Problem 1. (2 points off for each 3 wrong)

\[
\begin{align*}
2 \text{CH}_2\text{O}_2 + 2 \text{CO}_2 + 2 \text{ATP} & \rightarrow 2 \text{CH}_2\text{O}_{2}\text{PO}_4 + 2 \text{ADP} + 2 \text{Pi} \\
\text{Puruvate carboxylase} & \\
\text{Oxaloacetate} + 2 \text{GTP} & \rightarrow 2 \text{CH}_2\text{O}_{2}\text{PO}_4 + 2 \text{GDP} \\
\text{Enolase} & \\
2 \text{CH}_2\text{O}_{2}\text{PO}_4 + 2 \text{ATP} & \rightarrow 2 \text{CH}_2\text{O}_{2}\text{PO}_4 + 2 \text{ADP} \\
\text{Phosphoglycerate mutase} & \\
\text{PEP carboxykinase} & \\
2 \text{CH}_2\text{O}_{2}\text{PO}_4 & \rightarrow 2 \text{CH}_2\text{O}_{2}\text{PO}_4 + 2 \text{NAD} + 2 \text{Pi} \\
\text{Phosphoglycerate kinase} & \\
2 \text{CH}_2\text{O}_{2}\text{PO}_4 & \rightarrow 2 \text{CH}_2\text{O}_{2}\text{PO}_4 + 2 \text{NAD} + 2 \text{Pi} \\
\text{Glyceraldehyde-3-phosphate dehydrogenase} & \\
\text{Triose Phosphate Isomerase} & \\
\text{fructose-6-phosphate} & \rightarrow \text{fructose-1,6-bisphosphate} & \rightarrow \text{Dihydroxyacetone phosphate} \\
\text{Fructose 1,5-bisphatase} & \\
\text{Alcoholse} & \\
\text{Glucose 6-phosphatase} & \\
\text{Phosphoglucone isomerase} & \\
\text{Fructose-1,6-bisphosphate} & \rightarrow \text{fructose-6-phosphate} & \rightarrow \text{Dihydroxyacetone phosphate}
\end{align*}
\]
Problem 2
Problem 3

Complex I
NADH:ubiquinone oxidoreductase
net rxn: $\text{NADH} + 5\text{H}_N + Q - \text{QH}_2 + \text{NAD}^+ + 4\text{H}_P$
Mass : 850 kD in 42 polypeptides, FMN prosthetic groups and FeS centers

Complex II
Succinate dehydrogenase complex
net rxn: Succinate +Q $\rightarrow$ Fumarate + QH$_2$
(Book usually shows as FAD and FADH$_2$ but these are bound to the enzyme so they cannot leave. In reality the reducing equivalents are passed to ubiquinone QH$_2$)
Mass 140 kD in 5 polyptptides, FAD prosthetic group and FeS centers in proteins

Complex III
Cytochrome bc$_1$ complex or ubiquinone:cytochrome c oxidoreductase
net rxn: QH$_2$ + 2Cyt$_{c1}$(ox) $\rightarrow$ 2H$_N^+$ - Q + 2Cyt$_{c1}$(ox) + 4H$_P^+$
Actually 2 reactions:
$\text{QH}_2 + \text{Cyt}_{c1}(\text{ox}) \rightarrow \text{Q}^- + 2\text{H}_N^+ + \text{Cyt}_{c1}(\text{ox})$
$\text{QH}_2^+ + \text{Q}^- + 2\text{H}_N^+ + \text{Cyt}_{c1}(\text{ox}) \rightarrow \text{QH}_2 + 2\text{H}_N^+ + \text{Cyt}_{c1}(\text{ox})$
Mass 250 kDa in 11 polypeptides, Heme and FeS groups involved
Complex IV
Cytochrome oxidase
net rxn: \(4 \text{Cyt}_{c1}^{\text{ox}} + 8H^+_N + O_2 \rightarrow 4 \text{Cyt}_{c1}^{\text{ox}} + 4H^+_p + 2H_2O\)
Mass 160 kD in 13 polypeptides, Hemes and Cu\(_A\) and Cu\(_b\) involved

ATP Synthase
net rxn: \(\text{ADP} + \text{Pi} + 3H^+_p \rightarrow \text{ATP} + 3H^+_N\)
\(F_1\alpha_3\beta_3\gamma_6\delta\) the ATP syntase
\(F_0\ ab_2c_{10-12}\) The proton transporter
proton transport down its chemiosmotic gradient is mechanically linked to changing conformations in the \(F_1\) subunit to make the enzyme first bind ADP and PI then fuse these into ATP then kick the ATP out of the active site

4.
TPP Thiamine pyrophosphate - used to cleave bonds next to carbonyl groups-
- Seen in pyruvate decarboxylase, pyruvate dehydrogenase, and \(\alpha\)-ketoglutarate dehydrogenase

NAD - water solution hydride carrier - Seen in Glyceraldehyde-3-phosphate dehydrogenase, alcohol dehydrogenase, Lactic dehydrogenase, pyruvate dehydrogenase, isocitrate dehydrogenase, \(\alpha\)-ketoglutarate dehydrogenase, malate dehydrogenase, Complex I

FAD- Lipid soluble hydride carrier- pyruvate dehydrogenase, \(\alpha\)-ketoglutarate dehydrogenase, succinate dehydrogenase, Complex II, glycerol 3-phosphate dehydrogenase

Biotin - carrier of activated HCO\(_3\)\(^-\), Pyruvate carboxylase,

Coenzyme A - water soluble carrier of various groups via an activated carboxylic acid - pyruvate dehydrogenase, citrate syntase, \(\alpha\)-ketoglutarate dehydrogenase, Succunyl-CaA syntase, Other enzymes in fatty acid metabolism

Lipoic acid - enzyme bound carrier of activated acetate groups - Pyrovate dehydrogenase, \(\alpha\)-ketoglutarate dehydrogenase

Iron Sulfur cluster - Enzyme bound electron carrier - aconitase, Complex II, Complex III, probably glycerol 3-phosphate dehydrogenase

Heme - enzyme bound electron carrier - Complex III, cytochrome c, Complex IV

Uniquinone - Lipid soluble hydride carrier, Complex I, Complex II, glycerol 3-phosphate dehydrogenase, Complex III, acyl CoA dehydrogenase, ETF:Q oxidoreductase