

### Math 106: Review for Exam I

1. **Find the following.** [Substitution tip: usually let  $u =$  a function that's “inside” another function, especially if  $du$  (possibly off by a multiplying constant) is also present in the integrand.]

(a) Let  $u = \sqrt{x}$ , so  $du = \frac{dx}{2\sqrt{x}}$  and  $2 du = \frac{dx}{\sqrt{x}}$ .

$$\begin{aligned} \int_1^4 \frac{e^{\sqrt{x}}}{\sqrt{x}} dx &= \int_{x=1}^{x=4} e^u \cdot 2 du && \text{If you prefer to switch the limits, use } u = 1 \text{ to } u = 2. \\ &= 2e^u \Big|_{x=1}^{x=4} \\ &= 2e^{\sqrt{x}} \Big|_1^4 \\ &= 2e^2 - 2e \ (\approx 9.342) \end{aligned}$$

(b) Let  $u = \cos(5x)$ , so  $du = -5 \sin(5x)$  and  $-\frac{du}{5} = \sin(5x)$ .

This time, we'll change the limits:

$$x = \pi \Rightarrow u = \cos(5 \cdot \pi) = -1 \text{ and } x = 2\pi \Rightarrow u = \cos(5 \cdot 2\pi) = 1$$

$$\begin{aligned} \int_{\pi}^{2\pi} \cos^7(5x) \sin(5x) dx &= \int_{-1}^1 u^7 \cdot \frac{-du}{5} \\ &= -\frac{1}{5} \int_{-1}^1 u^7 du \\ &= -\frac{1}{5} \frac{u^8}{8} \Big|_{-1}^1 \\ &= -\frac{1}{40} \left[ \frac{1^8}{8} - \frac{(-1)^8}{8} \right] \\ &= 0 \end{aligned}$$

(c) Use  $u = x^3$ , so  $du = 3x^2 dx$  and  $\frac{du}{3} = x^2 dx$ .

$$\begin{aligned} \int \frac{7x^2}{1+x^6} dx &= 7 \int \frac{\frac{du}{3}}{1+u^2} \\ &= \frac{7}{3} \arctan u + C \\ &= \frac{7}{3} \arctan(x^3) + C \end{aligned}$$

(d) Use  $u = 10 - x$ , so  $du = -dx$  and  $dx = -du$ .

We'll change the limits:

$$x = 6 \Rightarrow u = 10 - x = 4 \text{ and } x = 10 \Rightarrow u = 10 - 10 = 0$$

$$\begin{aligned} \int_6^{10} x\sqrt{10-x} dx &= \int_4^0 (10-u)\sqrt{u}(-du) && \text{Since } u = 10 - x, \text{ we know } x = 10 - u. \\ &= \int_4^0 (u-10)\sqrt{u} du \\ &= \int_4^0 (u^{3/2} - 10u^{1/2}) du \\ &= \left[ \frac{2}{5}u^{5/2} - \frac{20}{3}u^{3/2} \right]_4^0 \\ &= (0-0) - \left( \frac{2}{5}4^{5/2} - \frac{20}{3}4^{3/2} \right) \\ &= \frac{608}{15} = 40.5\bar{3} \end{aligned}$$

2. If  $f(x)$  is decreasing and concave up, put the following quantities in ascending order.

$$L_{100}, R_{100}, T_{100}, M_{100}, \int_a^b f(x) dx \qquad R_{100} < M_{100} < \int_a^b f(x) dx < T_{100} < L_{100}$$

What can you say with certainty about where  $S_{200}$  would fit into your list above?

It would be somewhere between  $M_{100}$  and  $T_{100}$  but we don't know how it compares to  $\int_a^b f(x) dx$ .

3. Suppose  $f(t)$  is the rate of change (in animals per month) of a population  $P(t)$ .

(a) What does  $\int_4^{12} f(t) dt$  represent in this problem?

It represents the total (or net) change in the number of animals during the time period  $[4, 12]$ .

(b) Find the best possible left, right, midpoint, trapezoidal, and Simpson's approximations to  $\int_4^{12} f(t) dt$  given the data in the table below.

$t$	4	6	8	10	12
$f(t)$	15	11	8	4	3

$$L_4 = (15 + 11 + 8 + 4)(2) = 76 \qquad R_4 = (11 + 8 + 4 + 3)(2) = 52 \qquad T_4 = \frac{L_4 + R_4}{2} = 64$$

We cannot compute  $M_4$  because it requires the values of  $f$  at  $x = 5, 7, 9,$  and  $11$ . Instead, we do  $M_2$ .

$$M_2 = (11 + 4)(4) = 60 \text{ Now, to find } S_4, \text{ we need } T_2 = \frac{L_2 + R_2}{2} = \frac{(15 + 8)(4) + (8 + 3)(4)}{2} = 68.$$

$$S_4 = \frac{2M_2 + T_2}{3} = \frac{2(60) + 68}{3} = \frac{188}{3} = 62.\bar{6}$$

4. Find bounds for each of the following errors if  $I = \int_2^7 \ln x dx$ .

$$(a) |I - L_{100}| \leq \frac{K_1(b-a)^2}{2n} = \frac{\frac{1}{2}(7-2)^2}{2(100)} = \frac{1}{16}$$

$$K_1 = \max \text{ of } |f'(x)| \text{ on } [2, 7] = \max \text{ of } \frac{1}{x} \text{ on } [2, 7] = \frac{1}{2} \text{ (occurs at } x = 2)$$

$$(b) |I - T_{100}| \leq \frac{K_2(b-a)^3}{12n^2} = \frac{\frac{1}{4}(7-2)^3}{12(100)^2} = \frac{1}{3840}$$

$$K_2 = \max \text{ of } |f''(x)| \text{ on } [2, 7] = \max \text{ of } \frac{1}{x^2} \text{ on } [2, 7] = \frac{1}{4} \text{ (occurs at } x = 2)$$

$$(c) |I - M_{100}| \leq \frac{K_2(b-a)^3}{24n^2} = \frac{\frac{1}{4}(7-2)^3}{24(100)^2} = \frac{1}{7680}$$

$$K_2 = \text{same as in previous part}$$

5. Use Euler's method with three steps on the differential equation  $\frac{dy}{dt} = y - t$  to estimate  $y(2.5)$  if  $y(1) = 0$ .

$t$	$y$	$\frac{dy}{dt} \cdot \Delta t = \Delta y$
1	0	$(-1)(0.5) = -0.5$
1.5	-0.5	$(-2)(0.5) = -1$
2	-1.5	$(-3.5)(0.5) = -1.75$
2.5	-3.25	

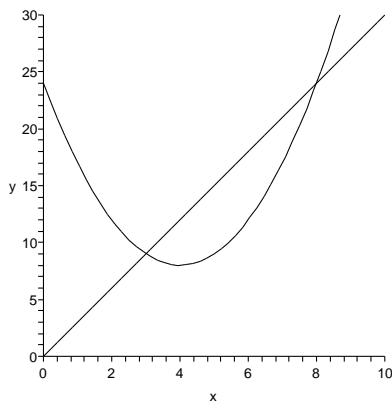
So,  $y(2.5) \approx -3.25$  (or  $-13/4$ ).

6. Write integrals equal to

- (a) the arc length of  $y = x^2$  on the interval  $[1, 5]$

$$\text{arc length of } y = f(x) \text{ on } [a, b] = \int_a^b \sqrt{1 + [f'(x)]^2} dx = \int_1^5 \sqrt{1 + (2x)^2} dx (\approx 24.395)$$

- (b) the area bounded by  $y = x^2 - 8x + 24$  and  $y = 3x$



First, find where the curves intersect.

$$x^2 - 8x + 24 = 3x$$

$$x^2 - 11x + 24 = 0$$

$$(x - 3)(x - 8) = 0$$

$$\Rightarrow x = 3, x = 8$$

Between  $x = 3$  and  $x = 8$ ,  $y = 3x$  is above  $y = x^2 - 8x + 24$ . (Plug in  $x = 5$  or graph to check.)

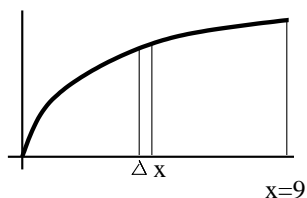
So, the area between them is

$$\int_3^8 [3x - (x^2 - 8x + 24)] dx.$$

[This equals  $125/6$ .]

7. Consider the region bounded by  $y = \sqrt{x}$ ,  $y = 0$ , and  $x = 9$ . Write an integral equal to the volume generated if this region is rotated about

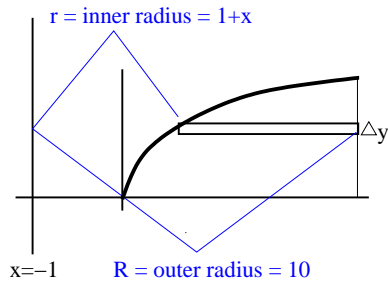
- (a) the  $x$ -axis



$$\begin{aligned}
 \text{volume of slice} &\approx \pi r^2 \Delta x \\
 &= \pi y^2 \Delta x \\
 &= \pi(\sqrt{x})^2 \Delta x \\
 &= \pi x \Delta x
 \end{aligned}$$

$$\text{total volume} = \pi \int_0^9 x \, dx$$

(b) the line  $x = -1$



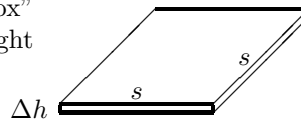
$$\begin{aligned}
 \text{volume of slice} &\approx \pi R^2 \Delta y - \pi r^2 \Delta y \\
 &= \pi(10^2) \Delta y - \pi(1+x)^2 \Delta y \\
 &= \pi[100 - (1+y^2)^2] \Delta y
 \end{aligned}$$

$$\text{total volume} = \pi \int_0^3 [100 - (1+y^2)^2] \, dy$$

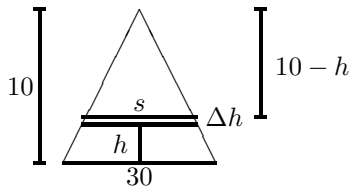
8. A pyramid has a square base 30 feet to a side and a height of 10 feet. Write integrals equal to

(a) the volume of the pyramid

We slice horizontally, so each slice is a “box” with a square top and bottom and a height (thickness) of  $\Delta h$ , as shown to the right.



The picture shown below is a vertical cross-section through the center of the pyramid.



$$\text{Similar triangles: } \frac{10}{30} = \frac{10-h}{s} \Rightarrow s = 3(10-h).$$

$$\text{volume of slice} \approx s^2 \Delta h \approx [3(10-h)]^2 \Delta h$$

$$\text{total volume} = \int_0^{10} [3(10-h)]^2 \, dh$$

(b) the work done in pumping all the fluid to a point 5 feet above the pyramid if the pyramid is filled to a height of 8 feet with water (62.4 pounds per cubic foot)

We use the same sketch as in the previous part.

$$\text{volume of slice} \approx s^2 \Delta h \approx [3(10-h)]^2 \Delta h$$

$$\text{weight of slice} \approx 62.4 [3(10-h)]^2 \Delta h$$

$$\text{work to lift slice} \approx 62.4 [3(10-h)]^2 \Delta h (15-h)$$

$$\text{total volume} = 62.4 \int_0^8 [3(10-h)]^2 (15-h) \, dh$$

From above.

Weight=(density)(volume).

Work=(force)(distance); here, force=weight.