M2P2 Algebra II   Problem Sheet 1

1. (*Revision!*) Decide whether each of the following statements is true or false. Throughout, G is a group.

1. If we can find elements g, h in G such that $gh = hg$ then G is abelian.
2. If G is cyclic then G is abelian.
3. If G is not cyclic then G is not abelian.
4. If G is infinite then no element of G has finite order.
5. If H is a subgroup of G and $H \cong G$, then $G = H$.
6. If $G = D_{2n}$ then every element of G has order $1, 2$ or n.
7. If $G = S_n$ then the size of every subgroup of G divides $n!$.
8. If $G = S_n$ then no element of G has order greater than n.
9. If the order of every non-identity element of G is a prime number then G is cyclic.
10. If $G = \langle g \rangle$ is an infinite cyclic group, then g and g^{-1} are the only generators of G.
11. If G is cyclic then G contains two different elements g_1 and g_2 such that $G = \langle g_1 \rangle = \langle g_2 \rangle$.
12. If $G = GL(2, \mathbb{R})$, then some elements of G have finite order and some have infinite order.
13. $\mathbb{Z}_7^*$ is a cyclic group.
14. Any two groups of size 13 are isomorphic to each other.
15. Every group of size 4 is abelian.

2. Let D_8 be the dihedral group of size 8 consisting of the rotations e, ρ, ρ^2, ρ^3 and reflections $\sigma_1, \ldots \sigma_4$ described in lectures. Write $\sigma = \sigma_1$. Prove

(a) $\sigma\rho = \rho^{-1}\sigma$
(b) $\{\sigma, \rho\sigma, \rho^2\sigma, \rho^3\sigma\} = \{\sigma_1, \sigma_2, \sigma_3, \sigma_4\}$
(c) for any i, j, the product $\sigma_i\sigma_j$ is a rotation (*hint: use (a) and (b)*)
(c) D_8 has five elements of order 2 and two elements of order 4
(d) D_8 has exactly seven different cyclic subgroups.

3. Do Q2, parts (a)-(c) for the dihedral group D_{2n} for n an arbitrary integer with $n \geq 3$.

4. Let Π be the infinite strip pattern

$$\ldots \text{D D D D D} \ldots$$

Show that every element of the symmetry group $G(\Pi)$ is of the form τ^n or $\tau^n\sigma$, where τ is a suitable translation and σ is a suitable reflection. Prove that $G(\Pi)$ is abelian.

5. For each of the following figures, describe the elements of the symmetry group of the figure, and state which of the groups is abelian:

(a) rectangle (non-square)

(b) square with diagonal line

(c) hexagon with 3 extra lines

(d) two perpendicular strips of squares

(e) one strip of squares