

1. (25 points) Use the limit definition of the definite integral and the sum formulas to compute

$$\int_1^3 \left[1 - x + \frac{x^2}{2} \right] dx.$$

Check your answer by using the Fundamental Theorem of Calculus.

Solution: The limit definition of the definite integral of a function $f(x)$ over the interval $[a, b]$ is

$$\int_a^b f(x) dx = \lim_{n \rightarrow \infty} \sum_{i=1}^n f(x_i^*) \Delta x$$

where $\Delta x = \frac{b-a}{n}$, $x_i = a + i\Delta x$ and x_i^* is some number between x_{i-1} and x_i for $i = 1, 2, \dots, n$. In our situation, our function is $f(x) = 1 - x + \frac{x^2}{2}$ and our interval is $[1, 3]$, so $\Delta x = \frac{3-1}{n} = \frac{2}{n}$ and $x_i = 1 + i\frac{2}{n} = 1 + \frac{2i}{n}$. Since f is continuous on $[1, 3]$, the integral exists, so we may freely take $x_i^* = x_i$ for $i = 1, 2, \dots, n$ and we have

$$\begin{aligned} \int_1^3 \left[1 - x + \frac{x^2}{2} \right] dx &= \lim_{n \rightarrow \infty} \sum_{i=1}^n \left[1 - x_i + \frac{x_i^2}{2} \right] \Delta x \\ &= \lim_{n \rightarrow \infty} \sum_{i=1}^n \left[1 - \left(1 + \frac{2i}{n} \right) + \frac{1}{2} \left(1 + \frac{2i}{n} \right)^2 \right] \frac{2}{n} \\ &= \lim_{n \rightarrow \infty} \frac{2}{n} \sum_{i=1}^n \left[-\frac{2i}{n} + \frac{1}{2} \left(1 + 2\frac{2i}{n} + \frac{4i^2}{n^2} \right) \right] \\ &= \lim_{n \rightarrow \infty} \frac{2}{n} \sum_{i=1}^n \left[\frac{1}{2} + \frac{2i^2}{n^2} \right] \\ &= \lim_{n \rightarrow \infty} \frac{2}{n} \left[\frac{1}{2} \left(\sum_{i=1}^n 1 \right) + \frac{2}{n^2} \left(\sum_{i=1}^n i^2 \right) \right] \\ &= \lim_{n \rightarrow \infty} \left[\frac{1}{n} (n) + \frac{4}{n^3} \left(\frac{n(n+1)(2n+1)}{6} \right) \right] \\ &= \lim_{n \rightarrow \infty} \left[1 + \frac{4}{6} \left(\frac{n+1}{n} \right) \left(\frac{2n+1}{n} \right) \right] \\ &= 1 + \frac{2}{3} \left(\frac{1}{1} \right) \left(\frac{2}{1} \right) = \frac{7}{3}. \end{aligned}$$

Now, using the **Fundamental Theorem of Calculus, Part II** (a.k.a., the *Evaluation Theorem*), we have

$$\int_1^3 \left[1 - x + \frac{1}{2}x^2 \right] dx = \left[x - \frac{x^2}{2} + \frac{1}{2} \frac{x^3}{3} \right]_1^3 = \left[\left(3 - \frac{9}{2} + \frac{27}{6} \right) - \left(1 - \frac{1}{2} + \frac{1}{6} \right) \right] = \frac{7}{3}.$$

As it should be, the two results are the same.

2. (25 points) Suppose f is a continuous function and that $\int_0^x f(t) dt = \sin(x/2)$.

(a) Show that $\int_a^x f(t) dt = \sin(x/2) - 1$.

Solution: By the **Fundamental Theorem of Calculus, Part I**, any function of the form $F(x) = \int_a^x f(t) dt$ is an *antiderivative* of $f(x)$. So, in our case, we are given

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Mark Dugopolski



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the bromine substituent in bromobenzene is an ortho para director the para position is favored due to steric effects in the reaction that takes place in this lab a nitro group is substituted onto bromobenzene at the para position to form 1 bromo 4 nitrobenzene

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over 5 minutes slowly pipet this bromobenzene into the icy cold nitration mixture hno 3 h 2 so 4 in the 125 ml flask and stir continue to stir the reaction mixture in the ice bath for 30 minutes do not heat in a new 250 ml erlenmeyer

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on the right the arenium cation has a nitro set with incredibly small 0.6 angstrom bond distances this will result in an optimization failure as the atoms are even close for the programme to accomodate their electrons demonstration of creating the p arenium cation by to nitration of bromobenzene

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the purpose of this lab was to observe where substituents are added on a benzene ring by way of electrophilic aromatic substitution the electrophilic source in the nitration of bromobenzene comes from a nitronium ion no₂ which acts as the electrophilic species

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