Problem 210D

A pump has the following non-dimensional characteristic, $\psi(\phi)$:

$$\Psi = 0.5 - 8(\phi - 0.04)^2$$
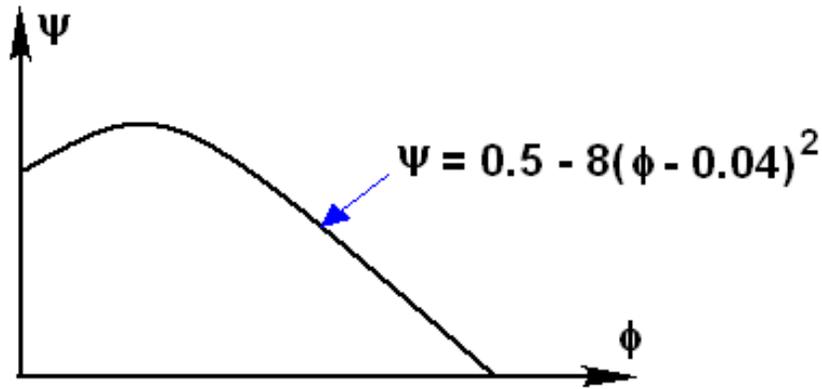
It is driven at $1000rpm$ and ψ and ϕ are based on the impeller radius of $15cm$ and a pump discharge area of $300cm^2$. It is used to pump water from one tall tank or reservoir to another:
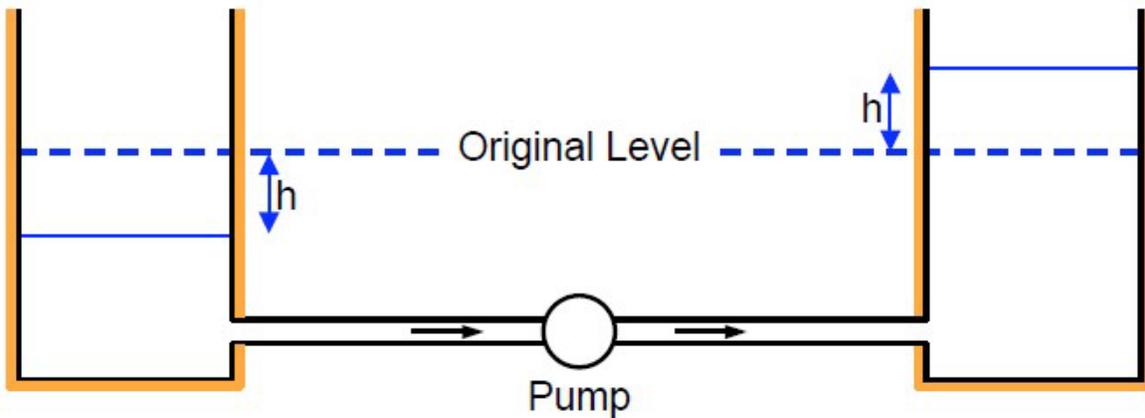
The pumping begins with the two reservoirs levels at the same elevation and the cross-sectional area of the surface of both reservoirs is the same. The pipes connecting the reservoirs to the pump both have an internal diameter of $10cm$ and a length of $50m$; the appropriate friction factor, f, for the flow in these pipes is 0.05. Find the difference in the reservoir levels, $2h$, at which the system becomes unstable and begins to oscillate.