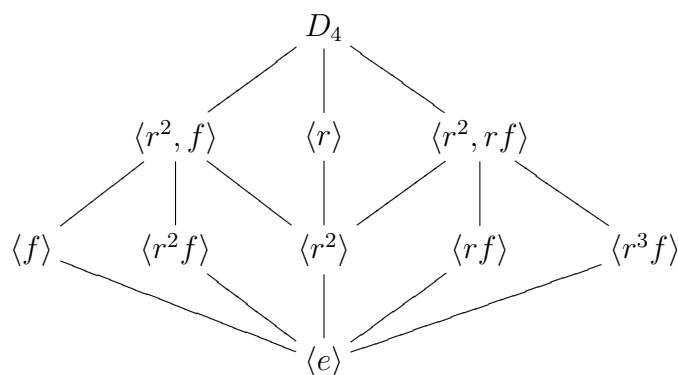


Read the following, which can all be found either in the textbook or on the course website.

- Chapters 6 of *Visual Group Theory* (VGT).
- VGT Exercises 6.6–6.9, 6.12, 6.17–6.20, 6.28–6.30.

Write up solutions to the following exercises.

1. Consider the subgroups $H = \langle (1\ 2\ 3) \rangle$ and $K = \langle (1\ 2), (3\ 4) \rangle$ of the alternating group $G = A_4$. Carry out the following steps for both of these subgroups.
 - (a) Write G as a disjoint union of the subgroup's left cosets.
 - (b) Write G as a disjoint union of the subgroup's right cosets.
 - (c) Determine whether the subgroup is normal in G .
2. The subgroup lattice of D_4 is shown below:



For each of the 10 subgroups of D_4 , determine whether it is normal. Justify each yes or no answer.

3. Consider a chain of subgroups $K \leq H \leq G$.
 - (a) Prove or disprove: If $K \triangleleft H \triangleleft G$, then $K \triangleleft G$.
 - (b) Prove or disprove: If $K \triangleleft G$, then $K \triangleleft H$.

4. The *center* of a group G is the set

$$\begin{aligned} Z(G) &= \{z \in G \mid gz = zg, \forall g \in G\} \\ &= \{z \in G \mid gzg^{-1} = z, \forall g \in G\}. \end{aligned}$$

Prove that $Z(G)$ is a subgroup of G , and that it is normal in G .

5. Let H be a subgroup of G . Given two fixed elements $a, b \in G$, define the sets

$$aHbH = \{ah_1bh_2 \mid h_1, h_2 \in H\} \quad \text{and} \quad abH = \{abh \mid h \in H\}.$$

Prove that if $H \triangleleft G$, then $aHbH = abH$.

6. Let H be a subgroup of an abelian group G . Prove that H and G/H are both abelian.