Answer Key

Fans, Blowers and Compressors

1

$$Q = mC_p(T_x - T_1)$$

$$\frac{T_x}{T_1} = \left(\frac{P_x}{P_1}\right)^{\frac{k-1}{k}} \quad ; \quad P_x = \sqrt{(100\ kPa)(700\ kPa)}$$

$$P_x = 264.5751\ kPa$$

$$\frac{T_x}{(26+273)\,k} = \left(\frac{264.5751\ kPa}{100\ kPa}\right)^{\frac{1.4-1}{1.4}}$$

$$T_x = 394.8203\ K$$

and;

$$P_1 V_1 = mRT_1$$

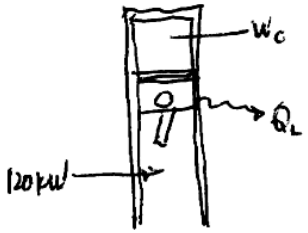
$$(100\ kPa)\left(\frac{720}{3600}\ \frac{m^3}{s}\right) = m\left(0.287\ \frac{kJ}{kg-k}\right)(26+273)\,k$$

$$m = 0.2331\ kg/s$$

Hence;

$$Q = \left(0.2331\ kg/s\right)\left(1.0062\ \frac{kJ}{kg-k}\right)(394.8203 - 299)\,k$$

$$Q = 22.4742\ kw$$



$$W_c = \frac{kP_1V_1'}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]$$

$$= \frac{(1A)(80\,kPa)(0.5\,m^3/s)}{1.4-1}\left[\left(\frac{650\,kPa}{80\,kPa}\right)^{\frac{1.4-1}{1.4}} - 1\right]$$

$$W_c = 114.7285\ kW$$

By Energy Balance;

$$[\dot{E}_{IN} = \dot{E}_{OUT}]$$

$$120\,kW = 114.7285\,kW + Q_L$$

$$\boxed{Q_L = 5.2715\ kW}$$

$Q = m C_p (T_x - T_1)$

and $P_1 V_1 = m R T_1$

$(98\ kPa)(0.122\ m^3/s) = m(0.287\ kJ/kg\text{-}K)(297\ K)$

$m = 0.1403\ kg/s$

From; $\frac{T_x}{T_1} = \left(\frac{P_x}{P_1}\right)^{\frac{k-1}{k}}$; $P_x = \sqrt{(98\ kPa)(680\ kPa)}$

$P_x = 258.1472\ kPa$

$$\frac{T_x}{(297\ K)} = \left(\frac{258.1472\ kPa}{98\ kPa}\right)^{\frac{1.4-1}{1.4}}$$

$T_x = 391.6875\ K$

Hence;

$Q = (0.1403\ kg/s)(1.0062\ kJ/kg\text{-}K)(391.6875 - 297)K$

$Q = 13.3670\ kW$

$$V_D = \left[\frac{\pi D^2}{4}\right]\frac{LN}{60} \quad ; \quad \text{Piston Speed} = v_p = \frac{2LN}{60}$$

$$V_D = \left[\frac{\pi D^2}{4}\right]\frac{v_p}{2}$$

$$0.25\ \frac{m^3}{s} = \left[\frac{\pi D^2}{4}\right]\left(\frac{150/60}{2}\right) m/s$$

$$D = 0.5046\ m$$

$$\boxed{D = 504.6\ mm}$$

$$P_x = \sqrt{P_1 P_2}$$

$$5\ \text{kg/cm}^2 = \sqrt{(0.8\ \text{kg/cm}^2)\, P_2}$$

$$P_2 = 31.25\ \text{kg/cm}^2$$

$$V_D = \left[\frac{\pi D^2}{4}\right]\frac{LN}{60} * (\#\text{ of cylinders})(\#\text{ of Actions})$$

$$V_D = \frac{\pi (0.52\,m)^2}{4}(0.65\,m)\frac{(660\,rpm)}{60}(1)(2)$$

$$V_D = 3.0369\ m^3/s$$

$$W_c = P_{mI} V_D$$

$$125\,kW = P_{mI}\left(\frac{19}{60}\ \frac{m^3}{s}\right)$$

$$P_{mI} = 394.7368\ kPa$$

Free air Capacity

$$\frac{P_F V_F}{T_F} = \frac{P_1 V_1'}{T_1}$$

$$\frac{(100\ kPa)\, V_F}{(296\ K)} = \frac{(98\ kPa)(0.22\ m^3/s)}{(301\ K)}$$

$$V_F = 0.2120\ m^3/s$$

$$\eta_v = \frac{V_1'}{V_D} \; ; \; V_D = \frac{\pi D^2}{4}\frac{LN}{60} = \frac{\pi (0.365\,m)^2}{4}(0.370\,m)\left(\frac{320\,rpm}{60}\right)$$

$$V_D = 0.2065\ m^3/s$$

and;

$$\eta_v = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/k} = 1 + 0.08 - 0.08\left(\frac{500\,kPa}{100\,kPa}\right)^{1/1.4}$$

$$\eta_v = 0.8274$$

Then;

$$0.8274 = \frac{V_1'}{0.2065\ m^3/s}$$

$$V_1' = 0.1709\ m^3/s$$

Hence;

$$P_1 V_1' = mRT_1$$

$$(100\,kPa)(0.1709\,m^3/s) = m\left(0.287\,\frac{kJ}{kg\text{-}K}\right)(297\,K)$$

$$\boxed{m = 0.200\ kg/s}$$

$$\eta_c = \frac{W_c}{EP}$$

$$0.75 = \frac{W_c}{(15\,hp)\left(\frac{0.746\,kW}{1\,hp}\right)}$$

$$W_c = 8.3925\ kW$$

Then;

$$W_c = \frac{\dot{m} R T_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] \qquad \left[\left(\frac{7P_1}{P_1}\right)^{\frac{1.4-1}{1.4}} - 1\right]$$

$$8.3925\ kW = \frac{(1.4)\,\dot{m}\left(0.287\ \frac{kJ}{kg\cdot K}\right)(302\ K)}{1.4-1}$$

$$\dot{m} = \left(0.03720\ \frac{kg}{s}\right)\left(\frac{60\,s}{1\,min}\right)$$

$$\dot{m} = 2.232\ \frac{kg}{min}$$

$$W_c = \frac{n P_1 V_1'}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$W_c = \frac{(1.33)(100\,kPa)(0.6\,m^3/s)}{1.33-1}\left[\left(\frac{600\,kPa}{100\,kPa}\right)^{\frac{1.33-1}{1.33}} - 1\right]$$

$$W_c = 135.3752\ kW$$

$$\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \left(\frac{V_1}{V_2}\right)^{k-1}$$

$$\left(\frac{720\ kPa}{98\ kPa}\right)^{\frac{1.4-1}{1.4}} = \left(\frac{V_1}{1{,}8\ m^3/s}\right)^{1.4-1}$$

$$V_1 = \left(7.4803\ \frac{m^3}{s}\right)\left(\frac{3.28\ ft}{1\ m}\right)^3\left(\frac{60\ s}{1\ min}\right)$$

$$V_1 = 15837.7225\ cfm$$

$$\frac{P_1}{N_1^3 \rho_1} = \frac{P_2}{N_2^3 \rho_2}$$

$$\rho_1 = \frac{P_1}{RT_1} = \frac{101.325\ kPa}{(0.287\ kJ/kg\text{-}K)(30+273)K} = 1.1652\ kg/m^3$$

$$\rho_2 = \frac{P_2}{RT_2} = \frac{101.325\ kPa}{(0.287\ kJ/kg\text{-}K)(333\ K)} = 1.0602\ kg/m^3$$

subst.

$$\frac{8\ kW}{(360\ rpm)^3(1.1652\ kg/m^3)} = \frac{P_2}{(620\ rpm)^3(1.0602\ kg/m^3)}$$

$$P_2 = 37.1830\ kW$$

$H_T = h_s + h_v$

$h_s = \dfrac{\gamma_w h_w}{\gamma_a}$

$P = \left(1.0\ \text{kg/cm}^2\right)\left(\dfrac{9.81\ \text{m/s}^2}{1000\ \frac{\text{kg-m}}{\text{kN-s}^2}}\right)\left(\dfrac{100\ \text{cm}}{1\ \text{m}}\right)^2 = 98.1\ \text{kPa}$

$\rho_a = \dfrac{P}{RT} = \dfrac{98.1\ \text{kPa}}{\left(0.287\ \frac{\text{kJ}}{\text{kg-K}}\right)(23.8889 + 273)\text{K}} = 1.1513\ \dfrac{\text{kg}}{\text{m}^3}$

subst;

$$110\text{m} = \frac{\left(9.81\ \text{kN/m}^3\right)h_w}{\left(1.1513\ \text{kg/m}^3\right)\left(\dfrac{9.81\ \text{m/s}^2}{1000\ \frac{\text{kg-m}}{\text{kN-s}^2}}\right)}$$

$h_w = 0.1266$ m of water

and; $h_v = \dfrac{V^2}{2g_0} = \dfrac{(18\ \text{m/s})^2}{2(9.81\ \text{m/s}^2)} = 16.5138$ m of air

$$16.5138\ \text{m} = \frac{\left(9.81\ \text{kN/m}^3\right)h_v}{\left(1.1513\ \text{kg/m}^3\right)\left(\dfrac{9.81\ \text{m/s}^2}{1000\ \frac{\text{kg-m}}{\text{kN-s}^2}}\right)}$$

$h_v = 0.01901$ m of water

Hence;

$H_T = h_s + h_v = (0.1266 + 0.01901)$ m of water

$H_T = 0.14561$ m of water

$H_T = 145.61$ mm of water

$H_T = h_s + h_v$

$$h_s = \frac{\gamma_w h_w}{\gamma_a} = \frac{\left(9.81\ \text{kN/m}^3\right)\left(0.220\ \text{m}\right)}{\left(1.18\ \text{kg/m}^3\right)\left(\frac{9.81\ \text{m/s}^2}{1000\ \frac{\text{kg-m}}{\text{kN-s}^2}}\right)}$$

$h_s = 186.4407$ m of air

subst;

$220\text{m} = 186.4407\text{m} + h_v$

$h_v = 33.5593$ m of air

then;

$$h_v = \frac{v^2}{2g_o}$$

$$33.5593\ \text{m of air} = \frac{v^2}{2\left(9.81\ \text{m/s}^2\right)}$$

$$v = 25.6599\ \text{m/s}$$

$$\frac{h_1}{h_2} = \frac{\rho_1}{\rho_2} \quad ; \quad \rho_1 = \frac{P}{RT} = \frac{100\ kPa}{(0.287\ kJ/kg\text{-}K)(28+273)K} = 1.1576\ kg/m^3$$

$$\rho_2 = \frac{P}{RT} = \frac{(15\ psi)\left(\frac{101.325\ kPa}{14.7\ psi}\right)}{(0.287\ kJ/kg\text{-}K)(96+273)K} = 0.9763\ kg/m^3$$

subst;

$$\frac{280\ mm}{h_2} = \frac{1.1576\ kg/m^3}{0.9763\ kg/m^3}$$

$$h_2 = 236.1472\ mm\ of\ water$$

$$\eta_F = \frac{AP}{EP}$$

$$AP_1 = \eta_F EP = (0.78)(55\ kw) = 42.9\ kw$$

$$AP_1 = Q_1 \gamma H_s$$

$$42.9\ kw = Q_1\left(1.2\ kg/m^3\right)\left(\frac{9.81\ m/s^2}{1000\ \frac{kg-m}{kN-s^2}}\right)(130\ m)$$

$$Q_1 = 28.0326\ m^3/s$$

subst;

$$\frac{Q_1}{Q_2} = \frac{P_1}{P_2}$$

$$\frac{28.0326\ m^3/s}{Q_2} = \frac{42.9\ kw}{55\ kw}$$

$$Q_2 = 35.9392\ kw$$

$H_T = h_s + h_v$

$h_s = h_2 - h_1 = (0.165 - 0.045)\,m = 0.12\ m$ of water

$h_v = \dfrac{v_2^2 - v_1^2}{2g_o} = \dfrac{(9^2 - 6^2)\ m^2/s^2}{2(9.81\ m/s^2)} = 2.2936\ m$ of air

$h_v = \dfrac{\gamma_w h_v}{\gamma_a}$

$2.2936\ m \text{ of air} = \dfrac{(9.81\ kN/m^3)h_v}{(1.12\ kg/m^3)\left(\dfrac{9.81\ m/s^2}{1000\ \frac{kg\text{-}m}{kN\text{-}s^2}}\right)}$

$h_v = 2.5688 \times 10^{-3}\ m$ of water

Hence,

$H_T = (0.12 + 2.5688 \times 10^{-3})\,m$ of water

$H_T = 0.1226\ m$ of water

$H_T = 122.6\ mm$ of water

$$\frac{P_1}{\rho_1} = \frac{P_2}{\rho_2}$$

$$\rho_2 = \frac{P}{RT} = \frac{100\ kPa}{(0.287\ kJ/kg\text{-}K)(36+273)K} = 1.1276\ \frac{kg}{m^3}$$

Substi;

$$\frac{110\ kW}{1.190\ kg/m^3} = \frac{P_2}{1.1276\ kg/m^3}$$

$$P_2 = 104.2319\ kW$$

$\eta_p = \frac{AP}{EP}$; $AP = Q\gamma H_T$

$H_T = h_s + h_v$

$h_s = \frac{\gamma_w h_w}{\gamma_a} = \frac{(9.81\ kN/m^3)(0.165\ m)}{0.011772\ kN/m^3}$

$h_s = 137.5\ m\ of\ air$

$h_v = \frac{v^2}{2g_o} = \frac{(25\ m/s)^2}{2(9.81\ m/s^2)}$

$h_v = 31.8552\ m\ of\ air$

$H_T = (137.5 + 31.8552)\ m\ of\ air$

$H_T = 169.3552\ m\ of\ air$

subst;

$AP = \left(\frac{100000}{3600}\frac{m^3}{s}\right)(0.011772\ kN/m^3)(169.3552\ m\ of\ air)$

$AP = 55.3792\ kW$

Hence;

$0.75 = \frac{55.3792\ kW}{EP}$

$EP = 73.8389\ kW$

$$AP = \theta \gamma_a H_T$$

$$H_T = h_s + h_v$$

$$h_s = \frac{\gamma_w h_w}{\gamma_a} = \frac{\left(9.81 \text{ kN/m}^3\right)\left(0.160 \text{ m of water}\right)}{\left(1.12 \text{ kg/m}^3\right)\left(\frac{9.81 \text{ m/s}^2}{1000 \frac{\text{kg-m}}{\text{kN-s}^2}}\right)} = 142.8571 \text{ m of air}$$

$$h_v = \frac{V^2}{2g_c} \quad ; \quad \theta = AV$$

$$45 \frac{\text{m}^3}{\text{s}} = (0.720 * 1.050)\text{m}^2 V$$

$$V = 59.5238 \text{ m/s}$$

$$h_v = \frac{\left(59.5238 \text{ m/s}\right)^2}{2\left(9.81 \text{ m/s}^2\right)} = 180.5853 \text{ m of air}$$

$$H_T = (142.8571 + 180.5853) \text{ m of air}$$

$$H_T = 323.4424 \text{ m of air}$$

subst;

$$AP = \left(45 \text{ m}^3/\text{s}\right)\left(1.12 \text{ kg/m}^3\right)\left(\frac{9.81 \text{ m/s}^2}{1000 \frac{\text{kg-m}}{\text{kN-s}^2}}\right)\left(323.4424 \text{ m of air}\right)$$

$$AP = \left(159.9177 \text{ kW}\right)\left(\frac{1 \text{ hp}}{0.746 \text{ kW}}\right)$$

$$AP = 214.3668 \text{ hp}$$