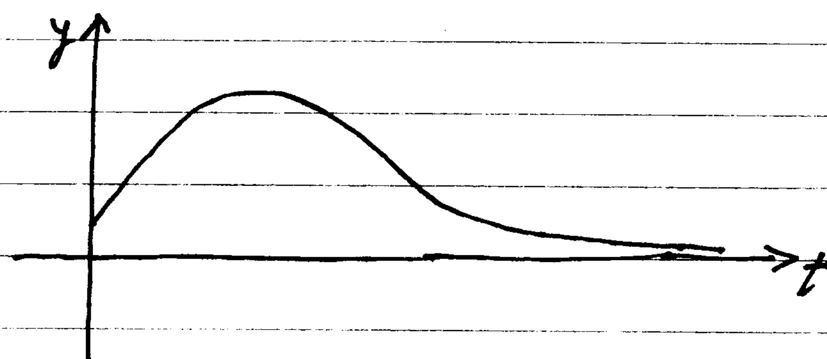
Critically damped $(b^2 = 4mk)$.
The a.e. has a double root $r = -b/2m$.
The general soln is
$$y(t) = (c_1 + c_2 t)e^{-(b/2m)t}$$

Overdamped $(b^2 > 4mk)$
The A.E. has 2 real solns
$$r_1 = \frac{-b}{2m} - \frac{\sqrt{b^2-4mk}}{2m} < 0$$
$$r_2 = \frac{-b}{2m} + \frac{\sqrt{b^2-4mk}}{2m} < 0 \quad \left(\text{since } \sqrt{b^2-4mk} < \sqrt{b^2} = b\right)$$

The general soln
$$y = c_1 e^{r_1 t} + c_2 e^{r_2 t}.$$
$$\lim_{t\to\infty} y(t) = 0.$$



NOTE: Assume $(c_1, c_2) \neq (0,0)$.

(1) The mass crosses the equilibrium point at most once.

~~Suppose~~ Note $r_1 < r_2 < 0$.
$$y = c_1 e^{r_1 t} + c_2 e^{r_2 t} = e^{r_1 t}\left(c_1 + c_2 e^{(r_2 - r_1)t}\right) = 0$$
when $c_1 + c_2 e^{(r_2-r_1)t} = 0$

ie $e^{(r_2-r_1)t} = -c_1/c_2$ (assuming $c_2 \neq 0$)

This has one soln if $-c_1/c_2 > 0$ ie $t = \frac{1}{(r_2-r_1)} \ln\left(\frac{-c_1}{c_2}\right)$
and no solns if $-c_1/c_2 \le 0$.