Math 3B: Lecture 6

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Introduction

Last time

- Examples of maxima/minima problems

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- Maximising functions with constaints

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- Examples of maxima/minima problems
- Maximising functions with constaints
- Competing economies

Differential equations (motivation)

A differential equation is an equation that involves derivatives of an unknown function.

$$\frac{\mathrm{d}^2 y}{\mathrm{d}x^2} = y - 3y^2$$

or

$$x^2 y'' + xy' + x^2 y = 0$$

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$$x^2 y'' + xy' + x^2 y = 0$$

The challenge is to find all the functions y = f(x) (or even just one) that satisfy a given equation.

Newton's second law (motivation)

The original differential equation!

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$$a = h''(t)$$

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The original differential equation!

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If $h(t)$ measures the height of an object (maybe an apple?) above the earth then

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The force due to gravity is roughly $-10m$ Newtons, so

$$-10m = mh''(t)$$

Population growth (motivation)

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If $P(t)$ is the population at time t:

$$\frac{\mathrm{d}P}{\mathrm{d}t} = rP(t)$$

Some more examples of differential equations

$$\frac{\mathrm{d}y}{\mathrm{d}x} = f(x)$$

$$\frac{\mathrm{d}y}{\mathrm{d}x} = y(1 - y)$$

$$y'' = \sqrt{a^2 - (y')^2}$$

$$\frac{\mathrm{d}y}{\mathrm{d}t} = k(A - y)^2$$

Antiderivatives

We will be concentrating on solving differential equations of the form

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A solution $y = F(x)$ is called an antiderivative of $f(x)$.

Example 1

Question

What is the antiderivative of $f(x) = 2x$?

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Solution

$$F(x) = x^2$$

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$$F(x) = x^2 + 8$$

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What is the antiderivative of $f(x) = 2x$?

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$$F(x) = x^2 + C$$

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Solution

$$F(x) = \frac{1}{2}e^{2x}$$

Example 4

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What is the antiderivative of $f(x) = \frac{1}{x}$ (for $x > 0$)?

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Solution

$$F(x) = \ln x$$

Example 5

Question

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Solution

Note that $f(x) = (1+x)^{-2}$. So

$$F(x) = \qquad \frac{1}{1+x}$$

Example 5

Question

What is the antiderivative of $f(x) = \frac{1}{(1+x)^2}$?

Solution

Note that $f(x) = (1+x)^{-2}$. So

$$F(x) = -\frac{1}{1+x}$$

Example 6

Question

What is the antiderivative of $f(x) = 2x\cos x^2$?

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What is the antiderivative of $f(x) = 2x \cos x^2$?

Solution

$$F(x) = \sin x^2$$

Example 7

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Solution

$$f(x) = x^{-\frac{1}{2}}$$

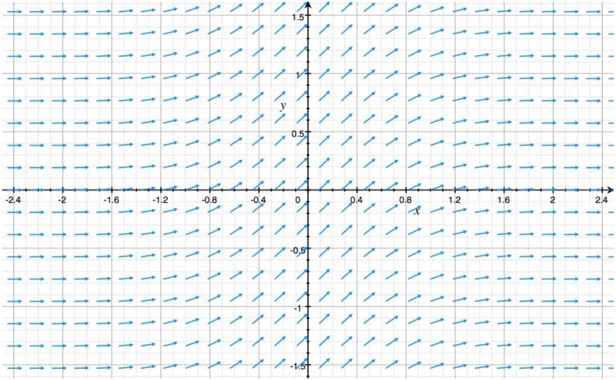
$$F(x) = 2x^{\frac{1}{2}}$$

Slope fields

In some cases it is impossible to find the antiderivative (without special functions). E.g.

$$f(x) = e^{-x^2}$$

But we can still (approximately) graph the antiderivative! First we draw the slope field



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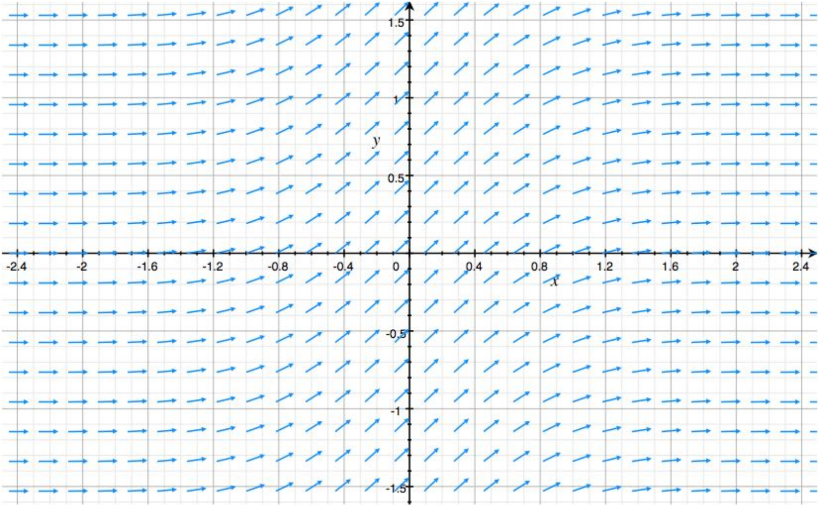
3. Answer given by differential equation above, slope is $f(x)$
4. Draw a small arrow with slope $f(x)$ and the point (x, y)
5. Do this for a grid of points on the xy-plane.

Example 1

$$f(x) = e^{-x^2}$$



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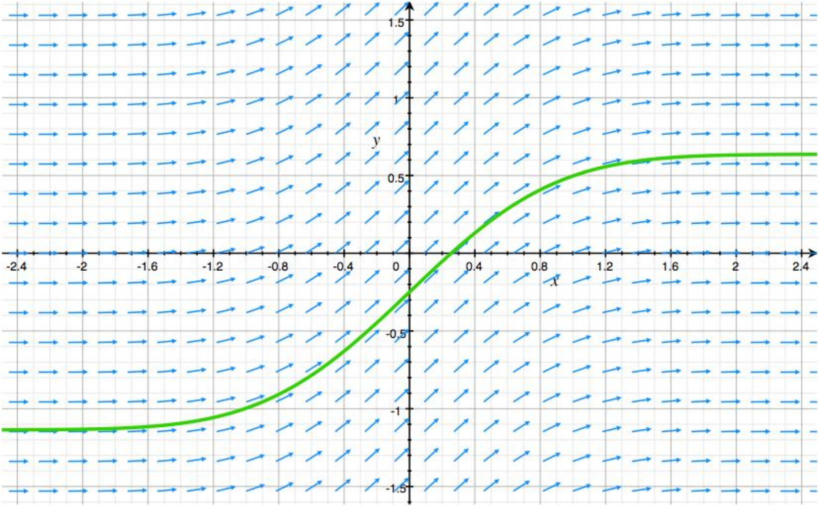
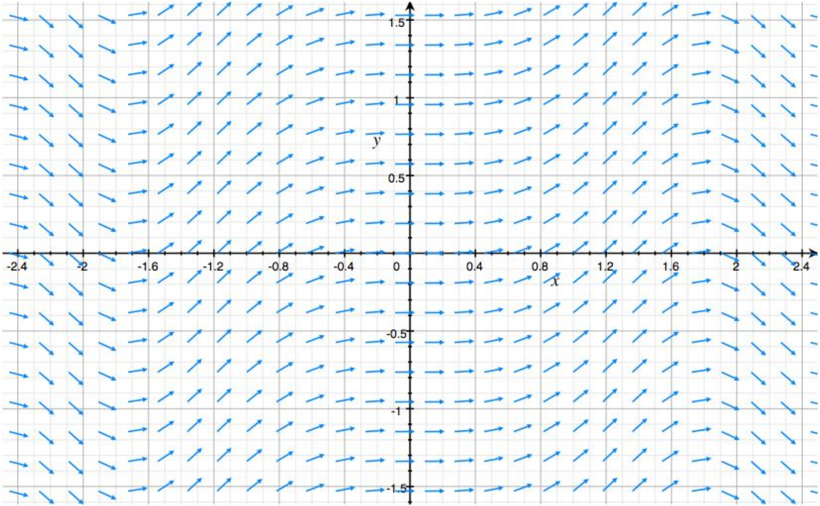


Example 2

$$f(x) = \sin(x^2)$$



Example 2

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