

## 12. The case of equal (or repeated) roots (section 3.4)

1. **Case 3:** two equal/repeated real roots  $r_1 = r_2 (= r)$  (in this case  $D = b^2 - 4ac = 0$ )

2. Recall that the **characteristic equation** of a linear homogeneous equation with constant real coefficients

$$ay'' + by' + cy = 0 \quad (1)$$

is

$$ar^2 + br + c = 0. \quad (2)$$

$$D = b^2 - 4ac = 0 \Rightarrow r = -\frac{b}{2a}$$

So, we found one particular solution  $y_1(t) = e^{rt}$ .

3. How to find a second particular solution  $y_2$  such that the set  $\{y_1, y_2\}$  be fundamental, i.e.  $W(y_1, y_2) \neq 0$ ?

Use “factorization” (in Leibnitz notation):

$$ay'' + by' + cy = a \frac{d^2 y}{dt^2} + b \frac{dy}{dt} + cy = \left( a \frac{d^2}{dt^2} + b \frac{d}{dt} + c \right) [y] = a \left( \frac{d}{dt} - r \right) \left[ \left( \frac{d}{dt} - r \right) [y] \right] = 0$$

4.  $\{y_1, y_2\} = \{e^{rt}, te^{rt}\}$  is fundamental set. Thus the general solution of (3) is

$$y(t) = C_1 e^{rt} + C_2 t e^{rt}.$$

5. Consider  $y'' - 6y' + 9y = 0$ .

- (a) Find general solution.
- (b) Find solution subject to the initial conditions  $y(0) = 2, y'(0) = \alpha$ .
- (c) For each  $\alpha$  what is the behavior of the solutions as  $t \rightarrow +\infty$ ?

**SUMMARY:**

Solution of linear homogeneous equation of second order with constant coefficients

$$ay'' + by' + cy = 0 \quad (3)$$

Sign of $D = b^2 - 4ac$	Roots of characteristic polynomial $ar^2 + br + c = 0$	General solution
$D > 0$	two distinct real roots $r_1 \neq r_2$	$y(t) = C_1e^{r_1t} + C_2e^{r_2t}$
$D < 0$	two complex conjugate roots $r_1 = \bar{r}_2$ : $r_{1,2} = \lambda \pm i\mu$	$y(t) = C_1e^{\lambda t} \cos(\mu t) + C_2e^{\lambda t} \sin(\mu t)$
$D = 0$	two equal(repeated) real roots $r_1 = r_2 = r$	$y(t) = C_1e^{rt} + C_2te^{rt}$