Section 1: Force diagrams and equilibrium

Exercise level 2

1. A car of mass M pulls a trailer of mass m along a straight level road at constant speed. The resistance to motion on the car is 5000 N and the resistance to motion on the trailer is 1000 N.
   (i) Draw diagrams showing all of the forces acting on the car and on the trailer.
   (ii) Find the tension in the towbar.
   (iii) Find the force being produced by the car's engine.

2. Ann and Beryl are both pushing a piano. Ann pushes in the direction $4\mathbf{i} + 3\mathbf{j}$ and Beryl in the direction $12\mathbf{i} + 5\mathbf{j}$, where $\mathbf{i}$ and $\mathbf{j}$ are the standard unit vectors. Together they produce a force of $(68\mathbf{i} + 33\mathbf{j})$ N so that

   $p(4\mathbf{i} + 3\mathbf{j}) + q(12\mathbf{i} + 5\mathbf{j}) = 68\mathbf{i} + 33\mathbf{j}$, where p and q are constants.

   Find the values of p and q and the magnitude of the forces with which each of Ann and Beryl pull.

3. A force of $(20\mathbf{i} - 15\mathbf{j})$ N acts on a particle at O. The vectors $\mathbf{i}$ and $\mathbf{j}$ are the standard unit vectors.
   (i) Calculate the magnitude of this force and the angle it makes with the $\mathbf{i}$ direction.
   (ii) A second force $(5\mathbf{i} - 40\mathbf{j})$ N also acts on the particle at O. What third force is required if the particle at O is in equilibrium with all three forces acting on it?