IAM 550 Introduction to Engineering Computing
Computer Lab 5
Newton-Raphson root finding
J. Raeder, October 1/3

Objectives:

This week you will be working on calculating an acceptable bungee jumper mass under prescribed conditions using the Newton-Raphson method. In doing so, you will need to

- Use the Newton-Raphson method to find the roots of an equation
- Work on your approach to solving engineering problems
- Employ a MATLAB while loops
- Continue to practice writing MATLAB scripts.

Deliverables **due at the end of your lab session:**

A MATLAB diary for your laboratory session (25% of your laboratory grade). This should be submitted via blackboard as an assignment no later than 2 days after your lab.

Deliverables **due at the beginning of your next lab session (October 8 or 10):**

A lab report summarizing your results and answering any questions asked in the lab instructions, and including any MATLAB files that have been requested. Make sure your name is on *all* pages of your lab report.

Background:

You are acting as a consultant for a bungee jumping company who is concerned with the potential for spinal injuries in jumpers who reach velocities during the free fall that are too high. This company has set a safety metric whereby they require that a jumper cannot exceed a velocity of 19.0 m/s after a 2.00 second freefall. They are asking you to find the mass at which this metric is exceeded.

You know that a jumper should be experiencing acceleration due to gravity as well as a drag force which will depend on both the jumper's cross-sectional area and the density of air. Based on this knowledge, you come up with an equation that describes the jumper velocity v as a function of time t:

$$v(t) = \sqrt{\frac{gm}{c_d}} tanh\left(\sqrt{\frac{gc_d}{m}} t\right) \qquad \text{Eq. 1}$$

where tanh() is the hyperbolic tangent (tanh in MATLAB), g is the acceleration due to gravity (9.81 m/s^2), c_d is a drag coefficient that accounts for both the jumper shape and the density of air, and m is the mass of the jumper.

After extensive testing the bungee jumping company is confident that a drag coefficient of c_d = 0.250 kg/m is a safe estimate for most jumpers, but because Eq. 1 is a transcendental equation they cannot solve for the mass explicitly and are unsure what jumper mass will yield a velocity of 19.0 m/s after 2.00 seconds. The bungee jumping company wishes to know this mass to the nearest 0.1 kg.

Task 1 of 1

Write a MATLAB script that uses the Newton-Raphson method to solve for the mass *m* at which *v(t=2.00 seconds) = 19.0 m/s* using Eq. 1 (or a re-arranged version of it). Note that in solving this problem, you will need to know the derivative of $\sqrt{\frac{gm}{c_d}}\tanh\left(\sqrt{\frac{gc_d}{m}}t\right)$ with respect to the mass, *m*. To make this a bit easier for a 1h lab we provide it here:

$$\frac{d}{dm}\left(\sqrt{\frac{gm}{c_d}}\tanh\left(\sqrt{\frac{gc_d}{m}}t\right)\right) = \frac{1}{2}\sqrt{\frac{g}{mc_d}}\tanh\left(\sqrt{\frac{gc_d}{m}}t\right) - \frac{gt}{2m}\operatorname{sech}^2\left(\sqrt{\frac{gc_d}{m}}t\right) \qquad \text{Eq. 2}$$

Use inline functions as shown in class. You can use the bisection code shown in class as a starting point. Make sure you check your value for the mass in Eq. 1 at a time of two seconds. After you solve for the mass, evaluate and plot the velocity of the jumper at times between 0 and 10 seconds with a time increment of 10 milliseconds. Provide your script and the plot as an appendix to your lab report.

Don’t forget to submit your diary file.