Answer Key

Diesel Electric Power Plant

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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

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

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

and;

$$SG_{corrected @ 30°C} = SG_{15.6°C}\left[1 - 0.0007(t_o - 15.6)\right]$$

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

$$SG_{corrected @ 30°C} = 0.8782$$

for the density of fuel @ 30°C

$$SG_{@30°C} = \frac{\rho_F}{\rho_W}$$

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

$$\rho_F = 878.2\ kg/m^3$$

Analyze:

from; $SG = \dfrac{\rho_F}{\rho_W}$

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

$$\dot{V}SG = \frac{m_F}{\rho_W} \rightarrow \text{constant}$$

Therefore;

$$\frac{m_{F @ 15.6°C}}{\rho_W} = \frac{m_{F @ 30°C}}{\rho_W}$$

or

$$\dot{V}_{F @ 15.6°C}\, SG_{15.6°C} = \dot{V}_{F @ 30°C}\, SG_{30°C}$$

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

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

Hence;

The cost of fuel @ 15.6°C in ₱/kW-hr

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

$$\boxed{cost = ₱3.3020/kW\text{-}hr}$$

BP = 800 Bhp
Fuel = 30°API
BSFC = 0.82 lb/bhp-hr
Cost of fuel = ₱18.34/L
ambient temp. 38°C

REQUIRED: minimum volume of cubical day tank, in m³

$\rho_F = \frac{m_F}{V_F}$; $SG_{@15.6°C} = \frac{141.5}{°API + 131.5} = \frac{141.5}{30°API + 131.5}$

$SG_{@15.6°C} = 0.8762$

$SG_{corrected @ 38°C} = SG_{@15.6°C}\left[1 - 0.0007(t_c - 15.6)\right]$

$SG_{corrected @ 38°C} = 0.8762\left[1 - 0.0007(38 - 15.6)\right]$

$SG_{corrected @ 38°C} = 0.8625$

For density of fuel:

$SG_{@45°C} = \frac{\rho_F}{\rho_W}$

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

$\rho_F = 0.8625\ kg/L$

For the mass of fuel;

$BSFC = \frac{m_F}{Bhp}$

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

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

Subst, to solve for the volume of fuel, V_F

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

$V_F = \left(345.7181\ L/hr\right)\left(\frac{1\ m^3}{1000\ L}\right) = 0.3457\ m^3/hr$

Therefore; the minimum volume of cubical day tank

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

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

EXPONENTIAL LEAP ONLINE REVIEW

$\rho_F = 895.32\ kg/m^3$ @ 15.6°C

For the Heating value

$HHV = 41130 + 139.6(°API)$; kJ/kg

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

from;

$$°API = \frac{141.5}{SG_{F@15.6°C}} - 131.5$$

$$= \frac{141.5}{0.89532} - 131.5$$

$$°API = 26.5441$$

then;

$$HHV = 41130 + 139.6(26.5441)$$

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

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

EXPONENTIAL LEAP ONLINE REVIEW

$V_F = 950\ L/day$ @ 28°C

Fuel purchased @ 15.6°C and 32°API at ₱4.35/L

Required: cost of fuel to operate the engine per day

From; $V_{F@15.6°C}\, SG_{F@15.6°C} = V_{F@28°C}\, SG_{@28°C}$

Solving for $SG_{F@15.6°C}$;

$$SG_{F@15.6°C} = \frac{141.5}{°API + 131.5} = \frac{141.5}{32 + 131.5} = 0.8654$$

Solving for $SG_{F@28°C}$;

$$SG_{corrected@28°C} = SG_{F@15.6°C}\left[1 - 0.0007(t - 15.6)\right]$$

$$= 0.8654\left[1 - 0.0007(28 - 15.6)\right]$$

$$SG_{corrected@28°C} = 0.85793$$

Subst;

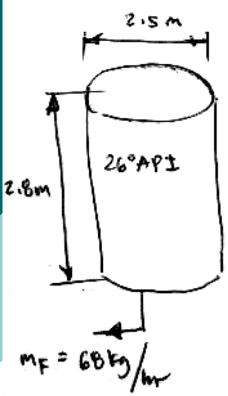
$$V_{F@15.6°C}(0.8654) = (950\ L/day)(0.85793)$$

$$V_{F@15.6°C} = 941.7997\ L/day$$

Hence;

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

$$\boxed{\text{cost} = ₱4096.8289/day}$$



Solving for the density of fuel;

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

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

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

$$\rho_F = 898.4\ kg/m^3$$

subst;

$$898.4\ kg/m^3 = \frac{68\ kg/hr}{\dot{V}_{F@15.6°C}}$$

$$V_{F@15.6°C} = 0.07569\ m^3/hr$$

Solving for the number of days;

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

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

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

$$HHV = 41130 + 139.6\,°API$$

$$44900.3\ kJ/kg = 41130 + 139.6\,°API$$

$$°API = 27$$

and; $$°API = \frac{141.5}{SG_{@15.6°C}} - 131.5$$

$$27 = \frac{141.5}{SG_{@15.6°C}} - 131.5$$

$$\boxed{SG_{f@15.6°C} = 0.8927}$$

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

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

Hence;

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

$$\boxed{e_o = 35.74\%}$$

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exponential LEAP ONLINE REVIEW

$BP = 3.2\ MW$

Fuel: 250L of 26°API

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

Required: Rate of fuel consumption

$$SG_{@15.6°C} = \frac{141.5}{°API + 131.5} = \frac{141.5}{26 + 131.5} = 0.8984$$

$$\rho_F = SG_{@15.6}\ \rho_W = (0.8984)(1\ kg/L) = 0.8984\ kg/L$$

for the mass of fuel;

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

for the time of operation;

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

therefore;

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

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

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

$$= \frac{\pi (0.22\ m)^2}{4} (0.38\ m) \left[\frac{(4)(1)(280\ rpm)}{60}\right]\left(\frac{2}{4}\right)$$

$$= \left(0.1348\ \frac{m^3}{s}\right)\left(\frac{1}{180\ kW}\right)\left(\frac{60\ s}{1\ min}\right)$$

$$\boxed{V_D = 0.04494\ \frac{m^3}{kW - min}}$$

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

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

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

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

$$IP = 2964705.882\ KJ$$

for m_F;

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

$$\rho_F = SG_F\,\rho_w = (0.8762)(1\,kg/L) = 0.8762\ kg/L$$

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

$$m_F = 139.0993\ kg$$

for HHV;

$$HHV = 41130 + 139.6\,^\circ API = 41130 + (139.6)(30^\circ API)$$

$$HHV = 45318\ KJ/kg$$

Hence; subst:

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

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

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$a = 1$
$c = 4$
$s = 4$
$D = 0.23 m$
$L = 0.30 m$
$N = 385 rpm$
$m_F = 8.9 kg/hr$
$HHV = 45300 kJ/kg$
$P_{mI} = 550 kPa$

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

$L_{arm} = 1.10 m$

req'd: Brake mean effective pressure, kPa

$$BP = P_{mB} V_D$$

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

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

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

$$V_D = 0.15996 m^3/s$$

Hence; subst;

$$52.2074 kW = P_{mB}(0.15996 m^3/s)$$

$$\boxed{P_{mB} = 326.3817 kPa}$$

Exponential LEAP ONLINE REVIEW

$a = 2$

$s = 2$

$c = 12$

$D = 0.760\,m$

$L = 1.5\,m$

$d = 0.250\,m$

$N = 130\,rpm$

$P_{mi} = 7\,bar$ (above) and $6\,bar$ (below)

$\eta_M = 85\%$

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

req'd: Brake power of the engine

@ Crank end

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

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

$V_D = 15.7778\ m^3/s$

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

@ top end

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

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

$V_D = 17.6922\ m^3/s$

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

Then; the total Indicated Power

$IP = (9466.6711 + 12384.5352)\,kW$

$IP = 21851.2063\ kW$

Hence;

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

$\boxed{BP = 18573.5254\ kW}$

$\eta_M = 85\%$

$\eta_g = 90\%$

Fuel: 26 °API

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

$$HHV = 41130 + 139.6\ °API$$

$$= 41130 + 139.6(26\ °API)$$

$$HHV = 44759.6\ kJ/kg$$

Hence;

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

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

exponential LEAP ONLINE REVIEW

$e_B = 40\%$

Fuel: 26°API

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

Required: Brake Power

$$e_B = \frac{BP}{\dot{m}_F\,HHV} * 100\%$$

$$HHV = 41130 + 139.6\,(°API)$$

$$= 41130 + 139.6\,(26°API)$$

$$HHV = 44759.6\ kJ/kg$$

Subst;

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

$$\boxed{BP = 223.798\ kW}$$

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

$N = 1900\ rpm$

$\eta_b = 35\%$

Required: Heat generated, Q_F

$e_b = \dfrac{BP}{Q_F}$; $BP = \dfrac{2\pi TN}{60} = \dfrac{2\pi(6\ kN\text{-}m)(1900\ rpm)}{60}$

$BP = 1193.8052\ kW$

Substi:

$0.35 = \dfrac{1193.8052\ kW}{Q_F}$

$\boxed{Q_F = 3410.8720\ kW}$

exponential LEAP ONLINE REVIEW

$BP_1 = 600\ kW$

$P_1 = 100\ kPa$, $t_1 = 20°C$ } IN manila $P_2 = 93\ kPa$, $t_2 = 20°C$ } IN BAGUIO

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

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

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

$FP_1 = FP_2$

$IP_1 - BP_1 = IP_2 - BP_2$

for IP_1

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

$0.80 = \dfrac{600\ kW}{IP_1}$

$IP_1 = 750\ kW$

Note: INDICATED Power is directly proportional of density

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

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

$IP_2 = 716.5039\ kW$

Hence; subst.

$750\ kW - 600\ kW = 716.5039\ kW - BP_2$

$\boxed{BP_2 = 566.5039\ kW}$

$BP = 55\ Bhp$

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

$HHV = 35800\ kJ/m^3$

Required: Brake thermal efficiency

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

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

$$\boxed{e_B = 22.06\%}$$

exponential LEAP ONLINE REVIEW

$$e_B = \frac{BP}{m_f\,HHV} \; ; \quad BP = \frac{2\pi T N}{60} = \frac{2\pi\,(2.8\ kN\text{-}m)(610\ rpm)}{60}$$

$$BP = 178.8613\ kW$$

Hence; subst;

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

$$\boxed{e_B = 31.79\%}$$