1. Derive the QGPV equation starting from the QG geopotential height tendency equation.

2. Compute the stationary wavelength for barotropic Rossby waves, assuming the following conditions: 45°N, and a mean zonal wind of 20 m sec$^{-1}$. If the entire mid-latitude flow was characterized by these type of waves, how many ridges/troughs would exist? How would your answer change if the mean zonal wind is increased to 80 m sec$^{-1}$? What does this answer imply about stationary ridges/troughs in strong westerly flow?

3. Determine the structure of the geopotential height perturbation and wave dispersion relationship for the case of a semi-infinite atmosphere (i.e., fixed surface with an atmosphere that goes to infinity) assuming constant static stability and a mean zonal wind that increases linearly with height and is in thermal wind balance with the mean temperature gradient. What is the necessary condition to obtain an unstable solution? Hint: Follow the steps used to derive the Eady solution, but with an appropriate boundary conditions at $z \to \infty$.

4. Derive an expression for the time rate of change of geostrophic kinetic energy ($K = \frac{1}{2}(u_g^2 + v_g^2)$) with respect to time starting from the quasi-geostrophic equations. Physically describe the processes that lead to an increase in kinetic energy following the flow.