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# 8.6.1 Linear scalar IVP and exponential solution

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MO2.4

MO2.5

The behavior of a linear scalar ( $M = 1$ ) IVP provides useful insight into the behavior of much more complex systems of equations. Further, many phenomena can be described by a linear scalar IVP. The meaning of linear is the  $f$  is at most a linear function of  $u$ . For the scalar  $M = 1$  case, consider the following linear differential model equation,

$$\frac{du}{dt} = \lambda u$$

(8.48)

where  $\lambda$  is a constant (i.e. independent of time). Thus, for this linear scalar IVP,  $f = \lambda u$ .

Recall that the derivative of the exponential function  $\exp(\lambda t)$  is  $\lambda \exp(\lambda t)$ , i.e.

$$\frac{d}{dt}[\exp(\lambda t)] = \lambda \exp(\lambda t)$$

(8.49)

Comparing this to Equation (8.48), we see that the solution to that equation is,

$$u(t) = u_I \exp(\lambda t)$$

(8.50)

For  $\lambda < 0$ , then as  $t$  increases, the state  $u(t)$  decreases in magnitude. This is known as an exponentially decaying solution. And vice-versa, for  $\lambda > 0$ , the state  $u(t)$  increases in magnitude as  $t$  increases. This is known as an exponentially growing solution. An example of these solutions is shown for  $\lambda = -1$  and  $\lambda = 1$  with  $u(0) = 1$  in Figure 8.11.

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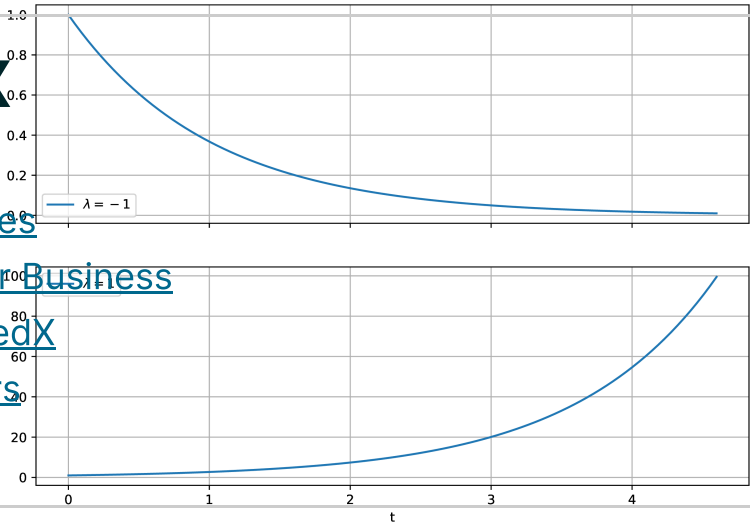
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Figure 8.11: Example of exponentially decaying ( $\lambda = -1$ ) and growing ( $\lambda = 1$ ) solutions with  $u(0) = 1$

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