For Problem 9.1 do parts a, b, c, & d only!
9.13 Consider a modification of the air-standard Otto cycle in which the isentropic compression and expansion processes are each replaced with polytropic processes having \( n = 1.3 \). The compression ratio is 9 for the modified cycle. At the beginning of compression, \( p_1 = 1 \text{ bar} \) and \( T_1 = 300 \text{ K} \). The maximum temperature during the cycle is 2000 K. Determine

(a) the heat transfer and work per unit mass of air, in kJ/kg, for each process in the modified cycle.
(b) the thermal efficiency.
(c) the mean effective pressure, in bar.

9.14 A four-cylinder, four-stroke internal combustion engine has a bore of 3.75 in. and a stroke of 3.45 in. The clearance volume is 17% of the cylinder volume at bottom dead center and the crankshaft rotates at 2600 RPM. The processes within each cylinder are modeled as an air-standard Otto cycle with a pressure of 14.6 lb/in.\(^2\) and a temperature of 60°F at the beginning of compression. The maximum temperature in the cycle is 5200°F. Based on this model, calculate the net work per cycle, in Btu, and the power developed by the engine, in horsepower.

9.15 At the beginning of the compression process in an air-standard Otto cycle, \( p_1 = 1 \text{ bar} \) and \( T_1 = 300 \text{ K} \). The maximum cycle temperature is 2000 K. Plot the net work per unit mass, in kJ/kg, the thermal efficiency, and the mean effective pressure, in bar, versus the compression ratio ranging from 2 to 14.

9.16 Investigate the effect of maximum cycle temperature on the net work per unit mass of air for air-standard Otto cycles with compression ratios of 5, 8, and 11. At the beginning of the compression process, \( p_1 = 1 \text{ bar} \) and \( T_1 = 295 \text{ K} \). Let the maximum temperature in each case vary from 1000 to 2000 K.

9.17 The pressure-specific volume diagram of the air-standard Atkinson cycle is shown in Fig. P9.17. The cycle consists of isentropic compression, constant volume heat addition, isentropic expansion, and constant pressure compression. For a particular Atkinson cycle, the compression ratio during isentropic compression is 8.5. At the beginning of this compression process, \( p_1 = 100 \text{ kPa} \) and \( T_1 = 300 \text{ K} \). The constant volume heat addition per unit mass of air is 1400 kJ/kg. (a) Sketch the cycle on \( T-s \) coordinates. Determine (b) the net work, in kJ per kg of air, (c) the thermal efficiency of the cycle, and (d) the mean effective pressure, in kPa. Compare your answers with those obtained for the Otto cycle in Problem 9.1 and discuss.

9.18 On a cold air-standard basis, derive an expression for the thermal efficiency of the Atkinson cycle (see Fig. P9.17) in terms of the volume ratio during the isentropic compression, the pressure ratio for the constant volume process, and the specific heat ratio. Compare the thermal efficiencies of the cold air-standard Atkinson and Otto cycles, each having the same compression ratio and maximum temperature. Discuss.

9.19 The pressure and temperature at the beginning of compression of an air-standard Diesel cycle are 95 kPa and 290 K, respectively. At the end of the heat addition, the pressure is 6.5 MPa and the temperature is 2000 K. Determine

(a) the compression ratio.
(b) the cutoff ratio.
(c) the thermal efficiency of the cycle.
(d) the mean effective pressure, in kPa.

9.20 Solve Problem 9.19 on a cold air-standard basis with specific heats evaluated at 300 K.

9.21 The compression ratio of an air-standard Diesel cycle is 17 and the conditions at the beginning of compression are \( p_1 = 140 \text{ lb/ft}^2 \), \( V_1 = 2 \text{ ft}^3 \), and \( T_1 = 520\text{°F} \). The maximum temperature in the cycle is 4000°F. Calculate

(a) the net work for the cycle, in Btu.
(b) the thermal efficiency.
(c) the mean effective pressure, in lb/ft\(^2\).
(d) the cutoff ratio.

9.22 Solve Problem 9.21 on a cold air-standard basis with specific heats evaluated at 520°F.

9.23 The conditions at the beginning of compression in an air-standard Diesel cycle are fixed by \( p_1 = 200 \text{ kPa} \) and \( T_1 = 380 \text{ K} \). The compression ratio is 20 and the heat addition per unit mass is 900 kJ/kg. Determine

(a) the maximum temperature, in K.
(b) the cutoff ratio.
(c) the net work per unit mass of air, in kJ/kg.
(d) the thermal efficiency.
(e) the mean effective pressure, in kPa.

(f) To investigate the effects of varying compression ratio, plot each of the quantities calculated in parts (a) through (e) for compression ratios ranging from 5 to 25.
9.24 For the Diesel cycle of Problem 9.23 with a compression ratio of 20 and a heat addition per unit mass of 900 kJ/kg:
(a) evaluate the exergy transfers accompanying heat and work for each process, in kJ/kg.
(b) devise and evaluate an exergetic efficiency for the cycle.
Let $T_0 = 300$ K, $p_0 = 100$ kPa.

9.25 An air-standard Diesel cycle has a compression ratio of 18 and a cutoff ratio of 2. At the beginning of compression, $p_1 = 14.2$ lb/in.$^2$, $V_1 = 0.5$ ft$^3$, and $T_1 = 520$°R. Calculate
(a) the heat added, in Btu.
(b) the maximum temperature in the cycle, in °R.
(c) the thermal efficiency.
(d) the mean effective pressure, in lb/in.$^2$.
(e) To investigate the effects of varying compression ratio, plot each of the quantities calculated in parts (a) through (d) for compression ratios ranging from 5 to 18 and for cutoff ratios of 1.5, 2, and 2.5.

9.26 For the Diesel cycle of Problem 9.25 with a compression ratio of 16 and a cutoff ratio of 2
(a) evaluate the exergy transfers accompanying heat and work for each process, in Btu.
(b) devise and evaluate an exergetic efficiency for the cycle.
Let $T_0 = 520$°R, $p_0 = 14.2$ lb/in.$^2$.

9.27 The displacement volume of an internal combustion engine is 3 L. The processes within each cylinder of the engine are modeled as an air-standard Diesel cycle with a cutoff ratio of 2.5. The state of the air at the beginning of compression is fixed by $p_1 = 95$ kPa, $T_1 = 22°C$, and $V_1 = 3.2$ L. Determine the net work per cycle, in kJ, the power developed by the engine, in kW, and the thermal efficiency, if the cycle is executed 2000 times per min.

9.28 The state at the beginning of compression of an air-standard Diesel cycle is fixed by $p_1 = 100$ kPa and $T_1 = 310$ K. The compression ratio of 15. For cutoff ratios ranging from 1.5 to 2.5, plot
(a) the maximum temperature, in K.
(b) the pressure at the end of the expansion, in kPa.
(c) the work per unit mass of air, in kJ/kg.
(d) the thermal efficiency.

9.29 An air-standard Diesel cycle has a maximum temperature of 1800 K. At the beginning of compression, $p_1 = 95$ kPa and $T_1 = 300$ K. The mass of air is 12 g. For compression ratios ranging from 15 to 25, plot
(a) the net work of the cycle, in kJ.
(b) the thermal efficiency.
(e) the mean effective pressure, in kPa.

9.30 At the beginning of compression in an air-standard Diesel cycle, $p_1 = 96$ kPa, $V_1 = 0.016$ m$^3$, and $T_1 = 290$ K. The compression ratio is 15 and the maximum cycle temperature is 1200 K. Determine
(a) the mass of air, in kg.
(b) the heat addition and heat rejection per cycle, each in kJ.
(e) the net work, in kJ, and the thermal efficiency.

9.31 At the beginning of the compression process in an air-standard Diesel cycle, $p_1 = 1$ bar and $T_1 = 300$ K. For maximum cycle temperatures of 1200, 1500, 1800, and 2100 K, plot the heat addition per unit mass of air, in kJ/kg, the net work per unit of mass, in kJ/kg, the mean effective pressure, in bar, and the thermal efficiency, each versus compression ratio ranging from 5 to 20.

9.32 An air-standard dual cycle has a compression ratio of 9. At the beginning of compression, $p_1 = 100$ kPa and $T_1 = 360$ K. The heat addition per unit mass of air is 1400 kJ/kg, with one half added at constant volume and one half added at constant pressure. Determine
(a) the temperatures at the end of each heat addition process, in K.
(b) the net work of the cycle per unit mass of air, in kJ/kg.
(c) the thermal efficiency.
(d) the mean effective pressure, in kPa.

9.33 For the cycle in Problem 9.32, plot each of the quantities calculated in parts (a) through (d) versus the ratio of constant-volume heat addition to total heat addition varying from 0 to 1. Discuss.

9.34 Solve Problem 9.33 on a cold air-standard basis with specific heats evaluated at 300 K.

9.35 The thermal efficiency, $\eta$, of a cold air-standard dual cycle can be expressed as
$$\eta = 1 - \frac{1}{r^2} - \frac{r - 1}{(r - 1) + k(r - 1)}$$
where $r$ is compression ratio, $r_2$ is cutoff ratio, and $p_1$ is the pressure ratio for the constant volume heat addition. Derive this expression.

9.36 An air-standard dual cycle has a compression ratio of 17 and a cutoff ratio of 1.23. At the beginning of compression, $p_1 = 95$ kPa and $T_1 = 310$ K. The pressure doubles during the constant volume heat addition process. If the mass of air is 0.25 kg, determine
(a) the heat addition at constant volume and at constant pressure, each in kJ.
(b) the net work of the cycle, in kJ.
(c) the heat rejection, in kJ.
(d) the thermal efficiency.

9.37 The pressure and temperature at the beginning of compression in an air-standard dual cycle are 14.0 lb/in.$^2$ and 520°F, respectively. The compression ratio is 15 and the heat addition per unit mass of air is 800 Btu/lb. At the end of the constant volume heat addition process, the pressure is 1200 lb/in.$^2$. Determine