ES360

Introduction to Controls Engineering

Spring 2007 Syllabus, Pre-Lab Assignments, and Final Project

Name:_____ Section:_____

Instructor:_____

Due Date	Assignment
	Lesson 2 Pre-Lab
	Lesson 3 Pre-Lab
	Lesson 4 Pre-Lab
	Lesson 5 Pre-Lab
	Lesson 6 Pre-Lab
	Lesson 7 Pre-Lab
	Lesson 8 Pre-Lab
	Lesson 9 Pre-Lab
	Lesson 10 Pre-Lab
	Lesson 11 Pre-Lab
	Final Project

Pre-Lab exercise are due at the start of class for their lesson.

The Pre-Lab assignments are designed to take less than 20 minutes each. If it takes longer than 30 minutes to complete an assignment, then you don't know the material well enough.

United States Naval Academy
Weapons and Systems Engineering Department
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Revision 2.2
December 2006

Week of	Week	Pre Lab Lesson	Lessons	Topic
8 Jan	1	None	1a	Complex Number Review
			1b	Block Diagrams
			1c	Introduction to the Frequency Domain
15 Jan	2	2	2a	Basic Element Types and Energy Domains
			2b	First Order Transfer Functions
22 Jan	3	3	3a	Input Types and the Final Value Theorem
			3b	Second Order Systems' Time Responses
29 Jan	4	4	4	Second Order Time Response Calculations
5 Feb	5	5	5a	Graphical Analysis of Second Order Responses
			5b	Measurement of an Actual Second Order Response
			5c	Modeling the F/A-18 Landing Gear
12 Feb	**6**	**None**	**None**	**EXAM #1**
19 Feb	7	6	6a	Introduction to Feedback
			6b	Introduction to Controllers
26 Feb	8	7	7	Feedback and Modeling a Gun Turret
5 Mar	9	8	8	Disturbances and Actuator Limitations
12 Mar				**Spring Break**
19 Mar	10	9	9	PID Control of a Generator Set
26 Mar	11	10	10	PID Control of a Cruise Missile and Discrete Sampling.
2 Apr	12	11	11	PID Speed Control of a Car (Hardware Lab)
9 Apr	**13**	**None**	**None**	**EXAM #2**
16 Apr	15	None	None	Final Project Due and Course Critiques

Due Dates

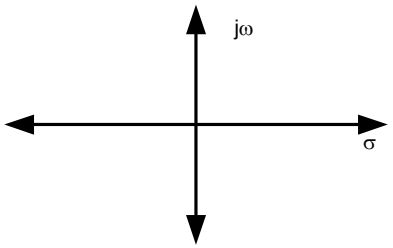
Pre lab assignments are due at the **start of class** for the week listed.

The lessons should be completed in class the week they are assigned. To receive credit for them they must be handed in prior to the start of the following class. If you miss a class, you have two weeks to be caught up unless other arrangements are made.

Lesson 2 Pre-Lab Exercise

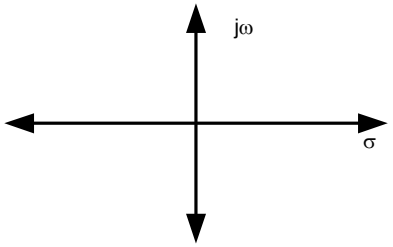
1) Solve $3x^2 + 14x + 2 = 0$. Plot the solution on the complex plane.

Answer

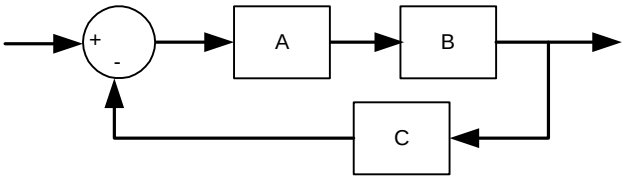


2) Solve $x^2 + 4x + 24 = 0$. Plot the solution on the complex plane.

Answer



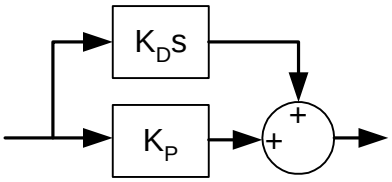
3) Reduce the following block diagram to a rational function. Sketching the intermediate block diagrams will be helpful. **Do not use your calculator.**



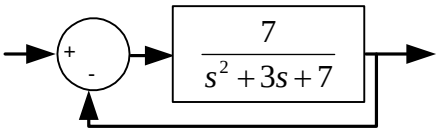
Answer

4) Simplify the following block diagrams. **Do not use your calculator.**

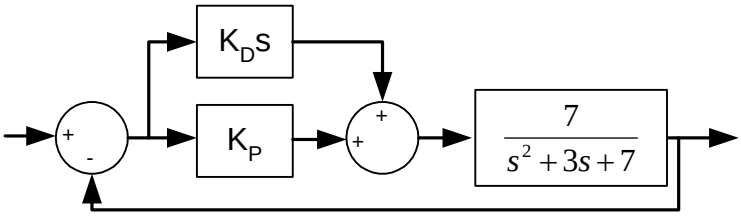
a)



b)



c)

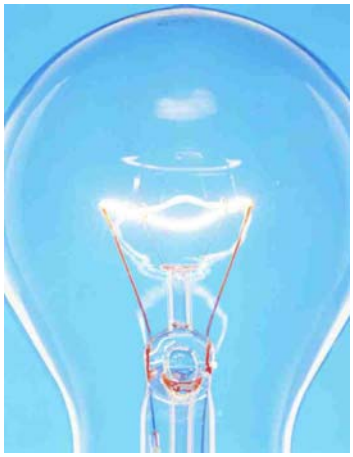


5) Summarize the main points of Lessons 1a, 1b, and 1c.

Lesson 3 Pre-Lab Exercise

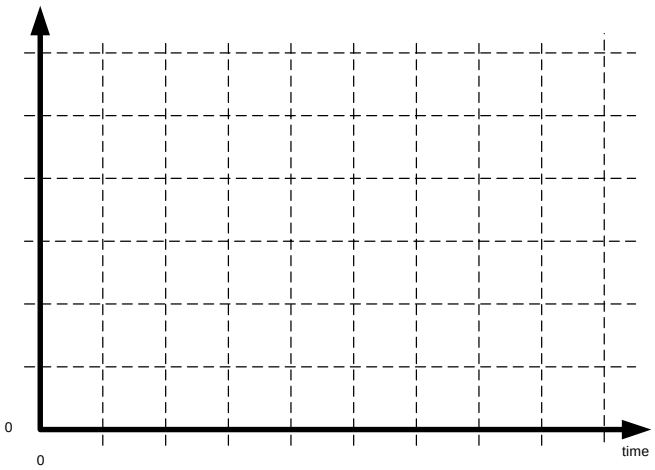
1) What is a transfer function?

2) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.



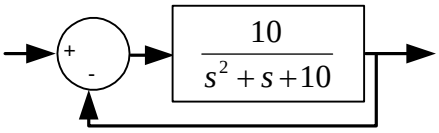
3) Solve for the DC gain and settling time and plot the unit step response for $G(s) = \frac{10}{s+2}$.

DC Gain:	Ts:

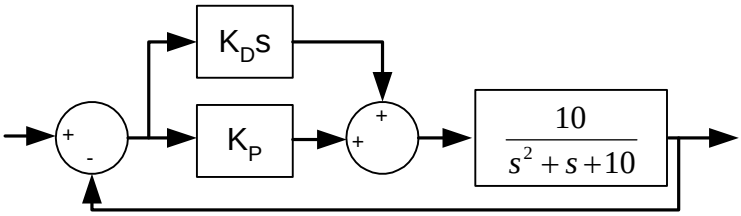


4) Simplify the following block diagrams. **Do not use your calculator.**

a)



b)



5) Complete the table below by finding an example of each type of element in your possessions (room, car, etc.).

System	Kinetic Energy Storage	Potential Energy Storage	Dissipative
Mechanical (translational)			
Mechanical (rotational)			
Electrical			
Fluid			
Thermal			

6) Summarize the main points of Lessons 2a and 2b.

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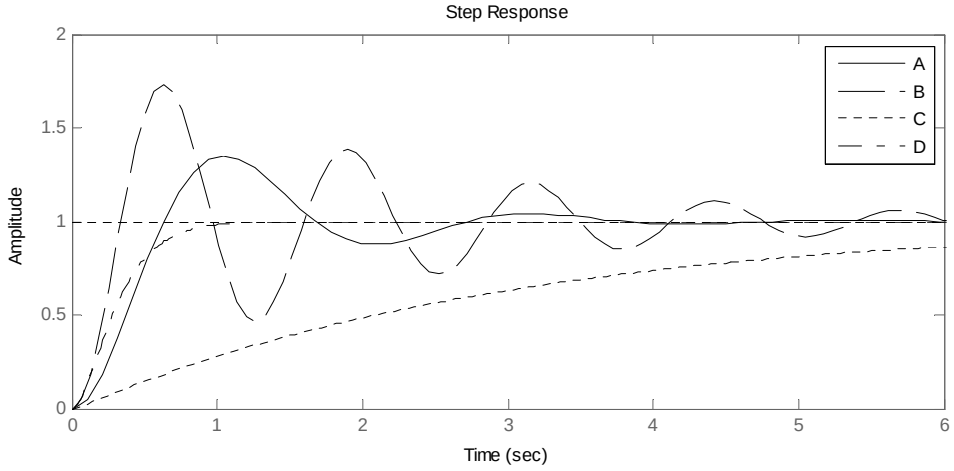
Lesson 4 Pre-Lab Exercise

1) Use the final value theorem to complete the table below.

Input	Transfer Function	TF's DC Gain	Final Value	Input Type or Freq Domain
step of magnitude 5	$\frac{4}{s^2+2s+2}$			
$\frac{3}{s^2}$	$\frac{3}{s^2+2s+3}$			

2) The time responses for several second order systems are plotted below. Place the systems in order from least to most friction. All other aspects of the systems are identical.

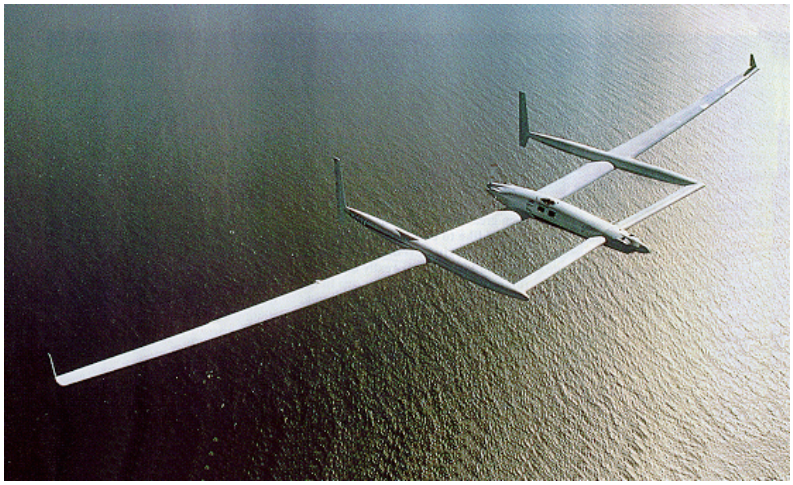


Least Friction ◄——► Most Friction

3) Solve for the roots of the characteristic equation and sketch the unit step response for the following transfer functions:

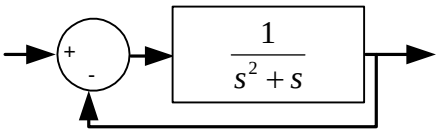
$G(s)=\frac{50}{s^2+10s+25}$	$G(s)=\frac{40}{s^2-5s+40}$

4) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.

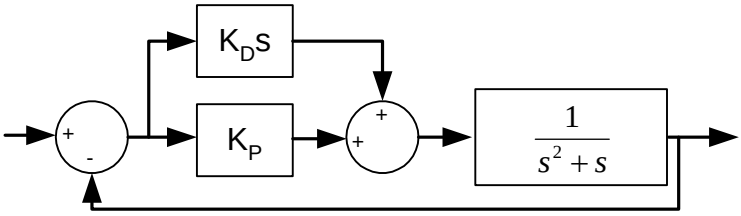


5) Simplify the following block diagrams. **Do not use your calculator.**

a)



b)



6) Summarize the main points of Lessons 3a and 3b.

Lesson 5 Pre-Lab Exercise

1) For the unit step applied to the transfer function $G(s) = \frac{8}{2s^2 + 4s + 4}$ find the following:

Characteristic Equation		ϖ_d	
Roots of the Characteristic Equation		Ts	
System Response Type: (Over Damped, Critically Damped, Under Damped, Unstable)		Tp	
ϖ_n		%OS	
$\zeta\varpi_n$		DC Gain	
ζ			

2) For the unit step applied to the transfer function $G(s) = \frac{4}{s^2 + 6s + 2}$ find the following:

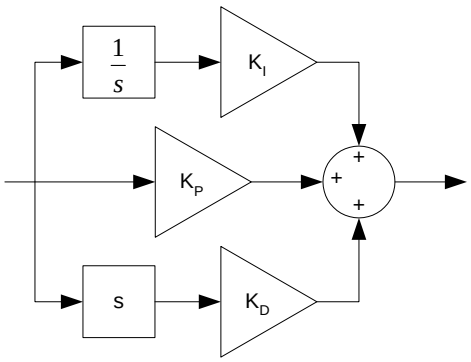
Characteristic Equation		ϖ_d	
Roots of the Characteristic Equation		Ts	
System Response Type: (Over Damped, Critically Damped, Under Damped, Unstable)		Tp	
ϖ_n		%OS	
$\zeta\varpi_n$		DC Gain	
ζ			

Lesson 5 Pre-Lab Exercise

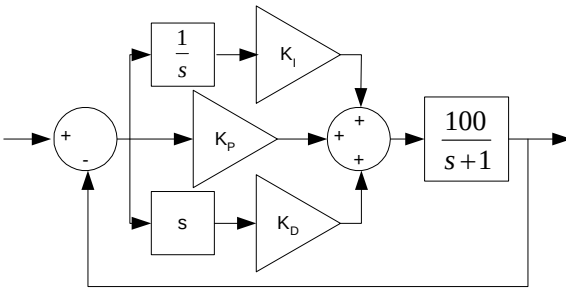
3) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.

4) Simplify the following block diagrams. **Do not use your calculator.**

a)



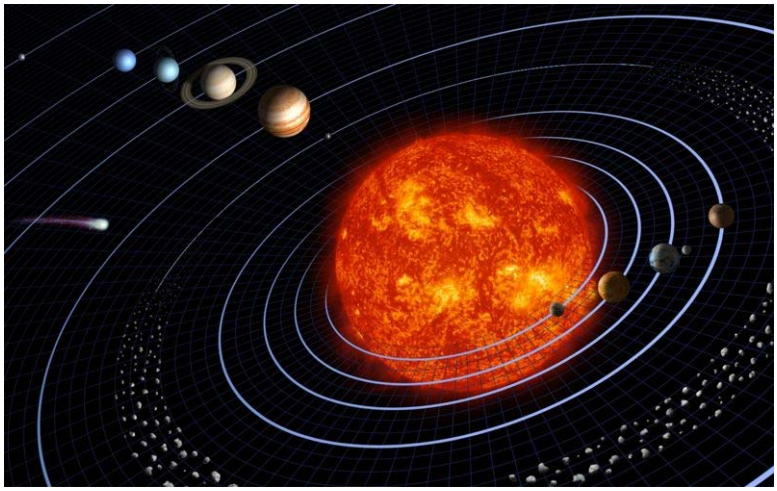
b)



5) Summarize the main points of Lesson 4.

Lesson 6 Pre-Lab Exercise

1) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.

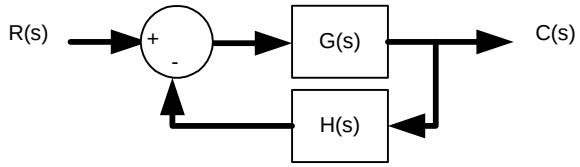


2) For the unit step applied to the transfer function $G(s) = \frac{10s + 25}{s^2 + 50s + 100}$, find the time response parameters.

Characteristic Equation		ϖ_d	
Roots of the Characteristic Equation		Ts	
System Response Type: (Over Damped, Critically Damped, Under Damped, Unstable)		Tp	
ϖ_n		%OS	
$\zeta\varpi_n$		DC Gain	
ζ			

3) Summarize the main points of Lesson 5a and 5b.

Lesson 6: Pre-Lab Exercise



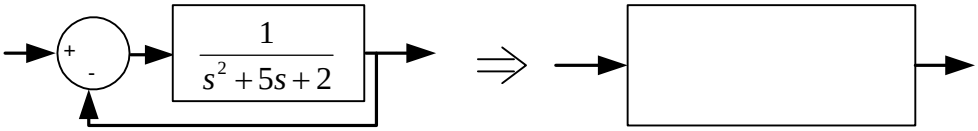
The closed loop transfer function (CLTF) for the negative feedback loop above is give by

$$CLTF_{negative}(s) = \frac{G(s)}{1 + G(s)H(s)}.$$

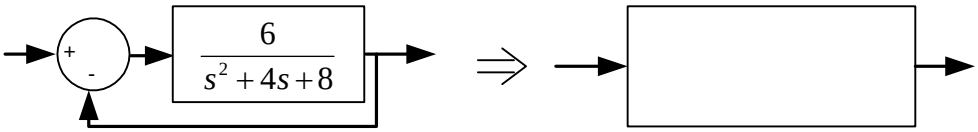
Find the closed loop transfer functions for the feedback loops below.

Do not use your calculator.

4)



5)



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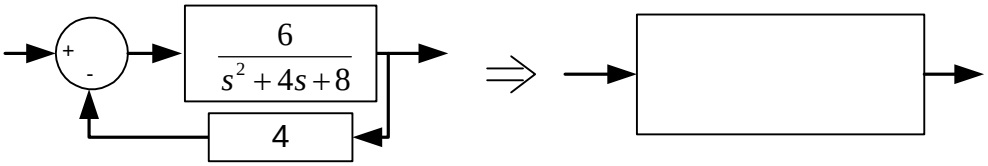

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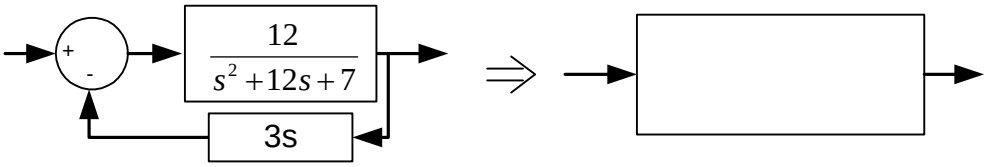
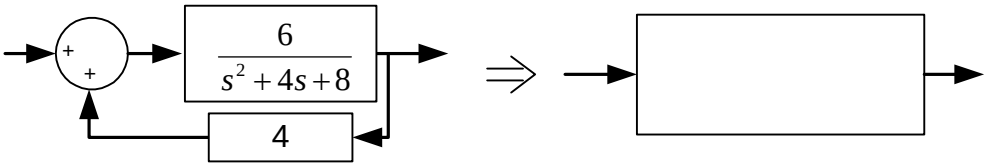


8) Note the sign in the feedback loop. See Lesson 1b.



Lesson 7 Pre-Lab Exercise

1) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.

2) The transfer function for the mass spring damper is given by

$$G(s) = \frac{\frac{1}{M}}{s^2 + \frac{B}{M}s + \frac{K}{M}}.$$

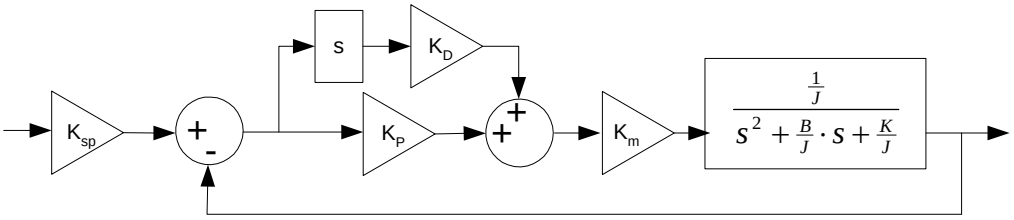
The system has the values of M = 2 kg, B = 1 Ns/m, and K = 4 N/m. A **step of magnitude 6** is applied as the input.

Solve for the following:

$G(s)$	
Tp	
Ts	
%OS	
Xss (steady state position)	

Lesson 7 Pre-Lab Exercise

3) Simplify the following block diagram. **Do not use your calculator.**



4) Summarize the key points of Lessons 6a and 6b.

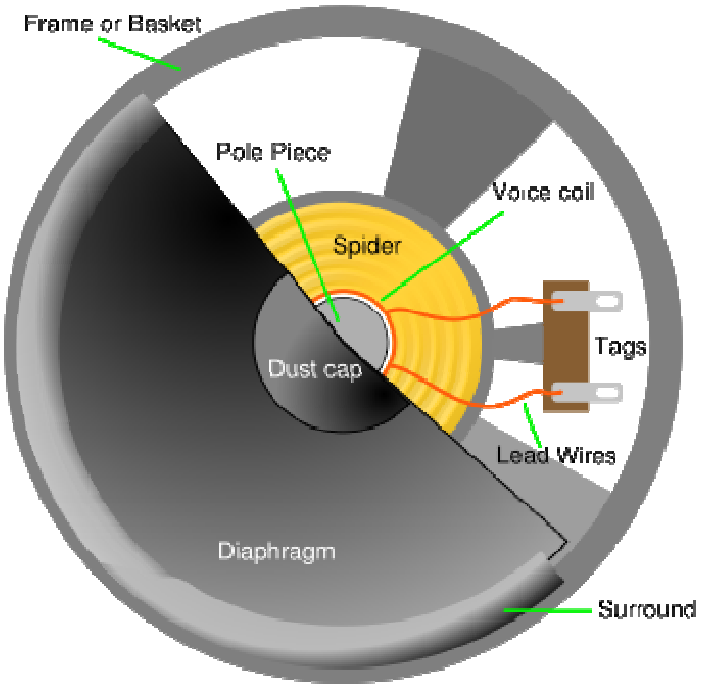
Lesson 8 Pre-Lab Exercise

1) How is the error signal for a feedback system calculated?

2) Sketch the block diagrams for a proportional controller and a proportional derivative controller.

3) A controller converts the _____ signal to a _____ signal.

4) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.



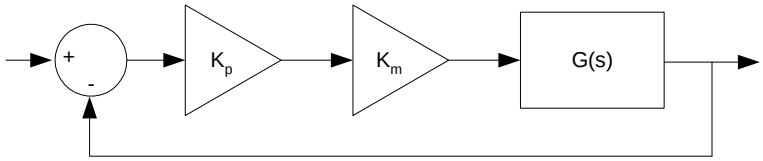
Loud Speaker

Lesson 8: Pre-Lab Exercise

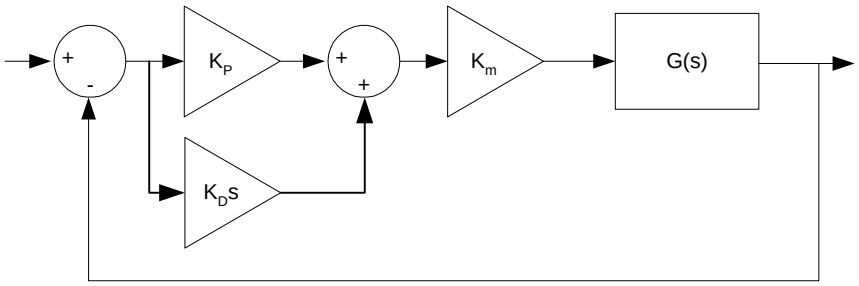
Find the closed loop transfer functions for the following block diagrams. The transfer function G(s) is

$$G(s) = \frac{a}{s^2 + b \cdot s}.$$

5)



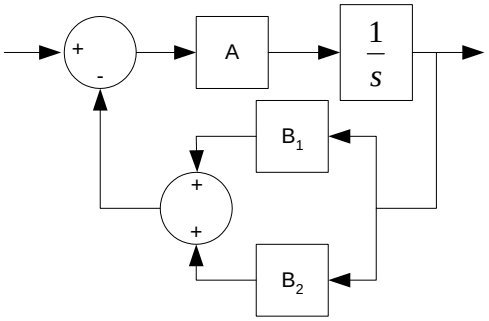
6)



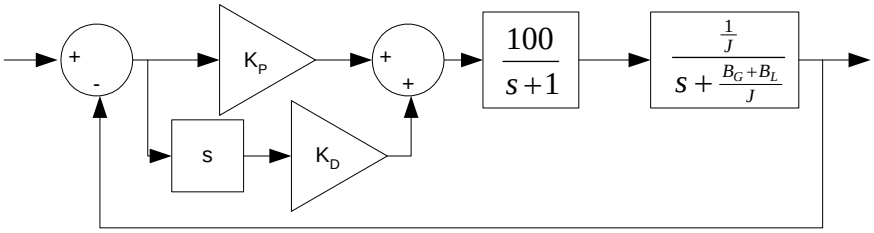
7) Summarize the main points of Lesson 7.

Lesson 9 Pre-Lab Exercise

1) Write the transfer function for the following block diagram.



2) Find the closed loop transfer function for the following system. **It will save a lot of time in Lesson 9 to have this done correctly here.**

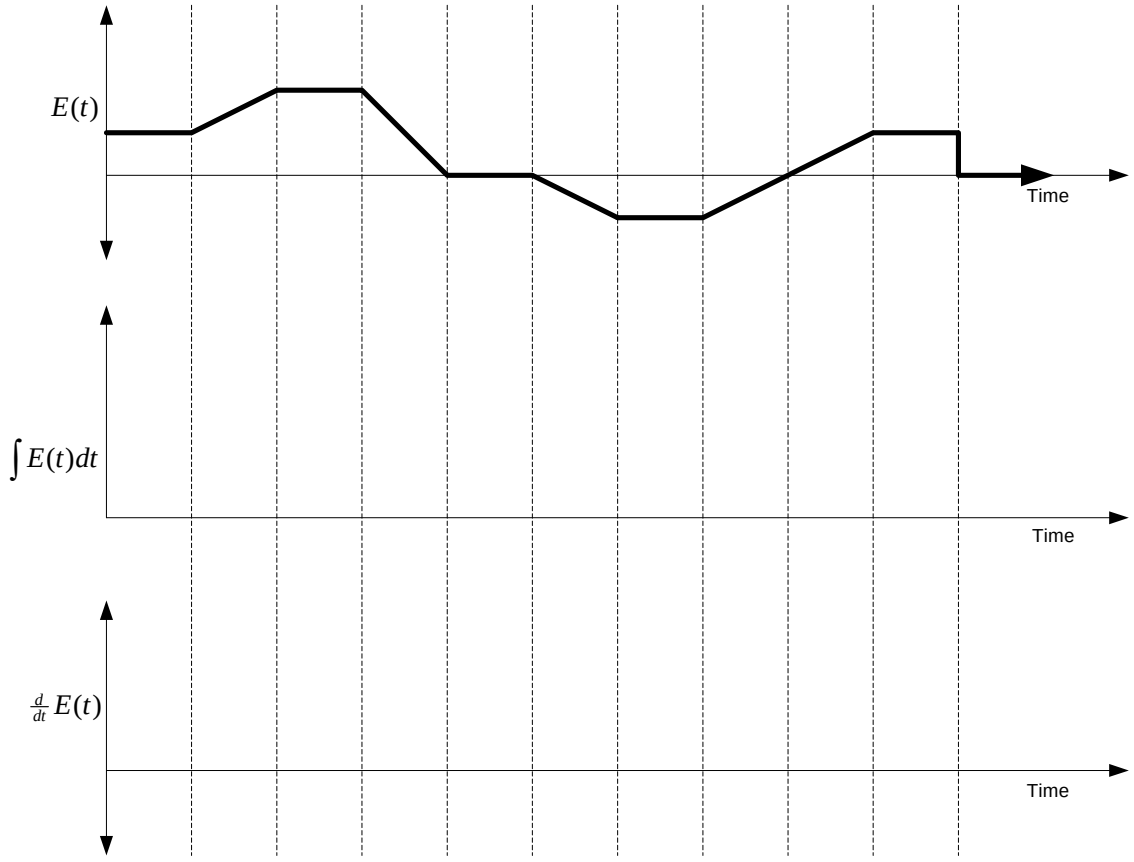


Lesson 9 Pre-Lab Exercise

3) Find the integral and derivative of the following functions:

Fcn	Integral	Derivative
0	$\int 0dt =$	$\frac{d}{dt}0 =$
3	$\int 3dt =$	$\frac{d}{dt}3 =$
t	$\int tdt =$	$\frac{d}{dt}t =$
t^2	$\int t^2 dt =$	$\frac{d}{dt}t^2 =$

4) Plot the integral and derivative of the following function.



5) Summarize the main points of Lesson 8.

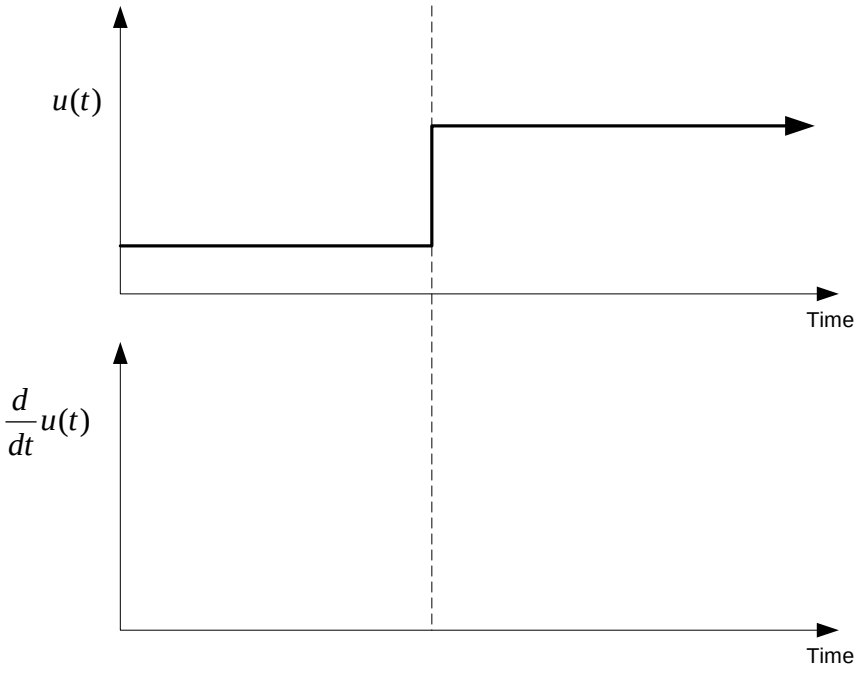
Lesson 10 Pre-Lab Exercise

1) Sketch the block diagram for a PID Controller.

2) Indicate which part of the system's response each gain term in a PID controller adjusts. Circle all that apply.

Gain	Response	
Proportional (K_P)	Transient	Steady State
Integral (K_I)	Transient	Steady State
Derivative (K_D)	Transient	Steady State

3) Plot the derivative of the step function on the axes below.



4) In the image below label the energy storage elements (kinetic and potential) and the dissipative elements. Label any conversions between energy domains.

5) Explain in terms of feedback why a musician would want a speaker pointed at the band (not the audience) during a concert.

6) Summarize the main points of Lesson 9.

Lesson 11 Pre-Lab Exercise

1) In a system with only proportional control, how does one reduce the steady state error?

2) In a system with proportional control, what happens to the transient response when K_P is **increased**? Be specific.

3) In a PID controller, which gain can reduce steady state error to zero? What determines the length of time required to reduce the steady state error to zero?

4) In a PID controller, which is the best gain to determine if the system's response will be under-damped, critically-damped, or over-damped?

5) What happens to a system's transient response as the derivative gain is **increased**?

6) What happens to a system's response as the integral term is **increased** much more than necessary?

7) Explain the "other" discrete sampling problem.

8) Summarize the main points of Lesson 10.

Final Project

For your final project submit a paper on a **control system** found on a military platform or in a weapon system. The project is due in accordance with the course syllabus.

The paper should meet the following requirements:

1. Include the statement at the end "All work submitted here is my own." and your signature.
2. Be not more than 2 typed pages.
3. Cite the references used for the project. Include the URL for any web sites used.
4. Include a photograph or drawing of the object being controlled. Label the kinetic and potential energy storage elements, the dissipative elements, and any elements which convert energy from one domain to another.
5. Discuss the parameters which the control system measures.
6. Discuss the actuator(s) which the control system drives to affect the output and any limitations of the actuator(s).
7. The system may **not** be one of the systems covered in the course lessons. That is:
    a. An automotive cruise control
    b. A gun turret
    c. Speed control of a generator
    d. Cruise missile speed control
8. Discuss anything interesting or unusual about this control system which you discover.
9. Discuss any errors or problems associated with the system (either in measurement or the response).
10. Discuss typical response times for the system.

Failure to meet the 10 requirements listed above will result in a maximum grade of a D.

You may not work with other students.

This assignment is not a "pro report". Unless it is related to the control system, I'm **not** interested in the following:

1. The history of the weapon system.
2. The cost of the weapon system.
3. A summary of its capabilities or performance parameters.