Today

- Comment on pre-lecture problems
- Finish up with integrating factors
- The structure of solutions
- Separable equations

Pre-lecture assignment comments

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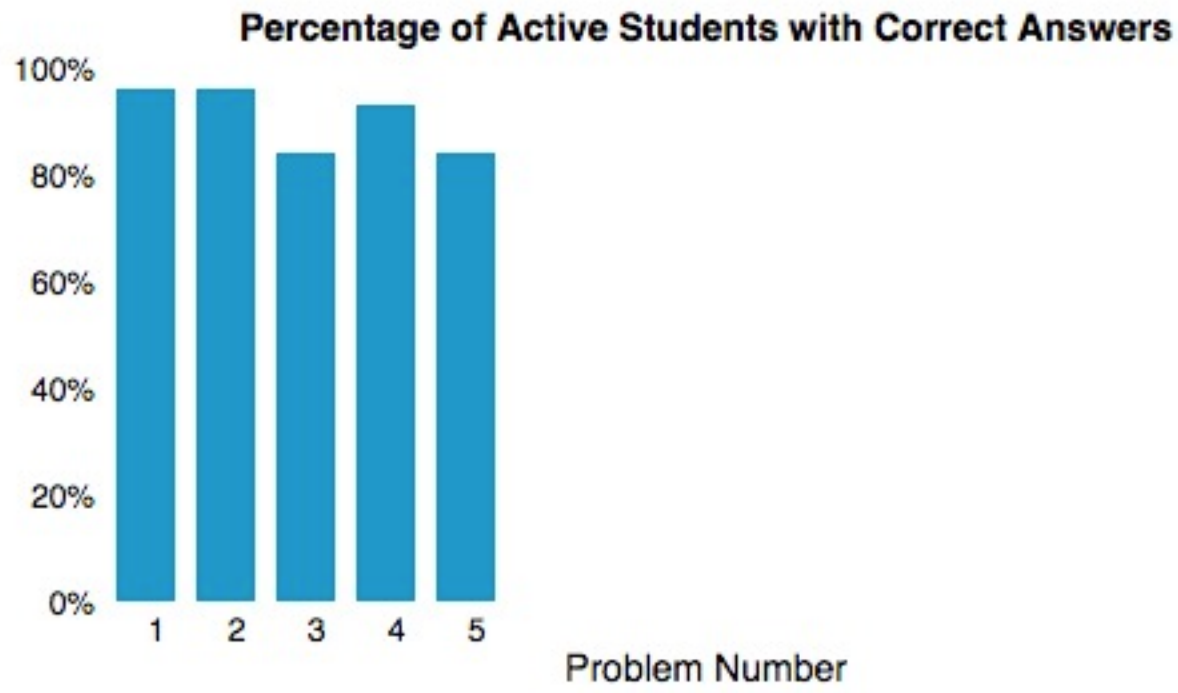

Pre-lecture assignment comments

Consider the initial value problem

$$\frac{dy}{dt} - 5y = 4e^{2t}, \quad y(0) = A.$$

a. Find the solution.

$y =$ ______

b. For what values of A does the above solution tend to ∞, 0 or $-\infty$ as $t \to \infty$?

As $t \to \infty$,

$y \to \infty$ if $A \in$ ______

$y \to 0$ if $A \in$ ______

$y \to -\infty$ if $A \in$ ______

Pre-lecture assignment comments

Solve the differential equation $\frac{dy}{dx} = \frac{x}{9y}$.

a. Find the equation of the solution through the point $(x, y) = (-3, 1)$.

help (equations)

b. Find the equation of the solution through the point $(x, y) = (0, -3)$.

help (equations)

Method of integrating factors (Section 2.1)

$$\frac{d}{dt}\left(t^2 y(t)\right) =$$

(A) $2t\dfrac{dy}{dt}$

(B) $t^2\dfrac{dy}{dt}$

(C) $2ty$

(D) $t^2\dfrac{dy}{dt} + 2ty$

(E) Don’t know.

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Method of integrating factors (Section 2.1)

- Given that $\frac{d}{dt}\left(t^2 y(t)\right) = \ t^2\frac{dy}{dt} + 2ty$

- if you're given the equation $t^2\frac{dy}{dt} + 2ty = 0$

- you can rewrite is as $\frac{d}{dt}\left(t^2 y(t)\right) = 0$

- so the solution is $t^2 y(t) = C$ or equivalently $y(t) = \frac{C}{t^2}$.

arbitrary constant that appeared at an integration step

Method of integrating factors (Section 2.1)

- Solve the equation $t^2 \frac{dy}{dt} + 2ty(t) = \sin(t)$ (not brute force checking).

(A) $y(t) = -\cos(t) + C$

(B) $y(t) = \frac{C - \cos(t)}{t^2}$

(C) $y(t) = \sin(t) + C$

(D) $y(t) = -\frac{1}{t^2} \cos(t)$

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(A) $y(t) = -\cos(t) + C$

(B) $y(t) = \frac{C - \cos(t)}{t^2}$ ← general solution (although that's not obvious)

(C) $y(t) = \sin(t) + C$

(D) $y(t) = -\frac{1}{t^2}\cos(t)$ ← a particular solution

(E) Don't know.

Initial conditions (IC) and initial value problems (IVP)

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(A) $y(t) = -\dfrac{C + \cos(\pi)}{\pi^2}$

(B) $y(t) = -\dfrac{1 - \cos(t)}{t^2}$

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- An Initial Value Problem (IVP) is a ODE together with an IC.

Method of integrating factors (Section 2.1)

- What's the integrating factor?

$$t\frac{dy}{dt} + 2y(t) = 1$$

$$t^2\frac{dy}{dt} + 4ty(t) = \frac{1}{t}$$

$$\frac{dy}{dt} + y(t) = 0$$

$$\frac{dy}{dt} + \cos(t)y(t) = 0$$

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$$t\frac{dy}{dt} + 2y(t) = 1 \qquad \rightarrow f(t) = t$$

$$t^2 \, dy \quad + 4ty(t) = 1 \qquad \rightarrow f(t) = t^2$$

In class, I referred to these f(t) functions as the integrating factors. This is incorrect. They are functions that you can multiply the ORIGINAL equation by to get a perfect "product rule" form. But an integrating factor is defined as the function that you would multiply the "normalized" equation by to get the "product rule" form. By "normalized", I mean after dividing through by the coefficient on dy/dt. So for the first example above, the integrating factor would be $I(t)=t^2$ and the equation you multiply it through is $dy/dt + 2/t \, y = 1/t$.

$$\frac{dy}{dt} + g'(t)y(t) = 0 \qquad \rightarrow f(t) = e^{g(t)}$$

Method of integrating factors (Section 2.1)

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$$\frac{dy}{dt} + p(t)y = q(t)$$

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$$y(t) = e^{-\int p(t)dt}\int e^{\int p(t)dt}q(t)dt + Ce^{-\int p(t)dt}$$

The structure of solutions

- When the equation is of the form (called homogeneous)

$$\frac{dy}{dt} + p(t)y = 0$$

- the solution is

$$y(t) = C\mu(t)^{-1}$$

- where

$$\mu(t) = \exp\left(\int p(t)dt\right)$$

- is the integrating factor.

The structure of solutions

- When the equation is of the form (called nonhomogeneous)

$$\frac{dy}{dt} + p(t)y = q(t)$$

- the solution is $y(t) = k(t) + C\mu(t)^{-1}$
- where k(t) involves no arbitrary constants.
- Think about this expression as $y(t) = y_p(t) + y_h(t)$
- Directly analogous to solving the vector equations $A\overline{x} = 0$ and $A\overline{x} = \overline{b}$.

Examples

- Find the general solution to

$$t\frac{dy}{dt} + 2y = 4t^2$$

- and plot a few of the integral curves.

- Integral curve - the graph of a solution to an ODE.

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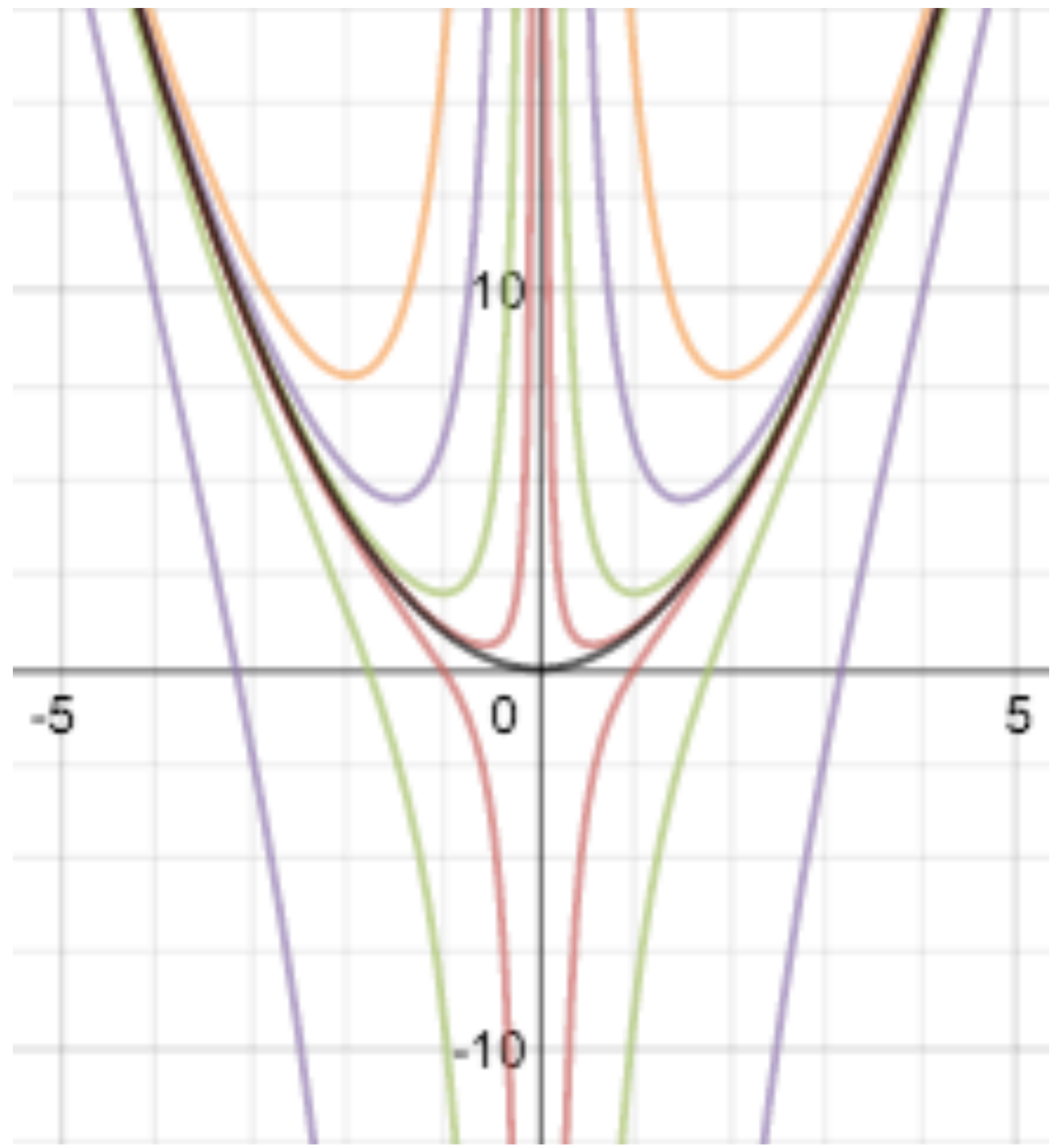

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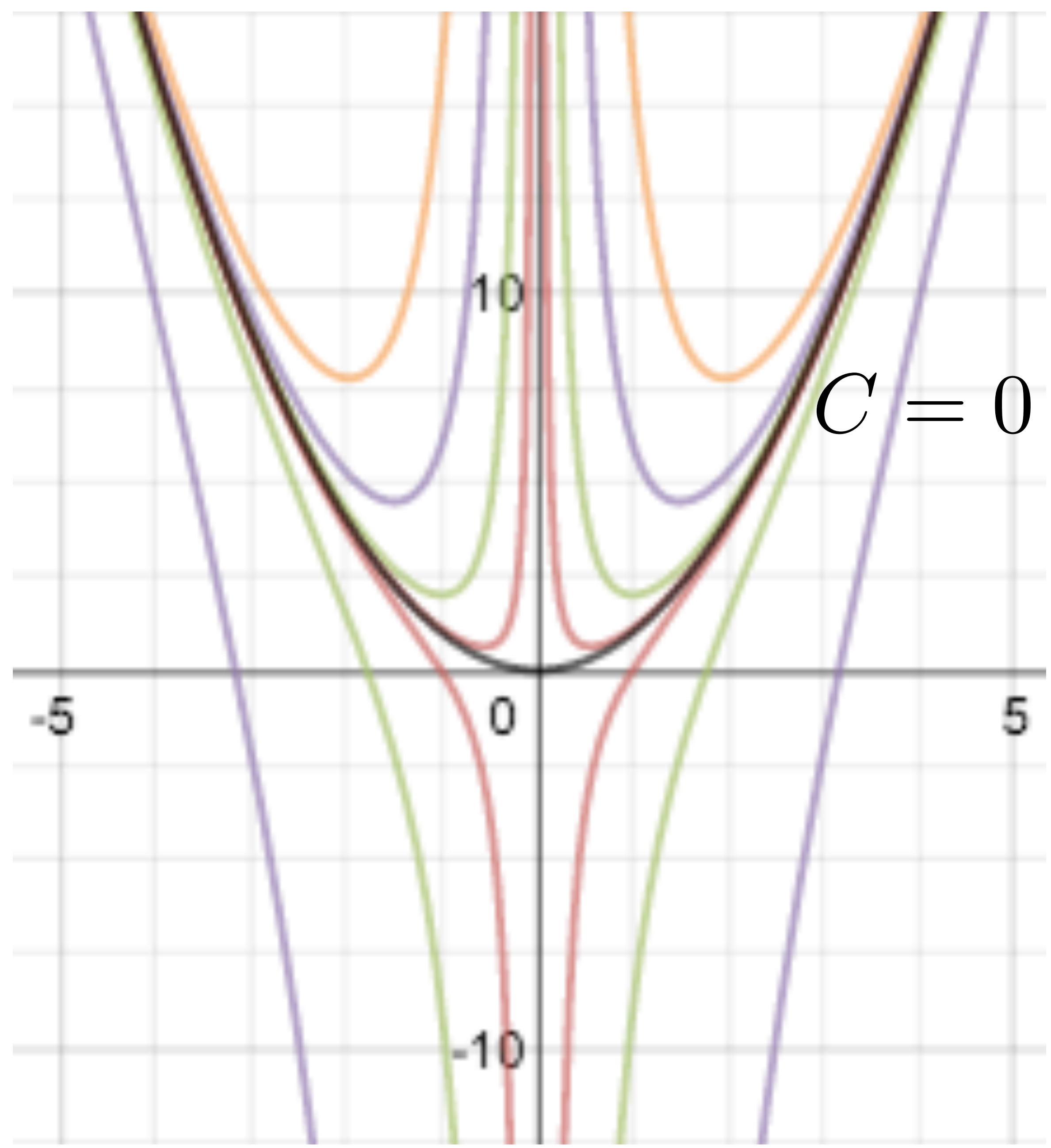

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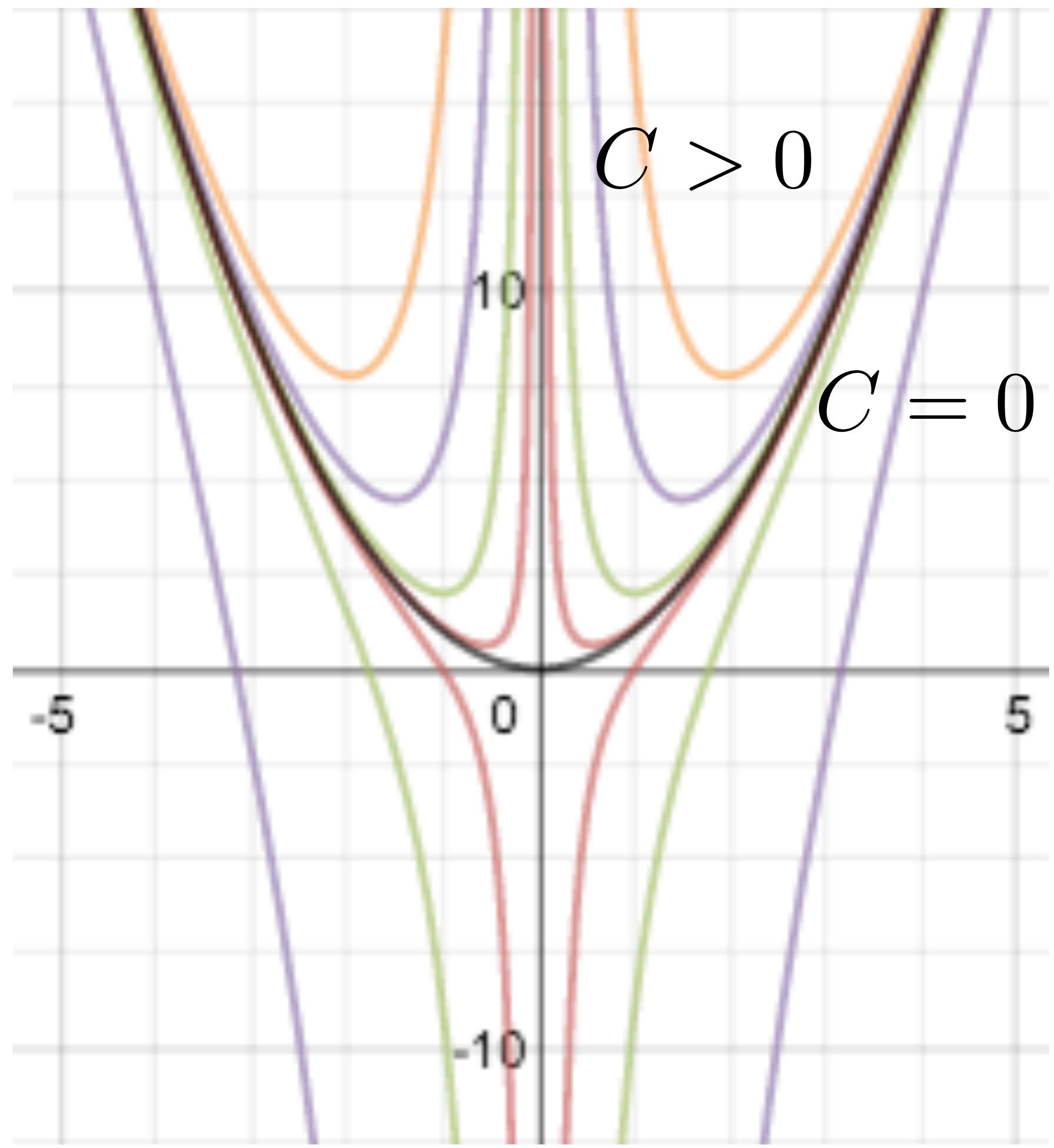

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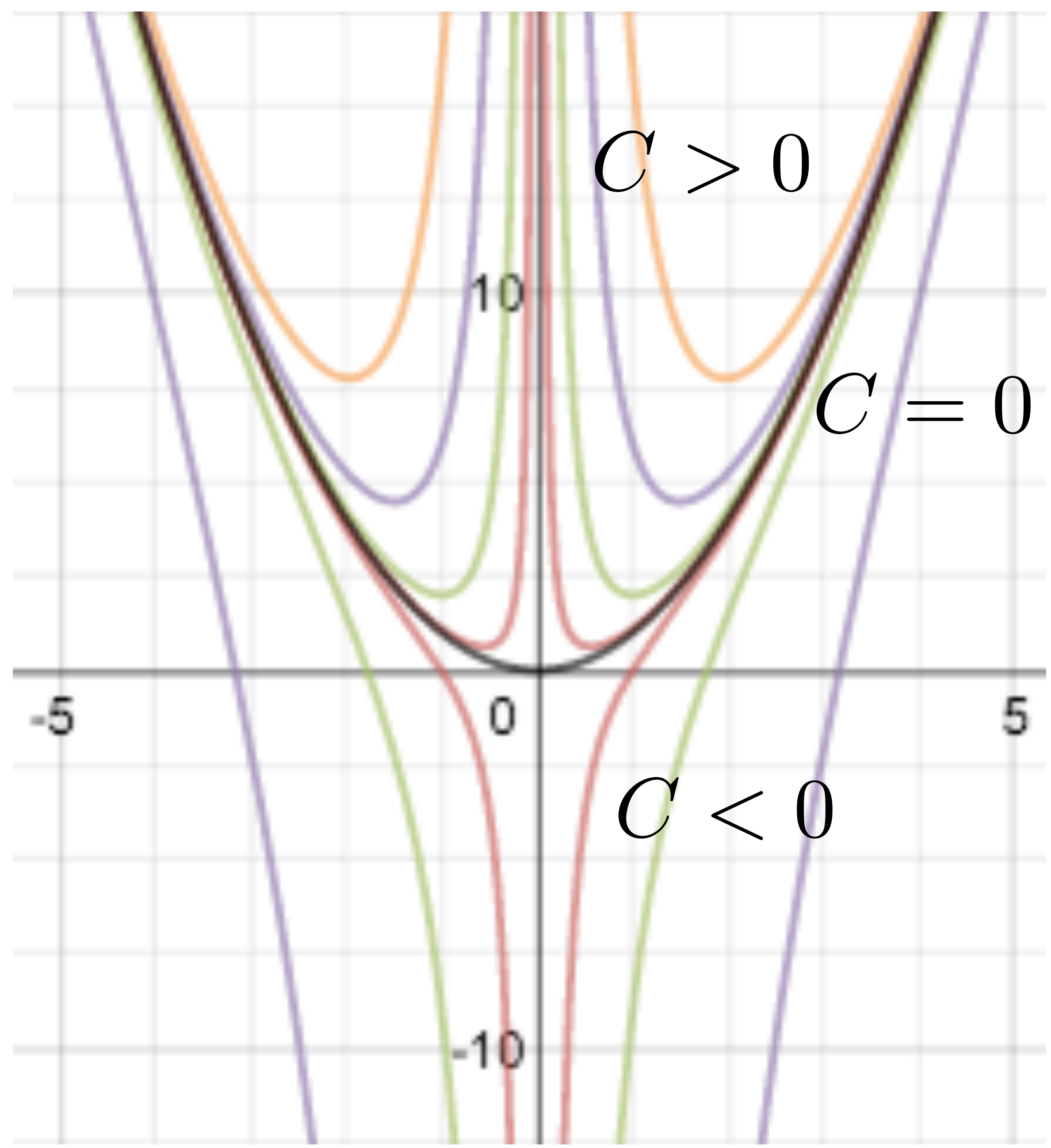

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$$\frac{dy}{dt} - 3y = -4e^{-t}$$

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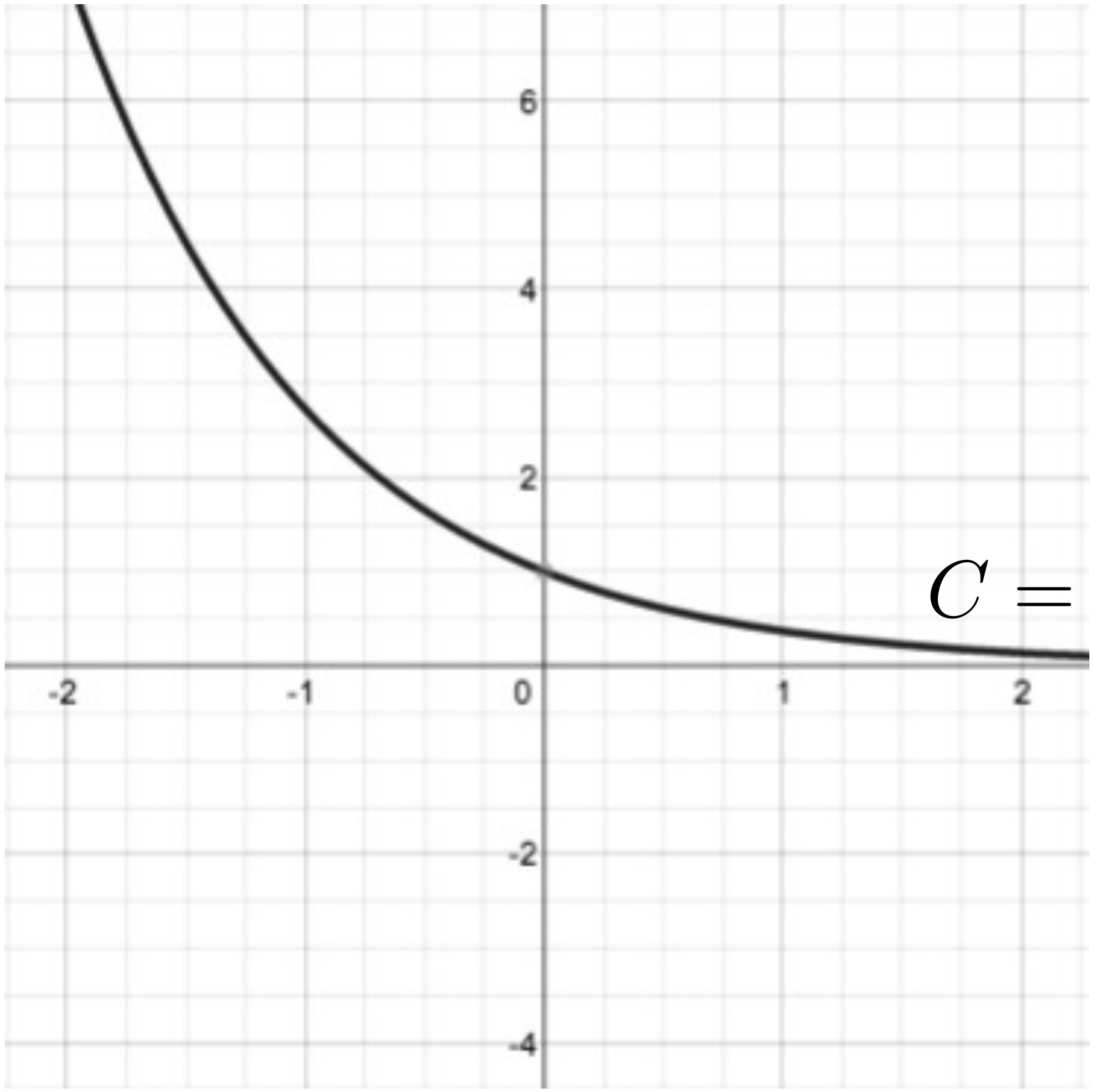

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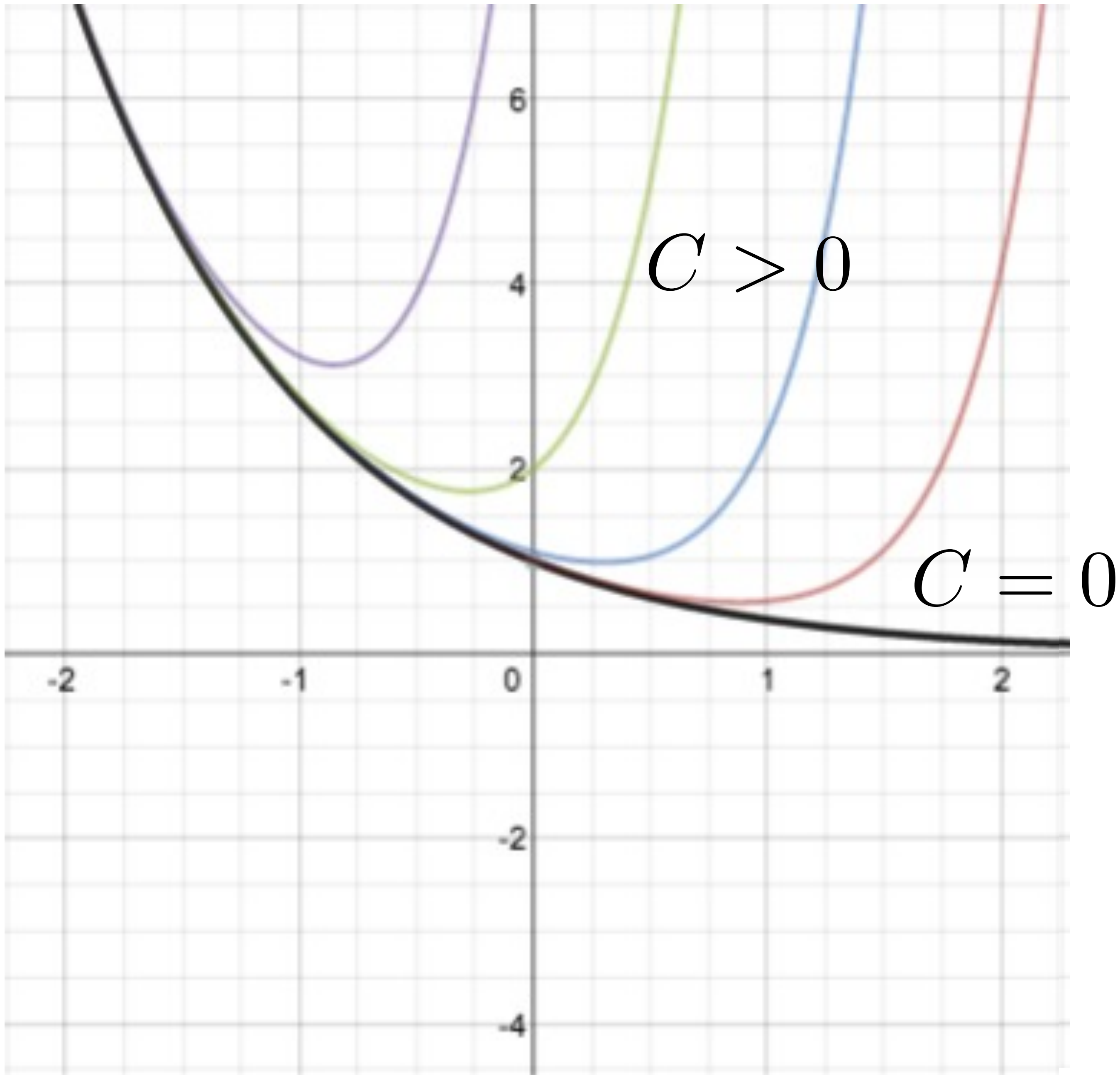

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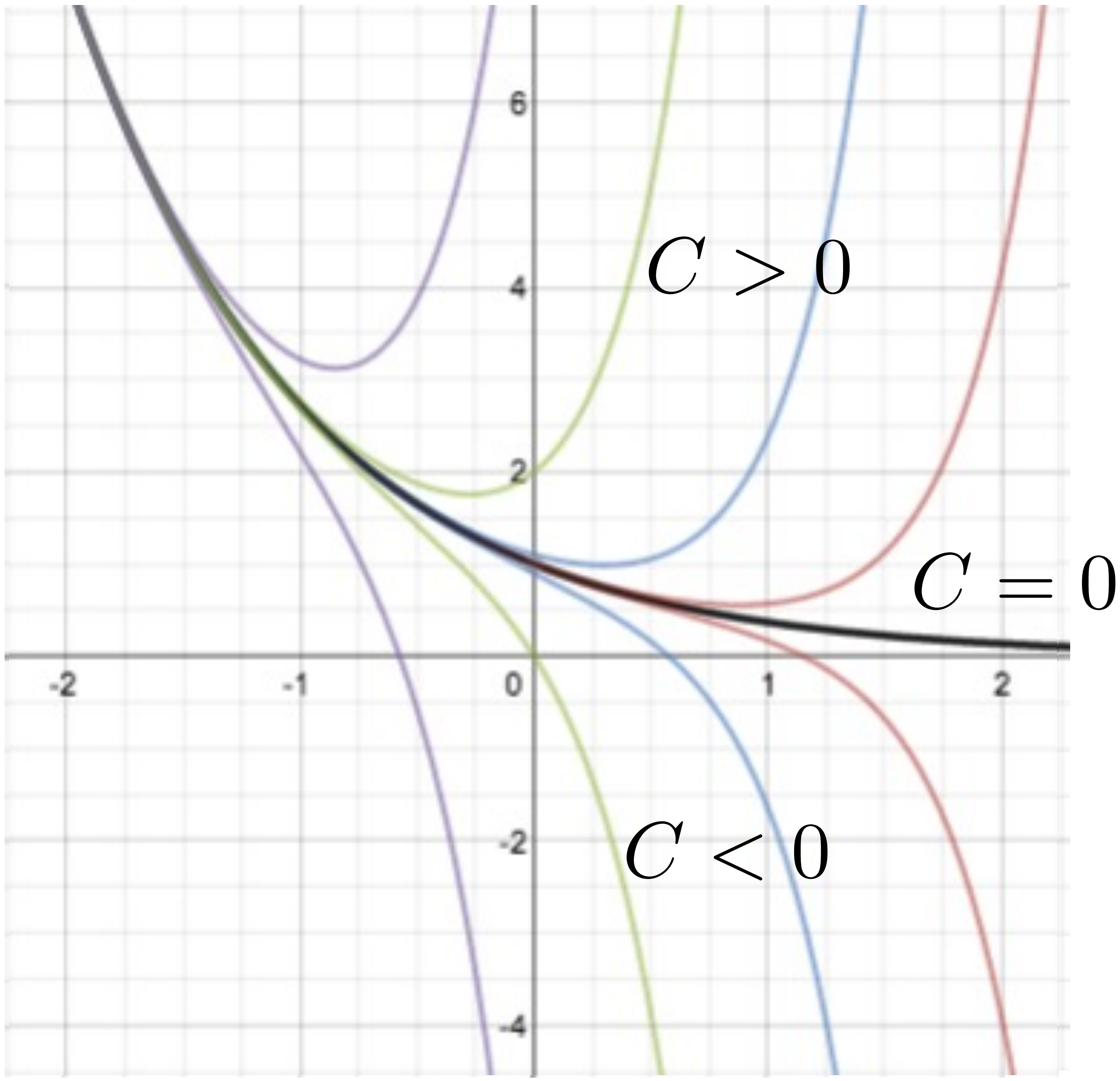

Limits at infinity

- If y(t) is a particular solution to

$$\frac{dy}{dt} - 3y = -4e^{-t}$$

- depending on C, how many different results are possible for

$$\lim_{t\to\infty} y(t) \text{ ?}$$

(A) 0

(B) 1

(C) 2

(D) 3

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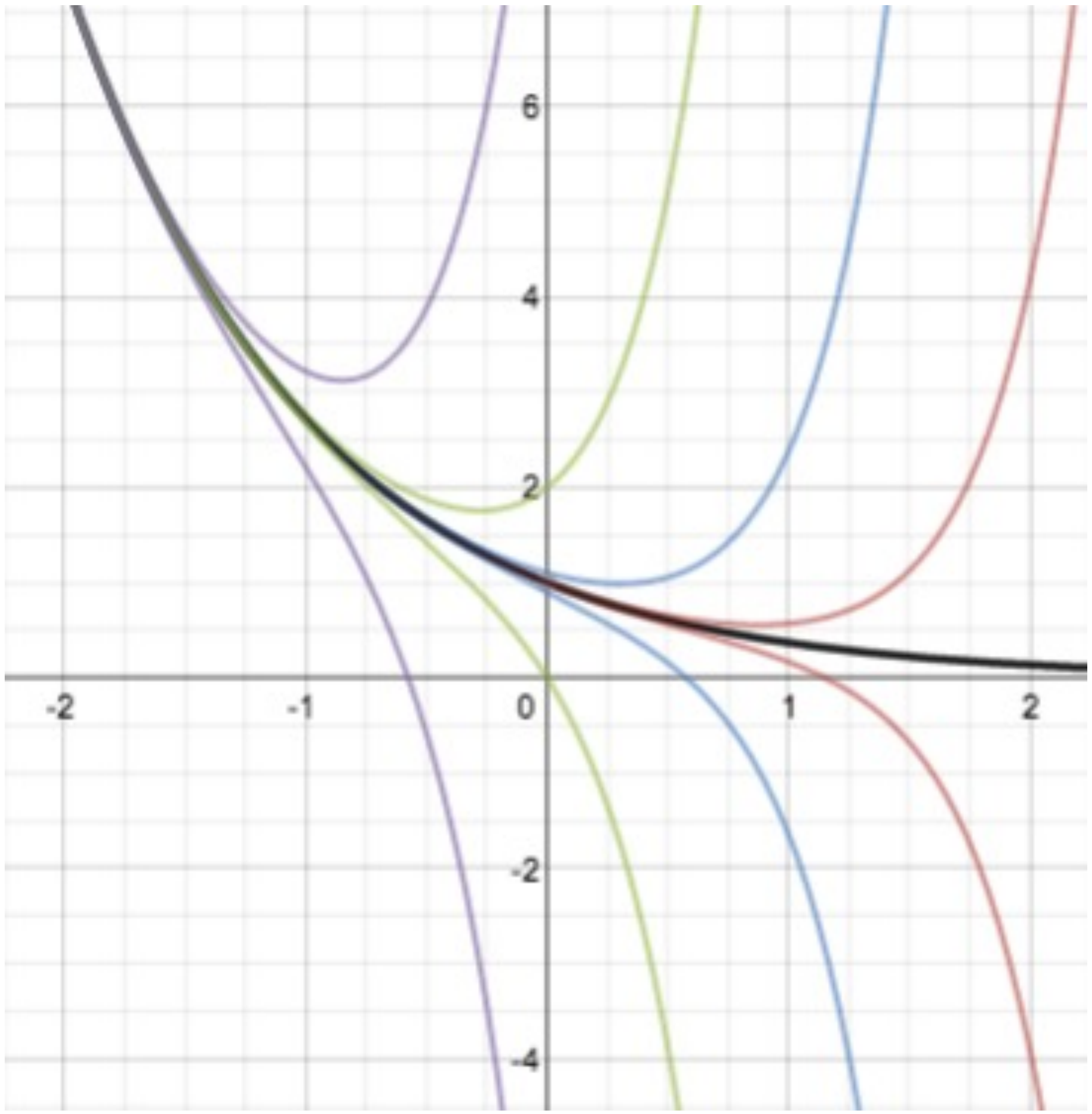

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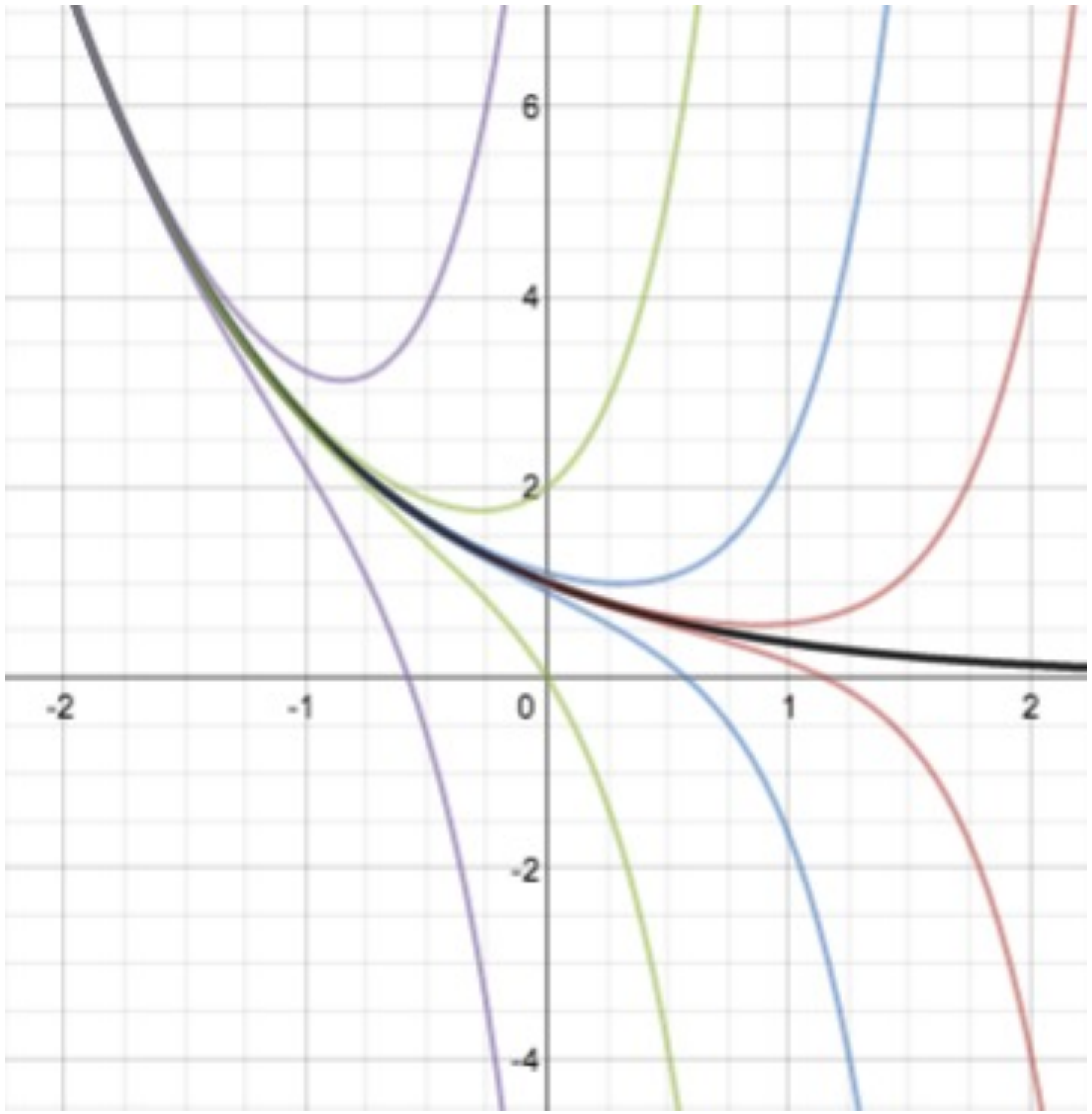

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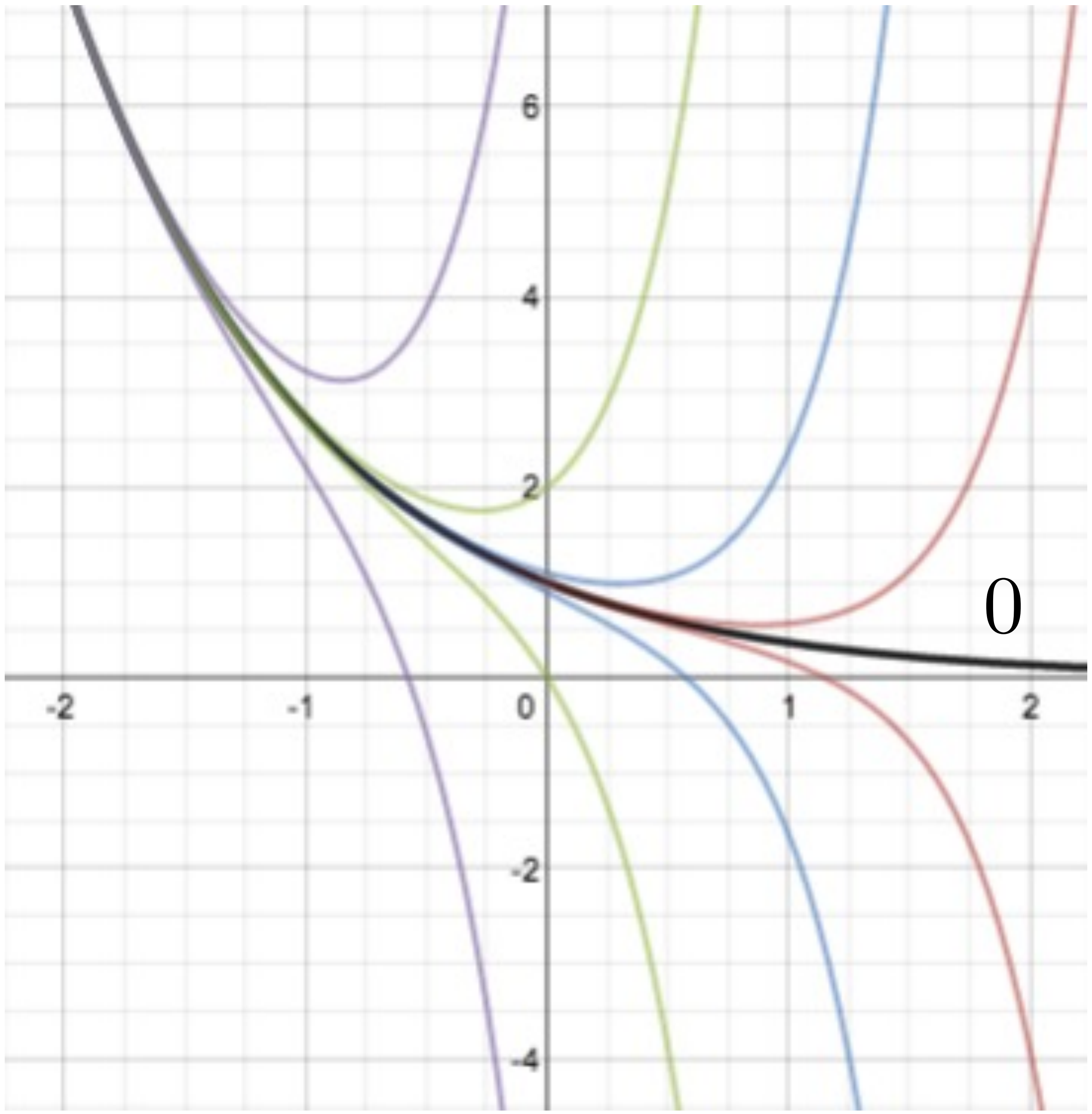

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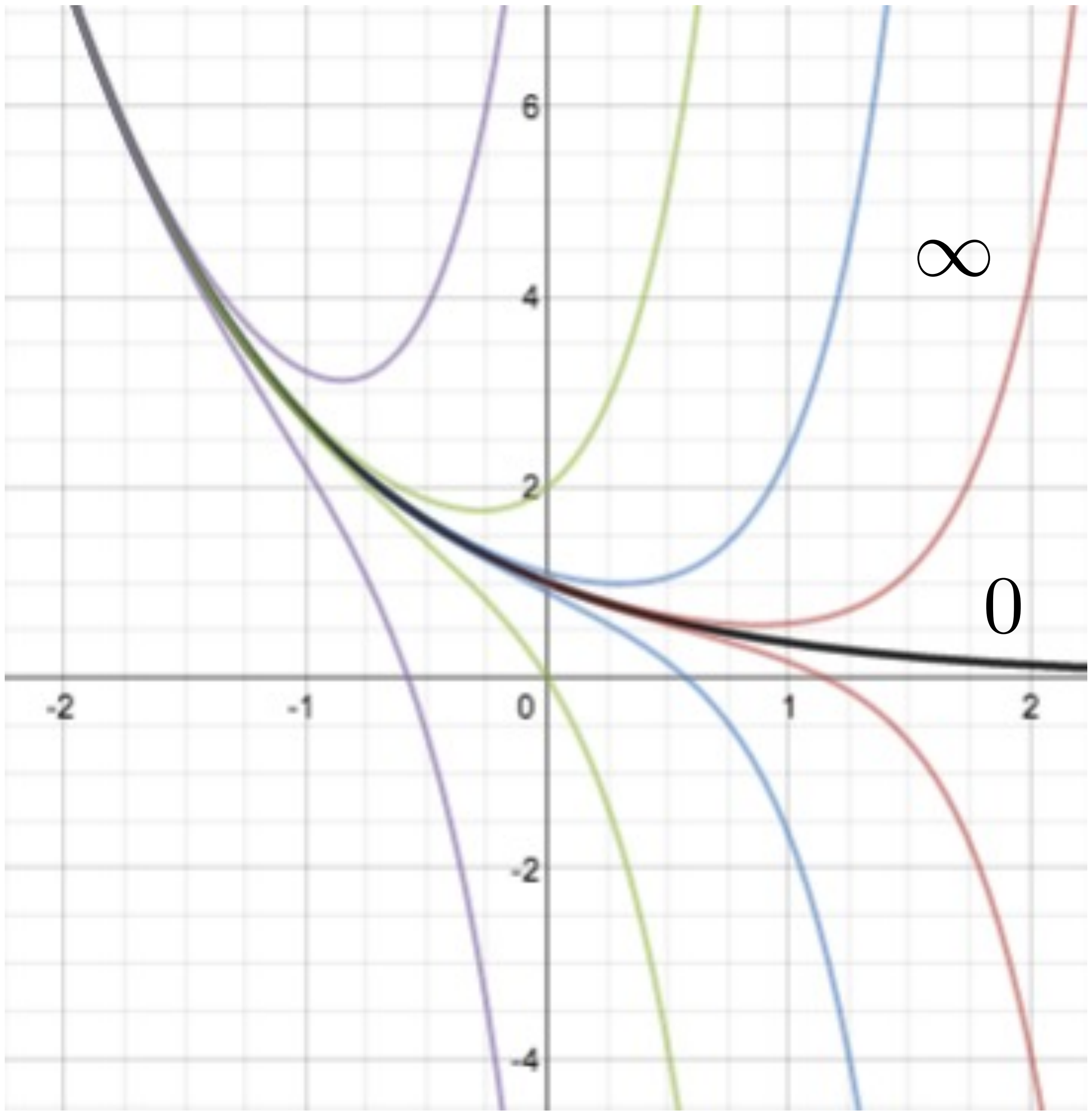

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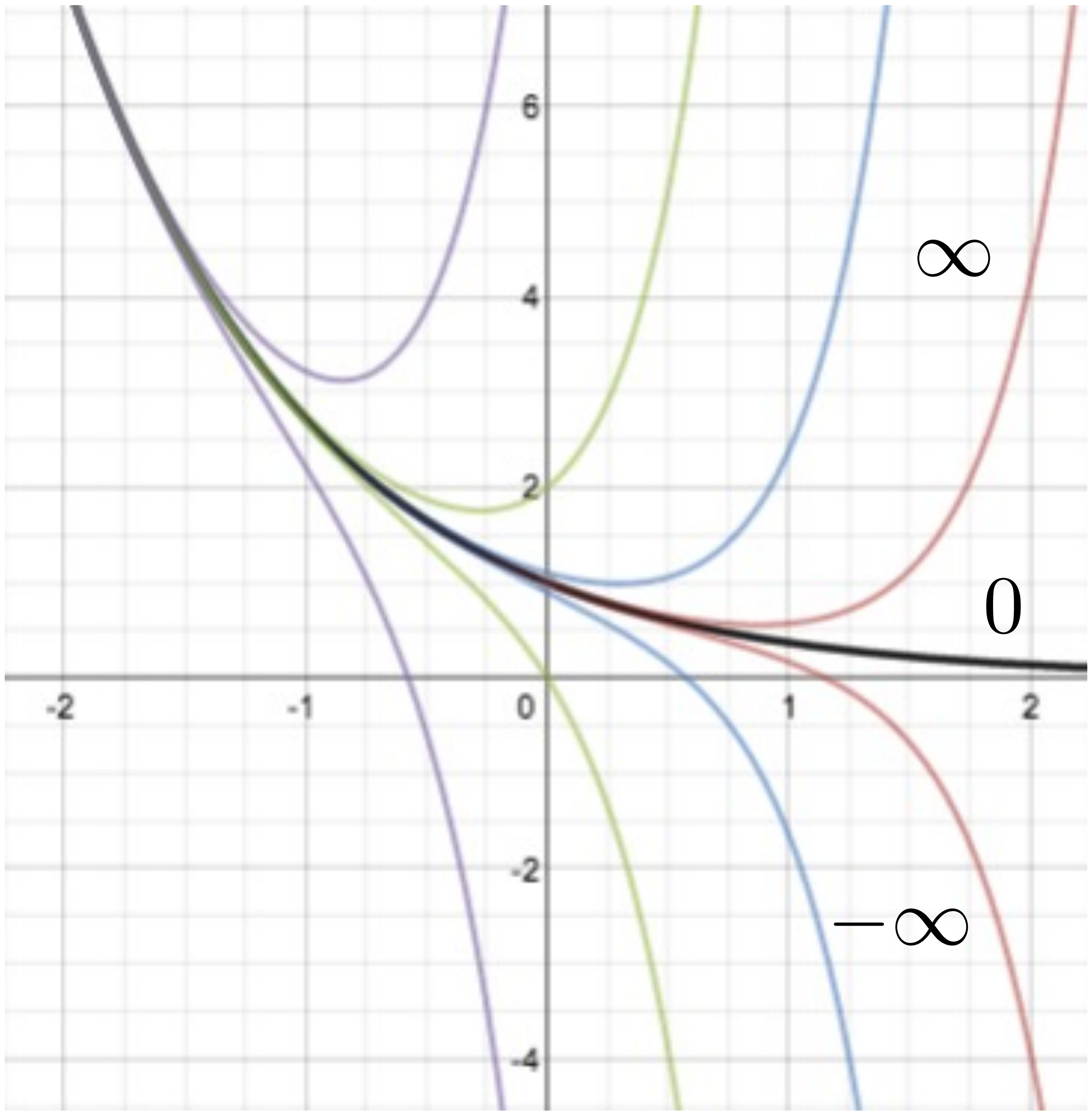

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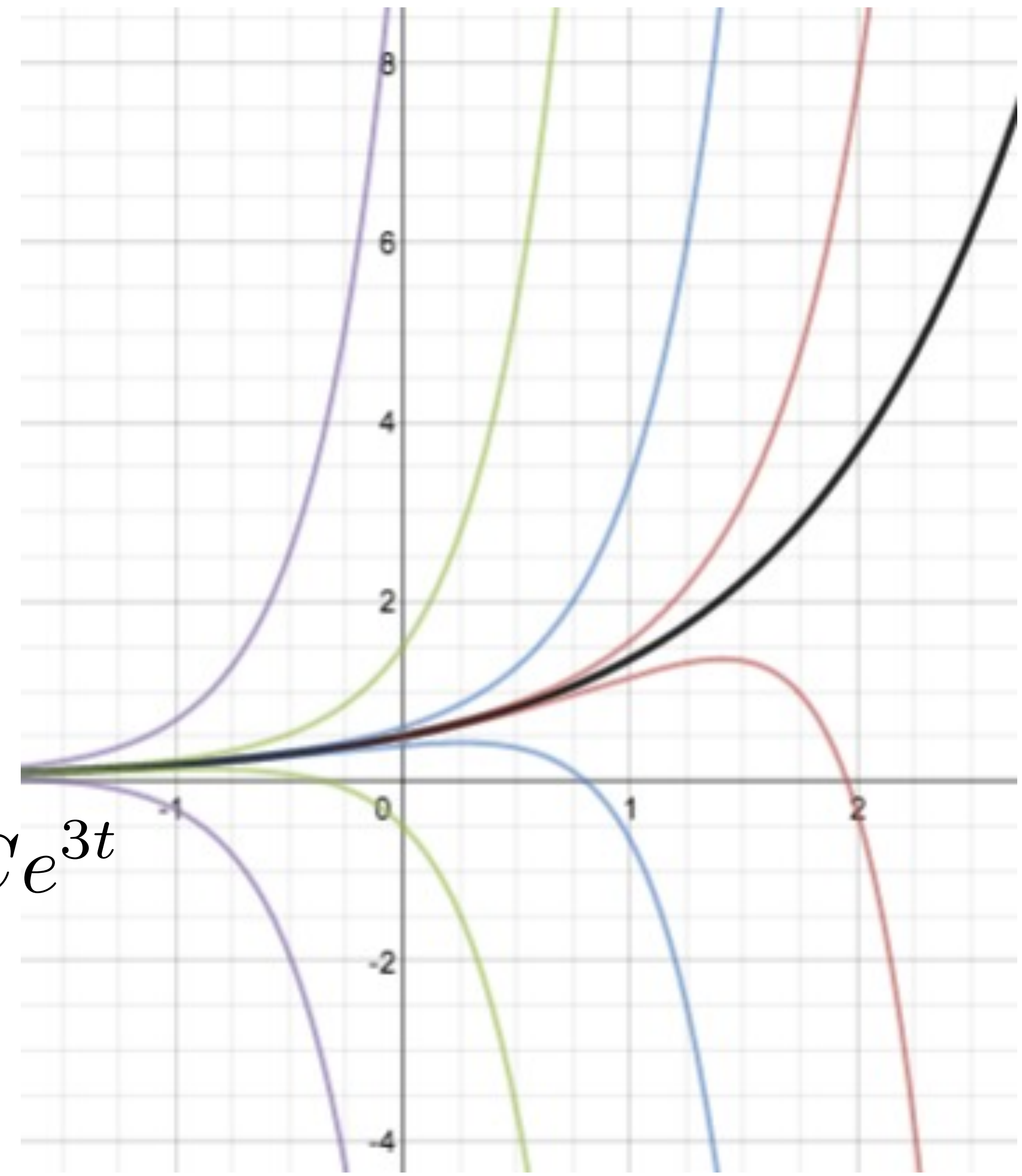

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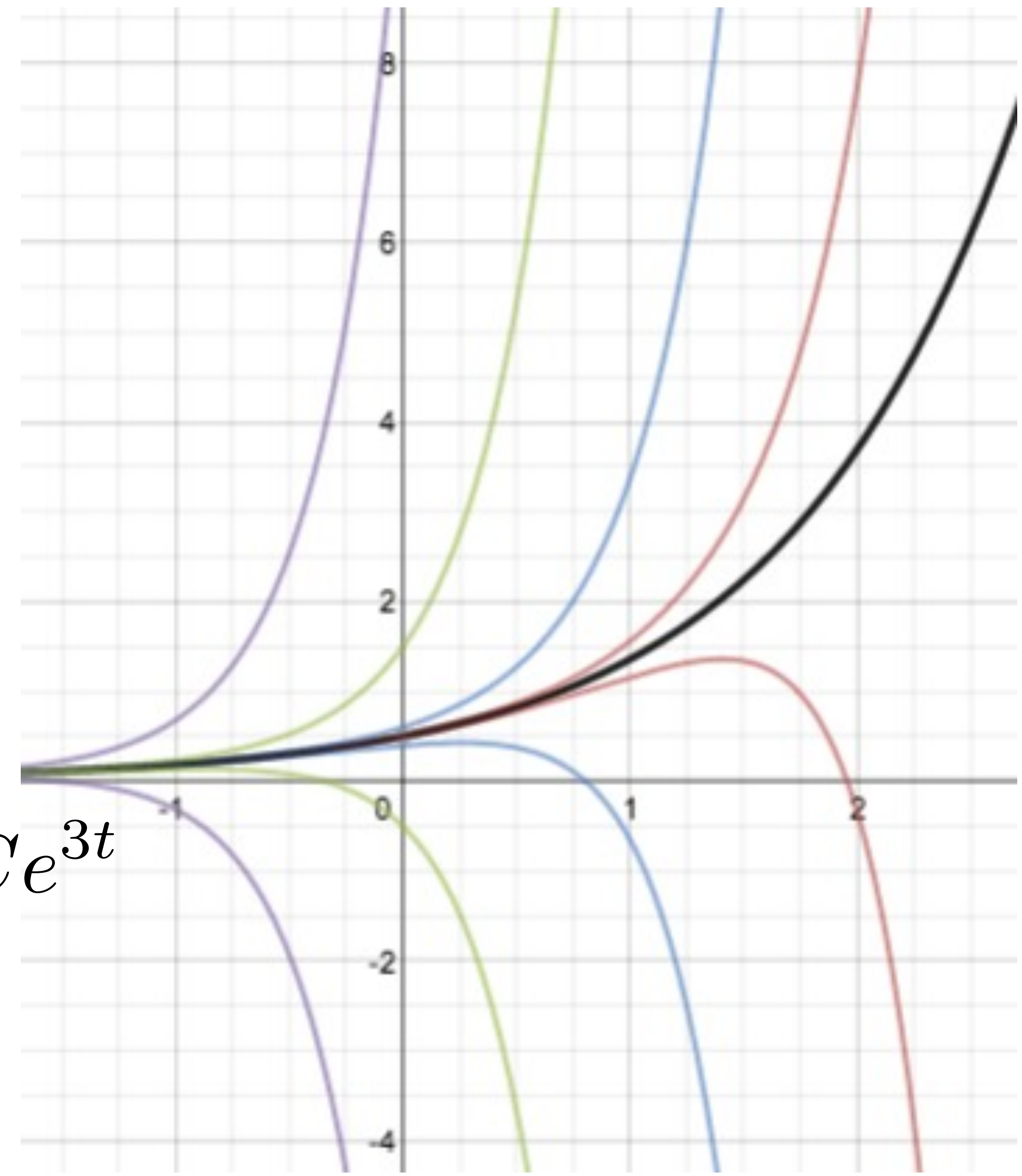

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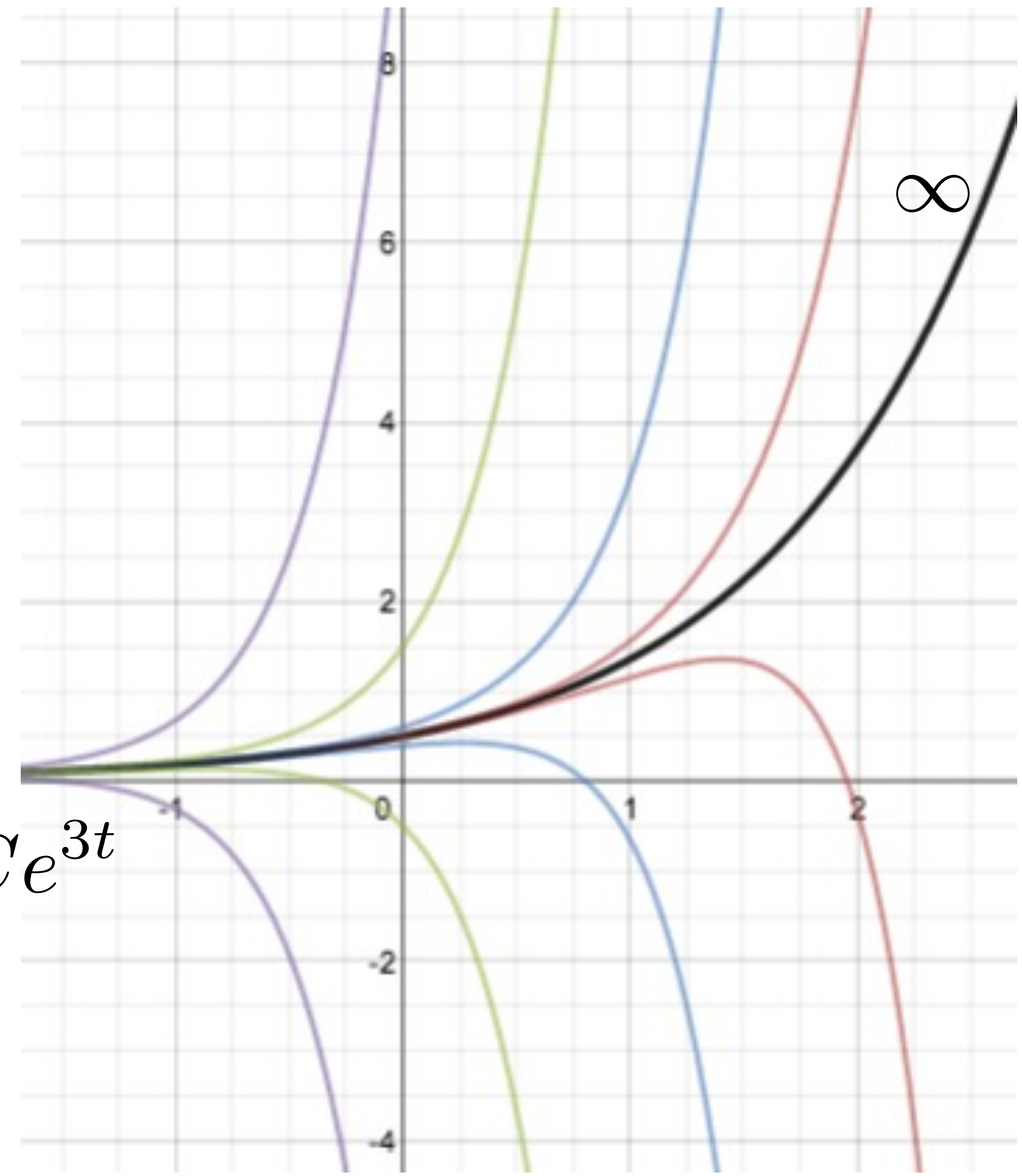

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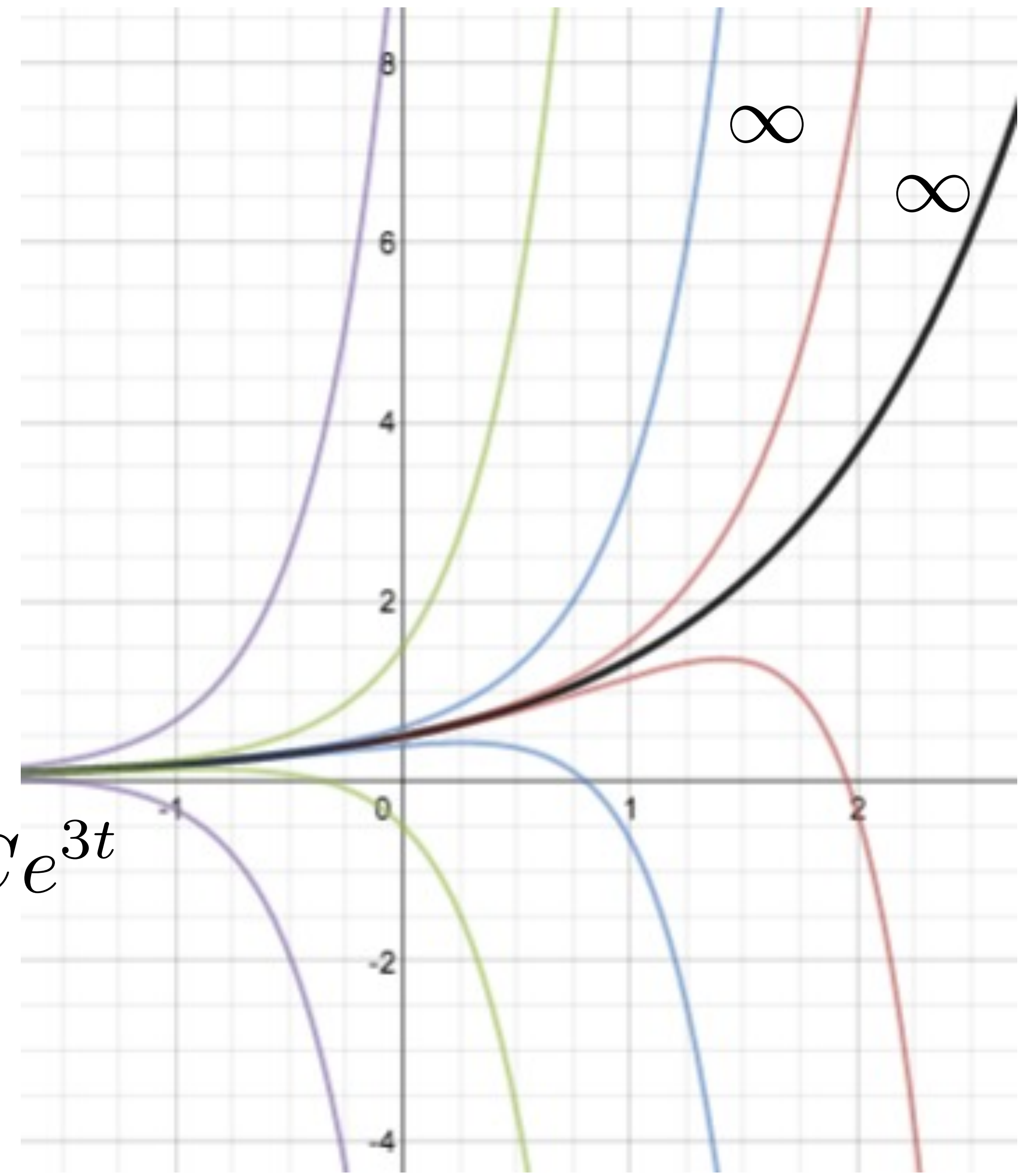

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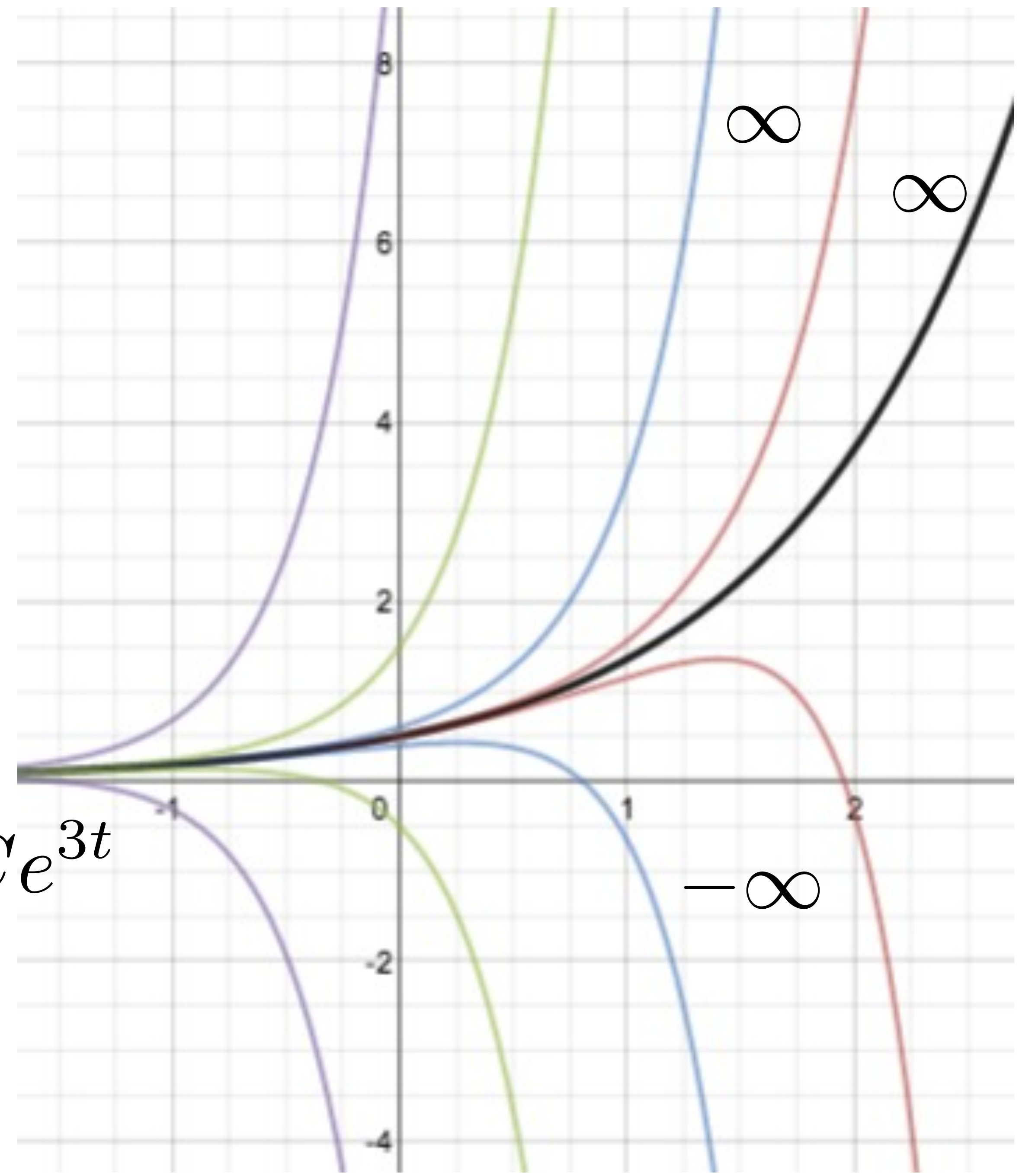
(E) Don’t know.

$$y(t) = \frac{1}{2}e^t + Ce^{3t}$$



Separable equations (Section 2.2)

- What is $\frac{d}{dt}e^y$?

(A) e^y

(B) $e^y \frac{dy}{dt}$

(C) ye^{y-1}

(D) $ye^{y-1}\frac{dy}{dt}$

(E) Don't know.

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- Solve $\frac{dy}{dt} = e^{-y}$.

(A) $y(t) = 0$

(B) $y(t) = \ln(t) + C$

(C) $y(t) = \ln(t + C)$

(D) $y(t) = e^{t+C}$

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Separable equations (Section 2.2)

- What is $\dfrac{d}{dt}e^{y}$?

Hint: rewrite as $e^{y}\dfrac{dy}{dt} = 1$.

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