AP Calculus AB Take-Home Final

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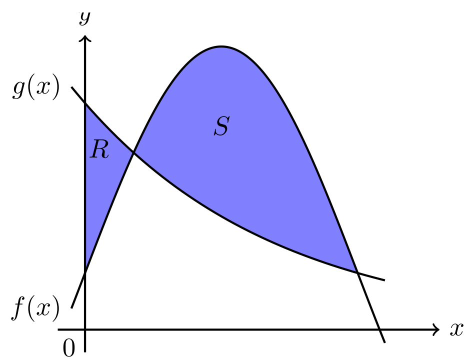
1



$$f(x) = \frac{1}{4} + \sin \pi x, \quad g(x) = 4^{-x}$$

Finding the area of R:

First, we find the first intersection of $f(x)$ and $g(x)$. We'll call the x value of the intersection k. We can then use a calculator approximate the integration of the difference between $g(x)$ and $f(x)$ from 0 until k to obtain the area R.

$$R = \int_0^k [g(x) - f(x)]dx \approx 0.064$$

Finding the area of S

Next, we can find the second intersection of $f(x)$ and $g(x)$ (which we will call j. We can then integrate similarly to get the area; Note that we reverse the order of $g(x)$ and $f(x)$ because $f(x)$ has a higher value of y.

$$S = \int_k^j [f(x) - g(x)]dx \approx 0.410$$

Revolving S:

To revolve S around the horizontal line $y = -1$, we have to adjust $f(x)$ and $g(x)$ by $+1$, and then shroud them in the circle area equation πr^2, finally integrating the resulting difference between k and j to obtain volume.

$$S_{\text{vol}} = \pi \int_k^j \left[(f(x)+1)^2 - (g(x)+1)^2 \right] dx \approx 4.56$$

Sorry there's no graphic for the revolve, it's *hard*.

2

$$f(0) = 2, \;\; f'(0) = -4, \;\; f''(0) = 3$$

2.1 Part A

$$g(x) = e^{ax} + f(x)$$

First, we need to know the derivatives of $g(x)$, so we evaluate them as such:

$$\frac{d}{dx} g(x) = g'(x) = ae^{ax} + f'(x)$$

$$\frac{d}{dx} g'(x) = g''(x) = e^{ax}a^2 + f''(x)$$

Next, we can evaluate the derivatives of $g(x)$ in line with the pre-defined derivatives of $f(x)$ like so:

$$g'(0) = ae^{a(0)} + f'(0) = ae^0 - 4 = a - 4$$

$$g''(0) = e^{a(0)}a^2 + f''(0) = a^2e^0 + 3 = a^2 + 3$$

2.2 Part B

$$h(x) = \cos(kx) f(x)$$

First, we derive $h(x)$:

$$\frac{d}{dx} h(x) = h'(x) = -k \sin(kx) f(x) + \cos(kx) f'(x)$$

This gave us the slope ($h'(0)$), but we still need to find the y value of $h(0)$ and the slope at $h'(0)$

$$y = h(0) = \cos[k(0)] f(0) = \cos(0)(2) = (1)(2) = 2$$

$$m = h'(0) = -k \sin(k0) f(x) + \cos(k0) f'(0) = 0 + \cos(1)(-4) = -4$$

We can finally find the tangent equation:

$$y - 2 = -4(x - 0)$$

3

$$R(t) = 2 + 5\sin\frac{4\pi t}{25}, \quad S(t) = \frac{15t}{1+3t}$$
$$A(t) = \text{Total rate} = S(t) - R(t)$$

3.1 Part A

We can integrate the loss function to obtain the amount removed over 6 hours like so:

$$\int_0^6 R(t) \approx 6.723 \;\; yd^3$$

3.2 Part B

We can simply integrate the total rate over time and add it to the initial condition:

$$Y(t) = \int_0^t A(x)\,dx + 2500$$

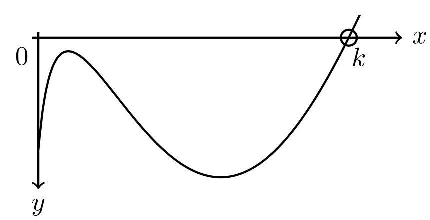
3.3 Part C

We evaluate $A(t)$ at the time point, because that's the total rate:

$$A(4.0) \approx 1.908 \;\; yd^3$$

3.4 Part D

It's intuitive to look at the graph of $A(t)$:



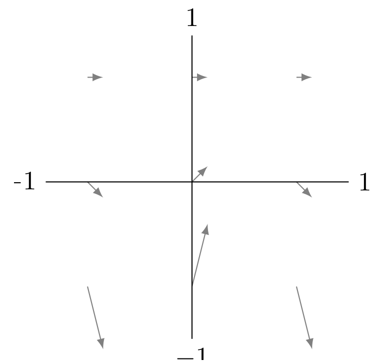
At point k, $A(t)$ intersects the x axis. Up until then, the amount of total sand has been decreasing (because $A(t)$ is below the x xis), and at k it has been decreasing the longest. We can no integrate $A(t)$ from 0 to k to obtain the total amount of sand at that point:

$$Y(k) \approx 2492.37 \;\; yd^3$$

4

4.1 Part A

$$\frac{dy}{dx} = (y-1)^2 \cos(\pi x)$$



4.2 Part B

Despite being able to simply look at the graph, we can infer that the slope from the differential equation will be zero at $y = 1$ because the entire equation is multiplied by $(y-1)^{-2}$.

4.3 Part C

$$f(1) = 0; \;\; y = 0, \;\; x = 1$$

$$\frac{dy}{dx} = (y-1)^2 \cos(\pi x)$$

$$\frac{dy}{(y-1)^2} = \cos(\pi x)\, dx$$

$$(y-1)^{-2}\, dy = \cos(\pi x)\, dx$$

$$\int (y-1)^{-2}\, dy = \int \cos(\pi x)\, dx$$

$$\frac{1}{1-0} = \frac{\sin(\pi 1)}{\pi} + C_3$$

$$1 = 0 + C_3$$

$$1 = C_3$$

$$\frac{1}{1-y} = \frac{\sin(\pi x)}{\pi} + 1$$

5

5.1 Part A

$$\int_{-1}^{10} (\sqrt{x-1})\, dx \approx$$

5.2 Part B

$$\pi \int_{-1}^{10} (x-1)\, dx \approx$$

5.3 Part C

$$y = \sqrt{x-1}$$
$$y^2 = x - 1$$
$$y^2 + 1 = x$$
$$\pi \int_{0}^{3} (y^2+1)^2\, dy \approx$$