

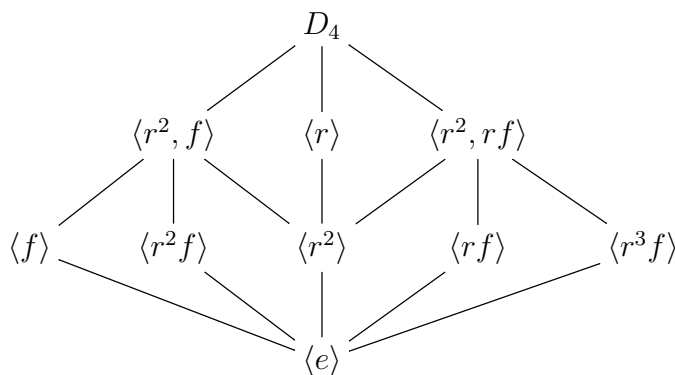
Read the following, which can all be found either in the textbook or on the course website.

- Chapters 6 of *Visual Group Theory*, or Chapters 7.3, 8.1 of *IBL Abstract Algebra*.
- 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 $H = \langle (123) \rangle$ and $K = \langle (12)(34) \rangle$ of the alternating group $A_4 = \langle (123), (12)(34) \rangle$. Carry out the following steps for both of these subgroups. When writing a coset, list all of its elements.
 - (a) Write A_4 as a disjoint union of the subgroup's left cosets.
 - (b) Write A_4 as a disjoint union of the subgroup's right cosets.
 - (c) Determine whether the subgroup is normal in A_4 .
2. The *center* of a group G is the set

$$Z(G) = \{z \in G \mid gz = zg, \forall g \in G\} = \{z \in G \mid gzg^{-1} = z, \forall g \in G\}.$$
 - (a) Prove that $Z(G)$ is a subgroup of G , and that it is normal in G .
 - (b) Compute the center of the following groups: C_6 , D_4 , D_5 , Q_8 , A_4 , S_4 , and $D_4 \times Q_8$.
3. The subgroup lattice of D_4 is shown below:



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

4. 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 $K \triangleleft H$.
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. Prove that $A \times \{e_B\}$ is a normal subgroup of $A \times B$, where e_B is the identity element of B . That is, show first that it is a subgroup, and then that it is normal.