Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

56.5% and 60.2%; a higher ratio heats the mixture so much that it ignites by itself: **knock**

2.2

$\dfrac{r_c^k - 1}{k(r_c - 1)} = \dfrac{1.639}{1.4} = 1.171$; $\eta = 1 - 0.315 \times 1.171 = \mathbf{63.2}\%$; Otto at $r = 18$ would give 68.5%; Diesel engines win because they can use much higher r

2.3

$w_P = v\Delta p = 0.00101 \times 7990 = \mathbf{8.1\ kJ/kg}$; a liquid has a tiny v, about 1/1000 of a gas, so it takes little work to pressurise

2.4

$w_C = \dfrac{281}{0.85} = 330$ kJ/kg, $w_T = 0.88 \times 678 = 597$ kJ/kg; $w_{net} = \mathbf{267\ kJ/kg}$

$T_{2a} = 300 + \dfrac{330}{1.005} = 629$ K, $q_{in} = 1.005(1400 - 629) = 775$ kJ/kg; $\eta = \mathbf{34.4}\%$

3.1

$h_1 = 191.81$; $h_2 = 191.81 + 8.07 = 199.88$ kJ/kg

$x_4 = \dfrac{6.7266 - 0.6492}{7.4996} = 0.810$, $h_4 = 2130.3$ kJ/kg

$w_T = 1269.2$, $q_{in} = 3199.6$ kJ/kg; $\eta = \dfrac{1269.2 - 8.1}{3199.6} = \mathbf{39.4}\%$

back-work ratio = $\mathbf{0.6}\%$; $x_4 = \mathbf{0.81}$

3.2

reheat : expand part way, heat the steam again, then expand: drier exit, efficiency about the same or a little higher

a higher boiler **temperature** moves state 3 to higher entropy: drier exit and higher efficiency (limited by the metal)

3.3

(a) $T_{4a} = 1400 - \dfrac{597}{1.005} = \mathbf{806\ K}$; 806 > 629 K, so the exhaust can heat the compressed air

(b) $T_x = 629 + 0.80(806 - 629) = 771$ K; $q_{in} = 1.005(1400 - 771) = \mathbf{633\ kJ/kg}$; $\eta = \dfrac{267}{633} = \mathbf{42}\%$, up from 34%

(c) now $T_{4a} = 691 < T_{2a} = 778$ K: the regenerator would **cool** the compressed air and waste fuel; drop it at high r_p, or keep r_p low and use the regenerator

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