1) Sketch the derivative of the following function

The derivative is the slope:
- From 0 to 2, the slope is zero. \( \frac{dx}{dt} = 0 \)
- From 2 to 3, the slope is +2.
- From 3 to 4, the slope is zero
- From 4 to 5, the slope is -3
- At \( t=7 \), the slope is + infinity
- At \( t = 8 \), the slope is - infinity

\[ x(t) \] (blue) and \( \frac{dx}{dt} \) (red)
2) Sketch the integral of the following function

\[ x(t) \] (blue) and the integral of \( x(t) \) (red)

The integral is the area to the left.

- Up until \( t = 2 \), the area to the left is zero
- At \( t = 3 \), the area increases to +1
- At \( t = 4 \), the area to the left increases to +3
- At \( t = 4.8 \), the area to the left is a maximum and starts to drop
- At \( t = 7 \), subtract 2.2
- At \( t = 8 \), add another one

•
4. Load 2-weeks worth of wind-speed data centered on your birthdate from NDAWN. (close to your home town if you're from North Dakota). Plot this in MATLAB as wind speed vs hour.

```matlab
WIND = [ (paste data here ) ];
>> size(WIND)
    336     1
>> hr = [1:336]';
>> plot(hr,WIND);
>> xlabel('Time (hr)');
>> ylabel('m/s');
>> title('2 Weeks of Wind Data from Rolla, ND');
```
5. Assume a Siemens SWT-2.5-120 wind turbine is used to generate wind energy where the wind-speed vs. energy is given in the following curve:

5a) Determine a function in Matlab to approximate this curve.

\[
\text{kW} = \left(\text{WIND} \times 1.8 / 5\right)^3 \times 2500;
\]

\[
\text{kW} = \min(\text{kW}, 2500);
\]

\[
\text{plot(WIND*1.8, kW + 0.1, '.');}
\]

\[
\text{xlabel('Wind Speed @ 80m (m/s)');}
\]

\[
\text{ylabel('Energy Produced (kW)');}
\]

5b) Use this function to compute how much power a Siemens SWT-2.3-101 wind turbine would produce from the wind data you found in problem 2.

The total energy produced for this site would be the last point. This is equal to the sum of kW * hours
6. Assume each pound of coal produces 1kWh of electricity. How many pounds of coal is this two weeks equivalent to?

This wind turbine would produce 679,450 kWh of electricity over this two week span.

This is equivalent to 679,450 pounds of coal

At 10 cents a kilowatt hour, this produces $67,945 in revenue over these two weeks.

The payback time for this wind turbine is

\[
N = \left( \frac{\text{Yearly Revenue}}{\text{Cost per turbine}} \right) = 1.41
\]

It takes 1.41 years for this wind turbine to pay for itself. (!)
Sidelight: How does wind and solar compare to coal / oil / and natural gas?

If you ignore environmental and cleanup costs, the cost to produce 1kWh is: (U.S. Energy and Information Administration)

<table>
<thead>
<tr>
<th></th>
<th>Capital Cost</th>
<th>O&amp;M</th>
<th>Fuel</th>
<th>Transmission</th>
<th>Total cents / kWh</th>
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<tbody>
<tr>
<td>Coal</td>
<td>6.57</td>
<td>0.41</td>
<td>2.92</td>
<td>0.12</td>
<td>10.02</td>
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<tr>
<td>&quot;Clean&quot; Coal</td>
<td>8.84</td>
<td>0.69</td>
<td>3.72</td>
<td>0.12</td>
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<tr>
<td>Natural Gas</td>
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<td>4.84</td>
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</tr>
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How does this compare to wind and solar power in North Dakota?

**Wind:**

Assume a Siemens 2.5MW wind turbine which costs approximately $2.5 million to build (includes tower, turbine, pad, etc). Repeat the previous analysis for a full year at Rugby, North Dakota

![Avg Wind Speed at 2m: Harvey, ND, 2017](image)

2017 Total: 14,201,583.19 kWh

10-year total: 142,015,831.9 kWh

Cost / kWh

\[
\left( \frac{\$2,500,000}{142,015,831.9\text{ kWh}} \right) = 0.018
\]

Wind energy has a cost of 1.8 cents / kWh, including construction costs, environmental cost and cleanup costs
Solar

Assume a Felicity Solar 10kW Solar Power System which sells for $22,000 as of January 30, 2018

Take data for a full year from NDAWN for Harvey, ND

A 32-panel solar array which costs $22,000 on ebay would produce

Yearly Total: 20,542 kWh
10-Year Total: 205,422 kWh
Cost / kWh

Source: https://ndawn.ndsu.nodak.edu
\[
\left( \frac{\$22,000}{205,422 \text{kWh}} \right) = \$0.107/\text{kWh}
\]

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<td>0.12</td>
<td>?</td>
<td>10.85</td>
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<tr>
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<td>0.12</td>
<td>0</td>
<td>2.12</td>
</tr>
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<td>0.2</td>
<td>0.12</td>
<td>0</td>
<td>11.02</td>
</tr>
</tbody>
</table>

Wind energy is by far the cheapest way to produce energy in North Dakota.

Solar PV actually isn't all that bad either. If any of the following happens
  - The efficiency of solar panels can be increased above 30%, or
  - The price per panel drops
solar energy will be able to beat out all other forms of energy production save wind energy.

From a purely economic standpoint, we're shifting to clean energy.

If you add in the environmental urgency to switch to clean energy, the transition will happen even sooner.
How much wind energy can North Dakota Produce?

According to the National Renewable Energy Laboratory (https://www.nrel.gov/gis/wind.html), there is enough wind in North Dakota to produce 1.18 trillion kWh of electricity each year.

This is enough to provide 25% of the entire U.S. demand for electricity,

At $0.10 / kWh, this would add $118 billion dollars to the state GDP each year.

Considering that the entire GDP for North Dakota was $46 billion in 2016,

- This would more than triple the states GDP, and
- Add $157,333 per person to the states GDP