## Calculus I: Final Exam

Name: $\qquad$

## Section: $\square$ 9:15 (Mohamed Nouh) $\square 11: 45$ (James Gossell) Online (Leah Berman)

## Rules:

- Partial credit will be awarded, but you must show your work.
- You may have a single handwritten $3^{\prime \prime} \times 5^{\prime \prime}$ notecard, both sides.
- Calculators are not allowed.
- Place a box around your FINAL ANSWER to each question where appropriate.
- Turn off anything that might go beep during the exam.
- You have two hours to complete the exam.

| Problem | Possible | Score |
| :---: | :---: | :---: |
| 1 | 8 |  |
| 2 | 8 |  |
| 3 | 10 |  |
| 4 | 7 |  |
| 5 | 7 |  |
| 6 | 15 |  |
| 7 | 10 |  |
| 8 | 6 |  |
| 9 | 8 |  |
| 10 | 11 |  |
| 11 | 10 |  |
| Extra Credit | $(5)$ |  |
| Total | 100 |  |

## 1. (8 points)

Compute the following indefinite integrals. Show your work. Clearly indicate any substitutions you use in such a way that someone else can follow your work.
a. $\int\left(\sin (2 x)+e^{x}-\frac{\sqrt[3]{x}}{6}+\frac{1}{\sqrt{1-x^{2}}}\right) d x$
b. $\int \frac{\ln (2 x+1)}{4 x+2} d x$
2. (8 points)

Compute the following limits. Show your work clearly. Make sure you use limit notation where required; an answer that does not use proper notation will not receive full credit. Use $=$ to show things are equal. If you use L'Hôpital's rule, write $\stackrel{H}{=}$ or $\stackrel{L^{\prime} H}{=}$ to indicate where you are applying it.
a. $\lim _{x \rightarrow \infty} \frac{6 x^{4}-5 x^{2}}{7 x^{4}-14}$
b. $\lim _{x \rightarrow 3} \frac{2 x^{2}-5 x-3}{x^{2}-9}$

## 3. (10 points)

Consider the graph of the function $f(x)$ shown below:

a. Compute $\int_{3}^{11} f(x) d x$.
b. Let $F(t)=\int_{-6}^{t} f(x) d x$. On the interval [-6,3], at what $t$-value does $F(t)$ have an absolute maximum? Where does it have an absolute minumum?

- $F(t)$ has a maximum at $t=$ $\qquad$
- $F(t)$ has a minimum at $t=$ $\qquad$
c. Determine $f^{\prime}(1)=$ $\qquad$
d. What can you say about $\lim _{x \rightarrow-1} f^{\prime}(x)$ ? (Note that's asking for the limit of the derivative, not the function.) Explain your answer.


## 4. (7 points)

A portion of the implicitly defined curve $3+x y^{2}=x^{3}$ is shown below.
a. Determine $\frac{d y}{d x}$.

b. Write the equation of the tangent line to the curve at the point $(-1,2)$, which is shown with a black dot on the curve. Clearly draw and label the tangent line on the graph.

## 5. (7 points)

Suppose a rectangular box has two square sides and four sides where the length of the side is two times the width of the side (see diagram).
Suppose the short side of the box is measured to be $10 \mathrm{~cm} \pm 1 \mathrm{~mm}$ ( $1 \mathrm{~mm}=$ $1 / 10 \mathrm{~cm}$ ), and the volume is computed. Use linearization or differentials to determine the error in the measurement of the volume. Write your answer
 with a sentence, using correct units.

## 6. (15 points)

A hot air balloon rises with an upward velocity of $v(t)=2 t e^{-t^{2}}=\frac{2 t}{e^{t^{2}}}$ kilometers per minute (km/min), $t$ minutes after it is launched $(t \geq 0)$.
a. What is the balloon's initial acceleration, $a(0)$ ? Include units in your answer.
b. At what time does the balloon reach its maximum upward velocity? Use calculus techniques to verify that the time you find really is where the velocity is a maximum. Include units in your answer, and show your work.
c. Evaluate the integral $\int_{0}^{2} v(t) d t$. Show your work and simplify your answer as much as possible.
d. Write a sentence explaining the meaning of your answer to the previous part in the context of the problem, in a way someone who has not taken calculus can understand. Include units in your answer.

## 7. (10 points)

A rocket is launched vertically off of a launch pad. A camera is positioned 5 kilometers from the launch pad. When the rocket is 12 kilometers above the launch pad, its velocity is $2 \mathrm{~km} / \mathrm{sec}$. (See the diagram below.)


Find the necessary rate of change of the camera's angle $\theta$ so that it stays focused on the rocket at the instant when the rocket is 12 kilometers above the launch pad. Answer the question with a sentence, including correct units.

## 8. (6 points)

The population of rabbits in a local park, measured since 2011, can be modeled by the equation

$$
P(t)=\frac{10000 e^{t / 10}}{480+20 e^{t / 10}}
$$

where $t$ measures time, in years, since 2011 .
a. How many rabbits were in the park in 2011? Simplify your answer.
b. Compute $\lim _{t \rightarrow \infty} P(t)$. Show your work clearly, with correct use of notation.
c. Write a sentence that explains the meaning of the limit you just calculated, in terms a person who has not taken calculus can understand.
9. (8 points)

Compute the following derivatives. Show your work. You do NOT need to simplify your answer.
a. $f(x)=\sqrt{x}\left(\ln \left(x^{3}-x^{2}\right)\right)$
b. $g(x)=\left(e^{-x}+\frac{\arctan (x)}{2}\right)^{5} \cdot\left(\right.$ Note $\left.\arctan (x)=\tan ^{-1}(x).\right)$

## 10. (11 points)

Sketch a graph of a function $h(x)$ that satisfies all of the following properties.
After drawing the graph:

- Label on the graph the following things, if they exist, by drawing a point on the graph and labeling: any local maximums by writing LOCAL MAX, local minimums by writing LOCAL MIN, inflection points by writing IP
- Draw any horizontal and vertical asymptotes with dashed lines and label them with their equation.
- Mark any important $x$-values and $y$-values (with numbers) on the $x$ - and $y$-axes.


## Properties:

- The domain of $h(x)$ is $(-\infty, 5)$
- $h(0)=0$ and $h(2)=-3$
- $h^{\prime}(x)<0$ on the interval $(-\infty, 2)$
- $h^{\prime}(x)>0$ on the interval $(2,5)$
- $h^{\prime \prime}(x)<0$ on the interval $(-\infty, 0)$
- $h^{\prime \prime}(x)>0$ on the interval $(0,5)$
- $\lim _{x \rightarrow-\infty} h(x)=3$
- $\lim _{x \rightarrow 5^{-}} h(x)=+\infty$



## 11. (10 points)

A hot cup of coffee in a room whose ambient temperature is $68^{\circ} \mathrm{F}$ is changing temperature at a rate of $R(t)$, where $t$ is measured in minutes and $R(t)$ is measured in ${ }^{\circ} \mathrm{F} /$ minute.
a. Write down a complete sentence carefully explaining the meaning of $R(5)=-9$ in the context of the problem. Use units in your answer.
b. Would you expect $R(t)>0$ or $R(t)<0$ ? Explain your answer in a sentence, given the context of the problem.
c. Write a complete sentence explaining the meaning of the quantity

$$
\int_{0}^{8} R(t) d t=-107
$$

in the context of the problem. Include units in your answer.
d. Assume the cup of coffee started at $200^{\circ} \mathrm{F}$ and was left sitting on the kitchen counter, untouched. Write an expression that you would need to compute to determine the temperature of the coffee an hour later.

Extra Credit (5 points) A portion of the graph of the function $f(x)=-\frac{4}{5} x^{5}+x+\frac{2}{5}$ is shown below.

a. Suppose Newton's method is used to find an approximate solution to $f(x)=0$ from an initial guess of $x_{1}=1$. Sketch on the graph how the next approximation $x_{2}$ will be found, labeling its location on the $x$-axis.
b. If your starting guess is $x_{1}=1$, compute $x_{2}$.

