1. Problem 2.1

   FCI using six-tenths method:

$$\text{FCI}_{110} = \$12 \text{ billion} \left(\frac{110,000}{140,000} \right)^{0.6}$$

$$\boxed{\text{FCI}_{110} = \$10.38 \text{ billion}}$$

2. Problem 2.2

$$\text{EtOH production} = 1800\frac{\text{ton}}{\text{day}} \cdot \frac{90\text{gal}}{\text{ton}} \cdot \frac{365\text{day}}{\text{yr}}$$
$$\text{EtOH production} = 59.13\frac{\text{MMgal}}{\text{yr}}$$

(a)

$$\text{FCI}_{2014} = 59.13\frac{\text{MMgal}}{\text{yr}} \cdot \frac{\$3.10}{\text{gal}}$$
$$\boxed{\text{FCI}_{2014} = \$183.3 \text{ MM}}$$

(b)

$$\text{CEPCI}_{2014} = 576.1$$
$$\text{CEPCI}_{\text{current}} = 833.1$$
$$\text{FCI} = \$183.3 \text{ MM} \cdot \frac{833.1}{576.1}$$
$$\boxed{\text{FCI}_{\text{current}} = \$265.1 \text{ MM}}$$

3. Problem 2.3

$$\text{current price of ethanol} = \$2.16$$

$$\text{FCI}_{\text{current}} = 59.13 \frac{\text{MMgal}}{\text{yr}} \cdot \frac{\$2.16}{\text{gal}}$$

$$\boxed{\text{FCI}_{\text{current}} = \$127.7 \text{ MM}}$$

4. Problem 2.4

   Solid-fluid process

$$\text{delivered cost} = \$40 \text{ MM} \cdot \frac{100}{139}$$
$$\text{delivered cost} = \$28.8 \text{ MM}$$
$$\text{Lang factor} = 4.3$$
$$\text{FCI} = \$28.8 \text{ MM} \cdot 4.3$$
$$\boxed{\text{FCI} = \$123.7 \text{ MM}}$$

5. Problem 2.5

Lang method:

$$\begin{aligned}
\text{delivered cost} &= \$5\text{ MM} + \$4\text{ MM} + \$2\text{ MM} + \$1\text{ MM} \\
\text{delivered cost} &= \$12\text{ MM} \\
\text{Lang factor} &= 5 \\
\text{FCI} &= 5 \cdot \$12\text{ MM} \\
\boxed{\text{FCI} &= \$60\text{ MM}}
\end{aligned}$$

Hand method:

$$\begin{aligned}
\text{distillation column factor} &= 4 \\
\text{fired heater factor} &= 2 \\
\text{heat exchanger factor} &= 3.5 \\
\text{tanks factor} &= 4 \\
\text{instruments factor} &= 4 \\
\text{FCI} &= 4 \cdot \$5\text{ MM} + 2 \cdot \$4\text{ MM} + 3.5 \cdot \$2\text{ MM} + 4 \cdot \$1\text{ MM} + 4 \cdot \$4\text{ MM} \\
\boxed{\text{FCI} &= \$55\text{ MM}}
\end{aligned}$$

6. Problem 2.6

   $< 60{,}000$ MTPA

$$\text{FCI} = 458000 \cdot 8 \cdot 40000^{0.3}$$

$$\boxed{\text{FCI} = \$88 \text{ MM}}$$

7. Problem 2.7

(a) Lang method

$$\text{FCI} = 5 \cdot \$200 \text{ MM}$$

$$\boxed{\text{FCI} = \$1000 \text{ MM}}$$

(b) Six-tenths method

$$\text{FCI} = \$1300 \text{ MM} \left(\frac{1 \cdot 10^6}{1.5 \cdot 10^6} \right)^{0.6}$$

$$\boxed{\text{FCI} = \$1019 \text{ MM}}$$

(c) Empirical method

$$\text{FCI} = 17000 \cdot 6 \cdot (1 \cdot 10^6)^{0.65}$$

$$\boxed{\text{FCI} = \$810.4 \text{ MM}}$$

(d) Turnover method

$$\text{Gulf Coast MeOH contract price} \approx \$600/\text{tonne}$$

$$\text{FCI} = \$600/\text{tonne} \cdot 1 \cdot 10^6 \text{ MTPA}$$

$$\boxed{\text{FCI} = \$600 \text{ MM}}$$

8. Problem 2.8

$$\text{Heat} = \frac{41.2\frac{\text{MMBTU}}{\text{h}}}{0.65} = 63.38\frac{\text{MMBTU}}{\text{h}}$$

Average Henry Hub spot price from January 19, 2023 to January 25, 2023

$$\text{price} = \$3.174/\text{MMBTU}$$

$$\text{operating cost} = 63.38\frac{\text{MMBTU}}{\text{h}} \cdot \$3.174/\text{MMBTU} \cdot 8760\frac{\text{h}}{\text{yr}}$$

$$\boxed{\text{operating cost} = \$1.762 \text{ MM}}$$

9. Problem 2.9

WTI crude future price on January 28, 2023

$$\text{price} = \$79.68/\text{bbl}$$

$$\text{operating cost} = 63.38\frac{\text{MMBTU}}{\text{h}} \cdot \frac{1\text{bbl}}{5.8\text{MMBTU}} \cdot \$79.68/\text{bbl} \cdot 8760\frac{\text{h}}{\text{yr}}$$

$$\boxed{\text{operating cost} = \$7.627 \text{ MM}}$$

It is significantly more expensive to use crude oil for heating than natural gas.

10. Problem 2.10

$$\text{operating cost} = 63400\frac{\text{SCF}}{\text{h}} \cdot \frac{1000\text{BTU}}{\text{CSF}} \cdot \frac{1\text{MMBTU}}{10^6\text{BTU}} \cdot \$3.174/\text{MMBTU}$$

$$\boxed{\text{operating cost} = \$1.763 \text{ MM}}$$

11. Problem 2.11

six-tenths scaling

$$\mathrm{FOB}_{50} = \$100000 \cdot \left(\frac{50\mathrm{m}^2}{100\mathrm{m}^2}\right)$$

$$\boxed{\mathrm{FOB}_{50} = \$65,975}$$

12. Problem 2.12

From cost chart:

$$\begin{aligned}
\text{carbon steel cost} &= \$35000 \\
\text{cast steel factor} &= 1.2 \\
\text{cast steel cost} &= 1.2 \cdot \$35000 \\
\boxed{\text{cast steel cost} &= \$42,000} \\
\text{316L stainless steel factor} &= 2.1 \\
\text{316L stainless steel cost} &= 2.1 \cdot \$35000 \\
\boxed{\text{316L stainless steel cost} &= \$73,500}
\end{aligned}$$