.2969 \text{ hr}$$

therefore;

$$\dot{m}_F = \frac{224.6032 \text{ kg}}{(0.2969 \text{ hr}) \left(\frac{3600 \text{ s}}{1 \text{ hr}} \right)}$$

$$\dot{m}_F = 0.2102 \text{ kg/s}$$

$$\begin{aligned}
 V_0 &= \frac{\pi D^2}{4} L \left(\frac{C a n}{60} \right) \left(\frac{2}{5} \right) \\
 &= \frac{\pi (0.122 \text{ m})^2}{4} (0.38 \text{ m}) \left[\frac{(4)(1)(180 \text{ rpm})}{60} \right] \left(\frac{2}{4} \right) \\
 &= \left(0.1348 \frac{\text{m}^3}{\text{s}} \right) \left(\frac{1}{180 \text{ kW}} \right) \left(\frac{60 \text{ s}}{1 \text{ min}} \right)
 \end{aligned}$$

$$V_0 = 0.04494 \frac{\text{m}^3}{\text{kW} \cdot \text{min}}$$

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$$\eta_{th} = \frac{IP}{m_F HHV} * 100\%$$

$$\eta_{th} \eta_g = \frac{EP}{IP} * 100\%$$

$$(0.80)(0.85) = \frac{560 \text{ kW-hr}}{IP}$$

$$IP = (823.5294 \text{ kW-hr}) \left(\frac{3600 \text{ s}}{1 \text{ hr}} \right)$$

$$IP = 2964705.882 \text{ kJ}$$

for m_F :

$$SG_{F@15.6^\circ} = \frac{141.5}{30^\circ \text{API} + 131.5} = 0.8762$$

$$\rho_F = SG_F \rho_w = (0.8762)(1 \text{ kg/L}) = 0.8762 \text{ kg/L}$$

$$m_F = \rho_F V_F = (0.8762 \text{ kg/L}) \left(166 \text{ L} \right) \left(\frac{42 \text{ gal}}{166 \text{ L}} \right) \left(\frac{3.78 \text{ L}}{1 \text{ gal}} \right)$$

$$m_F = 139.0993 \text{ kg}$$

for HHV:

$$HHV = 41130 + 139.6^\circ \text{API} = 41130 + (139.6)(30^\circ \text{API})$$

$$HHV = 45318 \text{ kJ/kg}$$

Hence; subst:

$$\eta_{th} = \frac{2964705.882 \text{ kJ}}{(139.0993 \text{ kg})(45318 \text{ kJ/kg})} * 100\%$$

$$\eta_{th} = 47.03\%$$

$$q = 1$$

$$C = 4$$

$$S = 4$$

$$D = 0.23 \text{ m}$$

$$L = 0.30 \text{ m}$$

$$N = 385 \text{ rpm}$$

$$m_f = 8.8 \text{ kg/hr}$$

$$H_f = 45300 \text{ kJ/kg}$$

$$P_{me} = 550 \text{ kPa}$$

$$F = (120 \text{ kg}) \left(\frac{9.81 \text{ m/s}^2}{1000 \frac{\text{kg} \cdot \text{m}}{\text{N} \cdot \text{s}^2}} \right) = 1.1772 \text{ kN}$$

$$L_{arm} = 1.10 \text{ m}$$

req'd: Brake mean effective pressure, kPa

$$BP = P_{me} V_D$$

$$BP = \frac{2\pi TN}{60} = \frac{2\pi (1.1772 \text{ kN}) (1.10 \text{ m}) (385 \text{ rpm})}{60} = 52.2074 \text{ kW}$$

$$V_D = \left(\frac{\pi D^2}{4} \right) L \left[\frac{C a n}{60} \right] \left(\frac{2}{5} \right)$$

$$= \pi \frac{(0.23 \text{ m})^2}{4} (0.30 \text{ m}) \left[\frac{(4)(1)(385 \text{ rpm})}{60} \right] \left(\frac{2}{4} \right)$$

$$V_D = 0.15996 \text{ m}^3/\text{s}$$

Hence; subst;

$$52.2074 \text{ kW} = P_{me} (0.15996 \text{ m}^3/\text{s})$$

$$P_{me} = 326.3817 \text{ kPa}$$

$$a = 2$$

$$s = 2$$

$$c = 12$$

$$D = 0.760 \text{ m}$$

$$L = 1.5 \text{ m}$$

$$d = 0.250 \text{ m}$$

$$N = 130 \text{ rpm}$$

$$P_{ME} = 7 \text{ bar (above) and 6 bar (below)}$$

$$\eta_M = 85\%$$

$$\eta_M = \frac{BP}{IP} \times 100\%$$

req'd: Brake power of the engine

@ Crank-end

$$V_D = \frac{\pi}{4} (D^2 - d^2) L \left[\frac{C a n}{60} \right] \left(\frac{2}{s} \right)$$

$$= \frac{\pi}{4} (0.760^2 - 0.250^2) \text{ m}^2 (1.5 \text{ m}) \left[\frac{(12)(2)(130 \text{ rpm})}{60} \right] \left(\frac{2}{4} \right)$$

$$V_D = 15.7778 \text{ m}^3/\text{s}$$

$$IP_B = P_{ME} V_D = (600 \text{ kPa}) (15.7778 \text{ m}^3/\text{s}) = 9466.6711 \text{ kW}$$

@ top and

$$V_D = \left(\frac{\pi}{4} D^2 \right) L \left[\frac{C a n}{60} \right] \left(\frac{2}{s} \right)$$

$$= \frac{\pi}{4} (0.760 \text{ m})^2 (1.5 \text{ m}) \left[\frac{(12)(2)(130 \text{ rpm})}{60} \right] \left(\frac{2}{4} \right)$$

$$V_D = 17.6922 \text{ m}^3/\text{s}$$

$$IP_T = P_{ME} V_D = (700 \text{ kPa}) (17.6922 \text{ m}^3/\text{s}) = 12384.5352 \text{ kW}$$

Then; the total Indicated power

$$IP = (9466.6711 + 12384.5352) \text{ kW}$$

$$IP = 21851.2063 \text{ kW}$$

Hence;

$$0.85 = \frac{BP}{21851.2063 \text{ kW}}$$

$$BP = 18573.5254 \text{ kW}$$

$$\eta_M = 85\%$$

$$\eta_g = 90\%$$

$$\text{Fuel: } 26 \text{ API}$$

$$\eta_g \eta_M = \frac{EP}{m_f \text{ HHV}}$$

$$\text{HHV} = 41130 + 139.6 \text{ API}$$

$$= 41130 + 139.6 (26 \text{ API})$$

$$\text{HHV} = 44759.6 \text{ kJ/kg}$$

Hence;

$$(0.90)(0.85) = \frac{EP}{(0.09 \text{ kg/s})(44759.6 \text{ kJ/kg})}$$

$$EP = 3081.6985 \text{ kW}$$

$$e_b = 40\%$$

$$\text{Fuel: } 26^\circ\text{API}$$

$$\dot{m}_F = 45 \text{ kg/hr}$$

REQUIREMENT: Brake Power

$$e_b = \frac{BP}{\dot{m}_F \text{HHV}} \times 100\%$$

$$\text{HHV} = 41130 + 139.6 (\text{API})$$

$$= 41130 + 139.6 (26^\circ\text{API})$$

$$\text{HHV} = 44759.6 \text{ kJ/kg}$$

Subst:

$$0.40 = \frac{BP}{\left(45 \frac{\text{kg}}{\text{hr}}\right) \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right) (44759.6 \text{ kJ/kg})}$$

$$BP = 223.750 \text{ kW}$$

$$T = 6 \text{ kN-m}$$

$$N = 1900 \text{ rpm}$$

$$\eta_b = 35\%$$

Parameter: Heat generated, Q_f

$$\eta_b = \frac{BP}{Q_f} ; BP = \frac{2\pi TN}{60} = \frac{2\pi (6 \text{ kN-m})(1900 \text{ rpm})}{60}$$

$$BP = 1193.8052 \text{ kW}$$

subst;

$$0.35 = \frac{1193.8052 \text{ kW}}{Q_f}$$

$$Q_f = 3410.8720 \text{ kW}$$

$$\begin{array}{l}
 BP_1 = 600 \text{ kW} \\
 P_1 = 100 \text{ kPa} \\
 t_1 = 20^\circ\text{C}
 \end{array}
 \begin{array}{l}
 \rangle \text{ IN manila} \\
 \end{array}
 \begin{array}{l}
 P_2 = 93 \text{ kPa} \\
 t_2 = 20^\circ\text{C}
 \end{array}
 \begin{array}{l}
 \rangle \text{ IN BANGALU}
 \end{array}$$

Required: BP_2 when $\eta_M = 80\%$

$$\text{IN manila: } \rho_1 = \frac{P_1}{RT_1} = \frac{100 \text{ kPa}}{(0.287 \text{ kJ/kg}\cdot\text{K})(301 \text{ K})} = 1.1576 \text{ kg/m}^3$$

$$\text{IN BANGALU: } \rho_2 = \frac{P_2}{RT_2} = \frac{93 \text{ kPa}}{(0.287 \text{ kJ/kg}\cdot\text{K})(293 \text{ K})} = 1.1059 \text{ kg/m}^3$$

$$FP_1 = FP_2$$

$$IP_1 - BP_1 = IP_2 - BP_2$$

for IP_1

$$\eta_M = \frac{BP_1}{IP_1}$$

$$0.80 = \frac{600 \text{ kW}}{IP_1}$$

$$IP_1 = 750 \text{ kW}$$

Note: Indicated Power is directly proportional of density

$$\frac{IP_1}{IP_2} = \frac{\rho_1}{\rho_2}$$

$$\frac{750 \text{ kW}}{IP_2} = \frac{1.1576 \text{ kg/m}^3}{1.1059 \text{ kg/m}^3}$$

$$IP_2 = 716.5039 \text{ kW}$$

Hence; subst.

$$750 \text{ kW} - 600 \text{ kW} = 716.5039 \text{ kW} - BP_2$$

$$BP_2 = 566.5039 \text{ kW}$$

$$BP = 55 \text{ Bhp}$$

$$\dot{V}_F = \left(\frac{12 \text{ ft}^3}{\text{Bhp-hr}} \right) (55 \text{ Bhp}) = 660 \text{ ft}^3/\text{hr}$$

$$HHV = 35800 \text{ kJ/m}^3$$

required: Brake thermal efficiency

$$\eta_b = \frac{BP}{m_F HHV} * 100\%$$

$$= \frac{(55 \text{ Bhp}) \left(\frac{0.746 \text{ kW}}{1 \text{ hp}} \right)}{\left(\frac{660 \text{ ft}^3}{\text{hr}} \right) \left(\frac{1 \text{ hr}}{3600 \text{ s}} \right) \left(\frac{1 \text{ m}}{3.28 \text{ ft}} \right)^3 (35800 \text{ kJ/m}^3)} * 100\%$$

$$\eta_b = 22.06\%$$

$$e_b = \frac{BP}{\dot{m}_f H_{HHV}} ; BP = \frac{2\pi T \omega}{60} = \frac{2\pi (2.8 \text{ kW}\cdot\text{m})(610 \text{ rpm})}{60}$$

$$BP = 178.8613 \text{ kW}$$

Hence; subst;

$$e_b = \frac{178.8613 \text{ kW}}{\left(\frac{45 \text{ kg}}{1 \text{ hr}}\right) \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right) (45000 \text{ kJ/kg})} \times 100\%$$

$$e_b = 31.79\%$$