

1. In this problem, you will estimate $\int_0^{1/2} e^{-x^2} dx$ using Taylor series, and also review some earlier parts of the course. Let

$$f(x) = \int_0^x e^{-t^2} dt.$$

All Taylor notation refers to the Taylor series for f centered at 0.

In this problem all conceptual parts should be justified briefly (e.g. cite a theorem, write a sentence). For computational parts, show your work. At a certain point you may be tempted to justify a bound using just a picture of a graph; you need more justification than that.

- (a) Why does f have a Taylor series?
(E.g. why is f differentiable at 0? twice differentiable at 0? etc.)
- (b) Assume that the Taylor series for e^{-x^2} at 0 converges on \mathbb{R} . Does the Taylor series T for f at 0 converge on \mathbb{R} ? What is the largest domain on which T is continuous?
- (c) Calculate $f^{(n)}(x)$ for $n \leq 4$ and $T_n(x)$ for $n \leq 3$.
- (d) Use T_3 to estimate $\int_0^{1/2} e^{-x^2} dx$.
- (e) Use Taylor's remainder formula to find a bound for the error associated to the approximation in the previous part.
Hint: if $|g(x)| \leq M_1$ and $|h(x)| \leq M_2$ for all $x \in S$, then $|g(x)h(x)| \leq M_1 M_2$.
- (f) Explain why your calculations above show that $\int_0^{1/2} e^{-x^2} dx < 0.6$. You may use a calculator for this part.
- (g) Where did you use the fundamental theorem of calculus in this problem?
- (h) In part (e), you should have found an upper bound for $f^{(4)}$ on $[0, 1/2]$. For higher remainder terms, you would have looked for an upper bound for $f^{(n)}$. Is it possible that $f^{(n)}$ for some n is not bounded on $[0, 1/2]$?
You don't need to compute all the higher derivatives to answer this question!
- (i) What is $\lim_{x \rightarrow +\infty} f^{(n)}(x)$?
Checking all the details is a pain; instead, just show you thought about it.
Hint: every $f^{(n)}$ has the form $p(x)e^{-x^2}$ where $p(x)$ is a polynomial.
- (j) Does the previous part imply that $\lim_{x \rightarrow +\infty} R_n(x) = 0$?

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