The following problems are worth 2 points each. You can get a total of 10 points.

4. Why is it not possible to create a transfer function that represents the exact behavior of a pendulum over the interval $-2\pi < \theta < 2\pi$?

   Transfer functions are always linear, but the exact pendulum equation is non-linear.

5. What is the time-domain equation that is equivalent to the following frequency-domain equation?

   $Y(s) = \frac{2}{s+3} \cdot \frac{7}{s^2+49}$ is equivalent to $y(t) = e^{-3t}u(t) * \sin(7t)u(t)$ where * stands for convolution. You could get the sin(7t) from the given Laplace transform of a decaying sine wave, setting the decay constant *a* to zero.

6. What is the purpose of a Schmitt trigger?

   A Schmitt trigger acts as a comparator with hysteresis. It saturates high as it passes one threshold, and saturates low as it passes a lower threshold. Its purpose is to reduce the effect of noise on the comparator's function.

7. What is the approximate doubling time of fibroblasts?

   a) 20 minutes
   b) 2 hours
   c) <u>20 hours</u>
   d) 2 days

8. Which of the following probably does NOT describe a fibroblast that is rounded up (spherical)?

   a) Dead
   b) Dividing
   c) Freshly added to medium
   d) <u>Moving itself around the dish</u>

9. In a phase portrait, a stable spiral point…

   a) Always goes clockwise inward
   b) Can spiral inward or outward
   c) <u>Always goes inward but either clockwise or counterclockwise</u>
   d) Always goes counterclockwise inward

10. What does DMEM stand for?

    Dulbecco's Modified Eagle's Medium (solution that mammalian cells grow in)

    Other interesting answers:
    Dull microscopes emit misguidance
    Dilapidated Materials Exasperate Mentors
    Differential MATLAB Expunges Matrices
    Differential Multiple Equation Model
    Don't make Everyone Mad
    Definitely Made Extreme Mistakes

11. Propose a way to implement a PID controller $G(s)$ using some or all of the following components, but no software. The input is a voltage representing the error signal, and the output is a voltage .
Capacitor, inductor, LED, resistor, voltage-controlled current source (VCCS), zener diode. *You may also use an op-amp.*

One option: The VCCS converts the error voltage to a current. This current is passed through R, L, and C in series. The total impedance of the series RLC is

$$\frac{1}{Cs} + R + Ls$$

which has the same form as the sum of the three PID terms. We set 1/C = Ki, R = Kp, and L = Ks. The voltage is then taken across all three components, that is to say at the output of the VCCS. It is also a good idea to include an op-amp at the output to decouple G(s) from the next stage in the system.

Equations

$$\frac{d}{dt}\sin(x) = \cos(x)$$

$$e^{-at}\sin(\omega t) \Leftrightarrow \frac{\omega}{(s+a)^2 + \omega^2}$$

$$e^{-at}\cos(\omega t) \Leftrightarrow \frac{s+a}{(s+a)^2 + \omega^2}$$

In the following definitions, ζ is defined in the following transfer function:

$$H(s) = \frac{1}{s^2 + 2\zeta\omega_n + \omega_n^2}$$

Overshoot, as fraction of step response $Mpeak = e^{-\pi\zeta/\sqrt{1-\zeta^2}}$

Settling time $t_s = \frac{4.6}{\zeta\omega_n}$