TA Review Session 12/12

Final Exam Review Problems Categorized Into Eight Categories (listed chronologically)

Topics

Search: SP09 #4.2, FA09 #6B, SP10 #8, Alt #7.1

Probability: SP09 #6, FA09 #5, SP10 #7, Alt #1

Circuits: SP09 #2, FA09 #4, SP10 #4, SP10 #5, SP10 #6

Control Systems: SP09 #7*, FA09 #3*

System Functions: SP09 #5, SP09 #7*, FAo9 #3*, SP10 #3

State Machines: FA09 #2, SP10 #2

Classes: SP09 #3, SP09 #4.1, FA09 #1, SP10 #1

Procedures: SP09 #1

* implies overlap, as all of the problems that seem to focus on different control & feedback systems rely on system functions for analysis.

Review 6.0

12/12

"Kendras' + Evan's Comedy Hr"

~~???~~

Strategies

- read everything
  - 5-10 min
- start w/ problems easy to solve and short - no long writing at code
- Skip over hard problems
- Ask proctors questions if you don't understand

- know the concepts / building blocks

Search

- Fall 09 #6

Heuristic - admissible, must underestimate

n-1 - is good
will always be less
can't have n-1 trips

n-2 - is always ≤ the proper value

\# of trips

? oh did not think

2

n-3 will sometimes be more

So n-2 is ~~best~~ best

<u>Roads</u>

- none of roads burried
- state
  - your current loc
  - your current car
  - <u>but</u> only 1 place to swap car → <u>loc A</u> is only place
    - excess info may hurt you
    - says <u>need to keep</u>
    - but keep it in for now if unsure
  - don't need cur cost because doing simple search
    - not doing A-star or Huristic

(loc, car)

('S', 'sports')

c) Goal test

- what pass in?
- its a procedure
  - need a lambda
- lambda loc: ~~...~~ loc[0] == 'D'

since state, and this is 1st component of loc

③ aha

```
def goalTest(self, state):
    return state[0] == 'D'
```

Can write either way

d) Now do the transducing

~~0~~ S sports → A sports → A suv → D suv

{the 0 means first path

e) Now breath 1st

- guarenteeded to get shortest # of hops
- and good since uniform cost (cost does not matter)

S sports

A sports   B sports

~~S sports~~   S sports   A SUV   can't go on D

Can't go anywhere thats not slippery

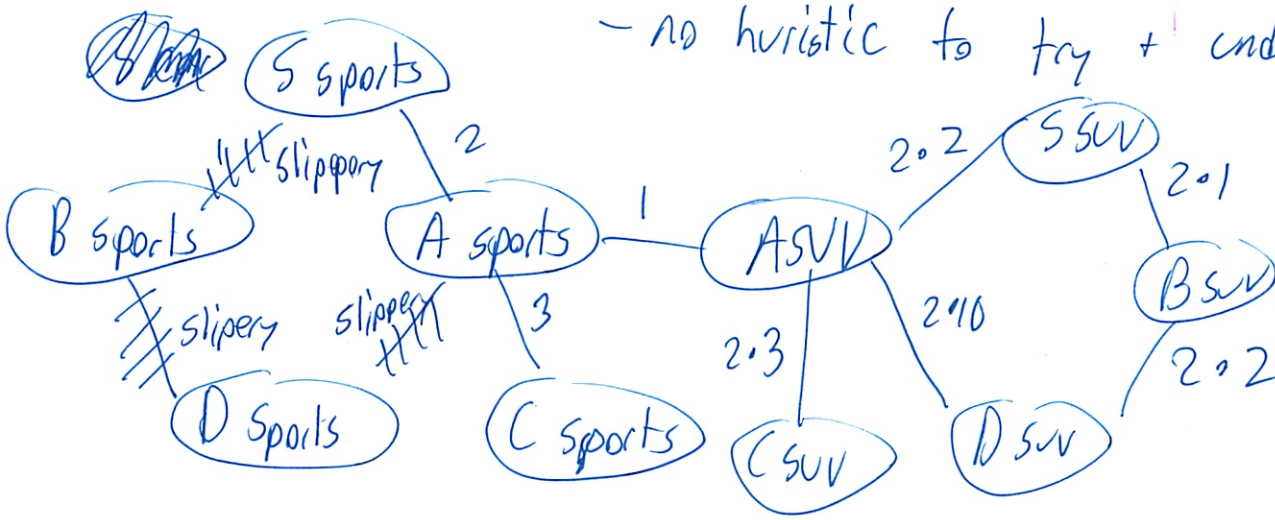
What will it do

S sports → A sports → A SUV → D suv ✓

(4)

e) Uniform Cost search

- ~~all paths are same cost~~
- ~~no here costs matter~~ Use the given costs - costs matter
- no huristic to try + under estimate



2 + 1 + 4 + 2 + 4 = 13

Draw the pathes

S sports is a different state From S SUV

- here might add cost to previous state

Depth First

- build code not to have it go backwards
- it picks the first item in the list of neighboors

f) Admissible heristic - anything that underestimates

$2n - 1$

better huristics get closer to actual value

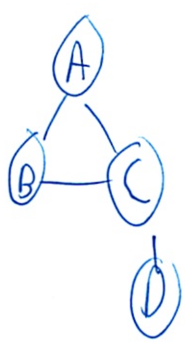
(5) Uniform Cost looks down every path

DF No DP

- ~~not~~ guarenteed to find a path
  - are some edge cases - if unsure, ask
  - but not gurented to be shortest
  - states can be visited multiple times
  - agenda is short

DF w/ DP

- yes will find path
- not nessarly finds best path
- will not visit same state multiple times



A → AB AC

AB → AC ~~ABC~~ already on agenda DP

AC → ~~AB~~ ACD

~~ABC → ABCD~~

but then stack

(6)

A ↳ A A
B C

↑ use last

A
C ↳ A A C
B D

AB ↳ AC
D

won't add ABC since DP

BF no DP

- guarenteed to find path
- " " " shortest path
- will visit pts again
- agenda will grow long

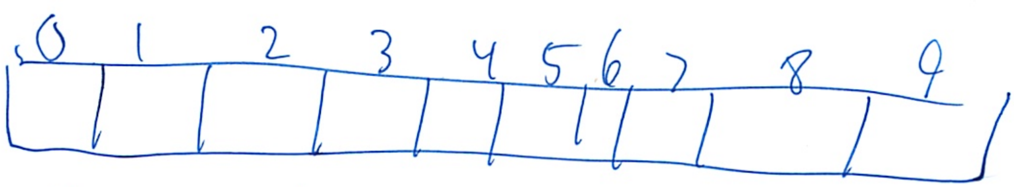
BF w/ DP

- will not visit pt agains

All will find a solution - assuming pruning rules

Probability

Cat + Mouse - extra problems packet



= mouse belief

like our robot in the hallway

7

Cat Loc {0, ..., 9} – knows where it is

start dist

.1	.1	.1	.1	.1	.1	.1	.1	.1	.1

assume cat in 5

20. Obs – hear noise

Cat hears "3"

so can be loc 2, 8

– (assuming cat has perfect hearing – can always do noise)

0	0	.5	0	0	0	0	0	.5	0

Cat

(post normalized)

21. Now transition update

– mouse .5 .5 ←→

– cat move is given – so don't have to track

– says cat moves →

0	.25	0	.25	0	0	0	.25	0	.25

new cat

(I think I got this)

(8)

need to review systems, circuits on own

22. Now cat hears again

- hears 5

0	1	0	0	0	0	0	0	0	0

? know where mouse is

Don't look at last 2 problems

- old code
- must write in 1 get next value
- SM abstraction

23. def __init__(self, catLoc, H=10):

    self.startState = ([1.0/H for h ~~in range(len(H))~~] in range(H)], catLoc)
    self.H = H

? should prob use a DDist

Could have noise in exam

will likely be more work than this

Fall 09 #5

Conditional probabilities

- I got this
- but did not do it formally, even though I thought about it

(9)

$$P(B|A) = \frac{P(A|B)\,P(B)}{P(A)}$$

$$P(S=w|O=n) = \frac{P(O=n|S=w)\,P(S=w)}{P(O=n)}$$

$$= \frac{.1 \cdot .4}{\Sigma = .28} = \frac{4}{28}$$

$$P(S=s|O=n) = \frac{.3 \cdot .5}{\Sigma = .28} = \frac{15}{28}$$

$$P(S=c|O=n) = \frac{.9 \cdot .1}{\Sigma = .28} = \frac{9}{28}$$

$$\Sigma = .1 \cdot .4 + .3 \cdot .5 + .9 \cdot .1 = .28$$

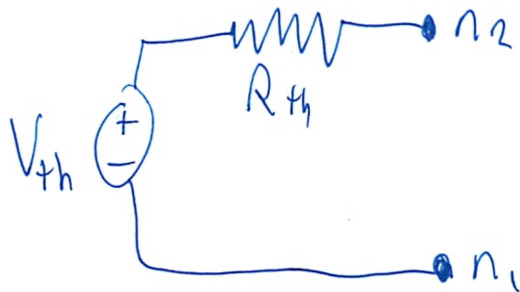
Not doing B

(10)

Circuits

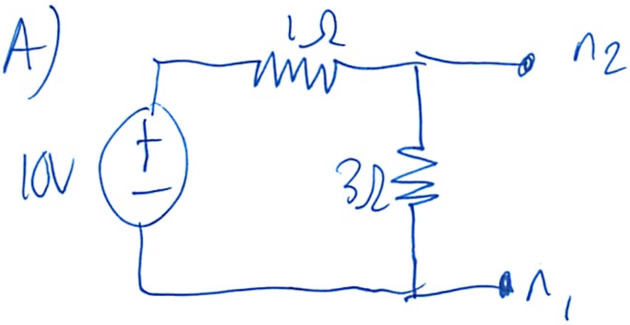
- 2nd exam
- Thevinence failed big time on exam 2
- lots of Op-amp problems

Thevinin



Match any other circuits to this circuit

A)



1st what is the voltage drop? voltage — just b/w pins

-voltage divider

$$V_{th} = \frac{3}{4}(10V) = 7.5V$$

2nd short the wires $n_1 \to n_2$

find eq resistance

$$R_{th} = \frac{V_{th}}{I_{short\ circuit}}$$ w/ current

(11)

$I_{sc} = ?$

$V = IR$

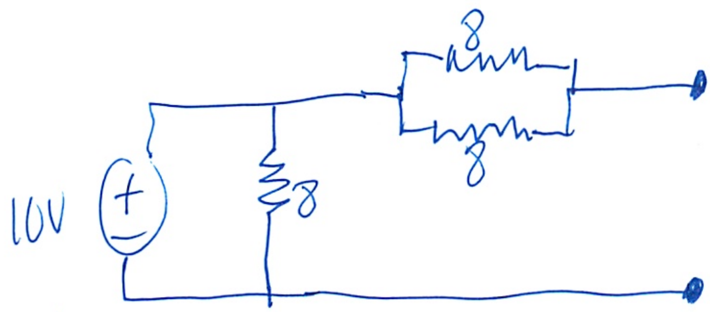
? ? 1 (only the 1Ω resistor in use)

10

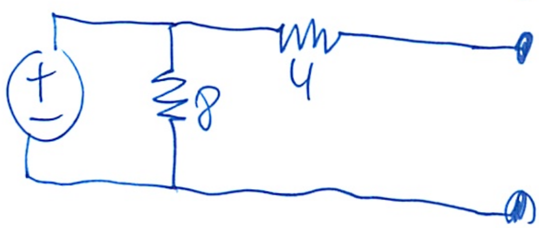
$I = \frac{10}{1}$

$R_{th} = \frac{7.5}{10} = .75$

B



First thought: this looks ugly
find eq resistance
- usually ends up helpful
- but not always need to hide



$V_{th} = 10V$
- no current drawn through wire - ignore 4Ω
- 8V not used either
- if did voltage divider $= \frac{8}{8}$

R_{TH} = add ~~[illegible]~~ short circuit wire

$= \frac{V_{th}}{I_{sc}}$

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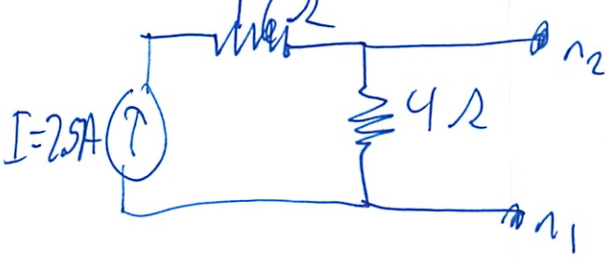
$I_{sc} =$

$V = IR$

$I = \frac{V}{R} = \frac{10}{4} = \frac{5}{2}$

$R_{th} = \frac{10}{\frac{10}{4}} = 4\,\Omega$

C

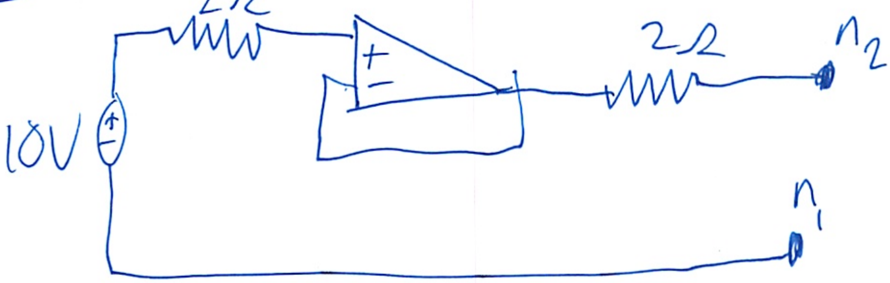


$V_{th} = IR = 2.5 \cdot 4 = 10\,V$

$R_{TH} = \frac{10}{2.5} = 4\,\Omega$

2.5 given

D



$V_{th} =$ op amp fed 10V

ignore first $2\,\Omega$

$= 10\,V$

- if op amp was limited to 5V = 5V

(13)

R_{th} = first 2 amp still ignore

Just 2nd resistor

$= 2\Omega$

$= \frac{10}{5}$

Norton almost same as Thevinin

$R_{Th} = R_{Norton}$

Just need to use current instead

and $V = IR$

Current Divider

...

Bathing Qu

$V_+ - V_- = .02(T_n - T_r)$

$\Delta T = 1$
$\Delta V = 5$

$k' = ?$ What gain do you need

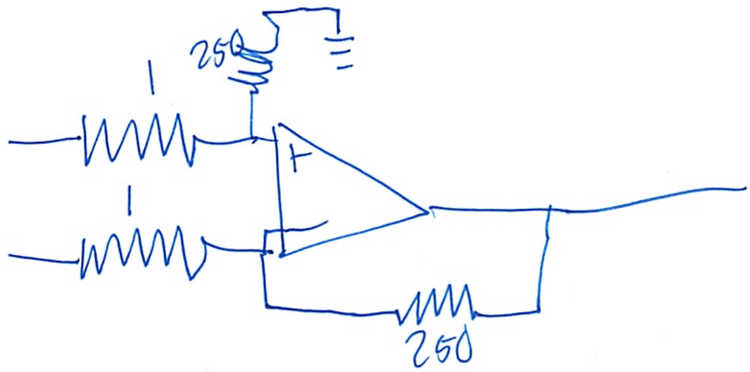
$k'(V_+ - V_-) = 1.02(T_n - T_r)$ so eq holds

$k' = 50 \cdot 5$ ← want 5 times stronger $= 250$

↑ makes it 1 tolcation - get rid of .02

(14)

Then just use a voltage subtractor from the book/notes

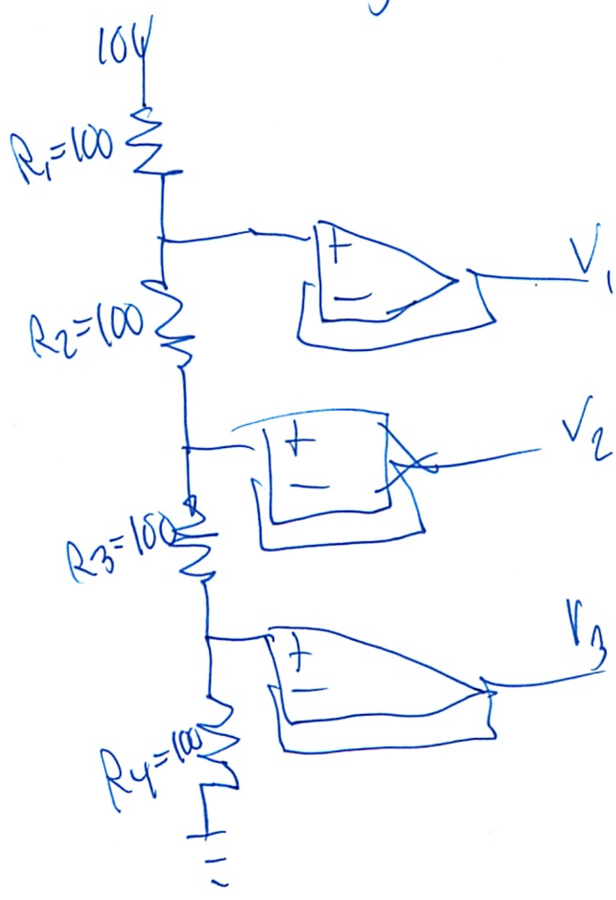


Gain defined as what again?

- relative resistor values (see above)

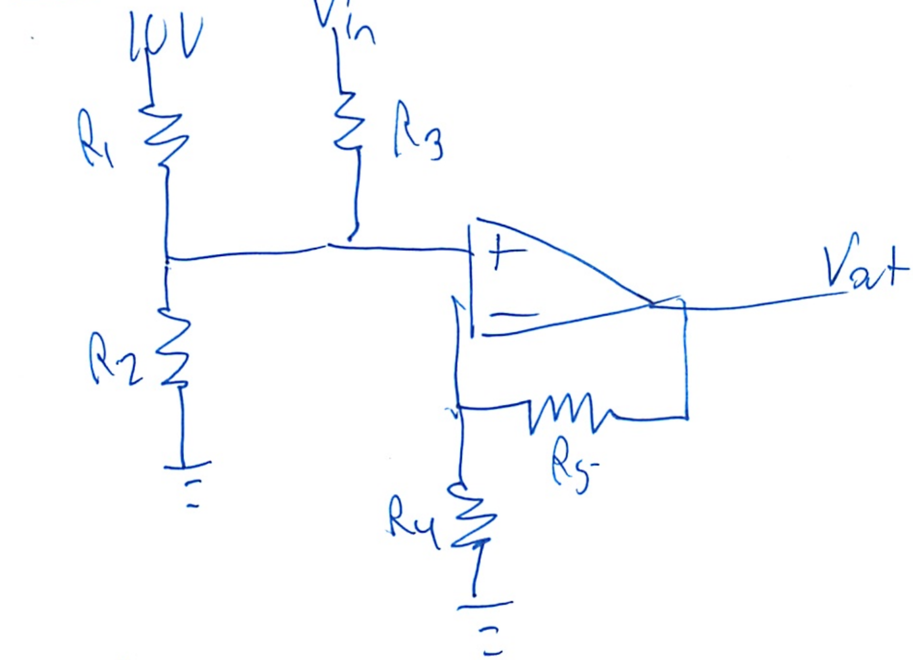
Fall 09 # 4

- ugly looking circuit thing



(15)

Part B



key items

$V = IR$

$V_+ = V_-$

A) V_+ $\quad i_2 = i_1 + i_3$

~~$V = IR$~~

if ground was not 0 - this would be something different

$$\frac{V_+ - 0}{R_2} = \frac{10 - V_+}{R_1} + \frac{V_{in} - V_+}{R_3}$$

now solve for V_+ (algebra)

$$R_1 R_3 V_+ = R_2 R_3 (10 - V_+) + R_1 R_2 (V_{in} - V_+)$$

...

B) Now that know V_+, want V_{out}

$i_4 = i_5$

(16)

$$\frac{V_+ - 0}{R_4} = \frac{V_{out} - 0}{R_4 + R_5}$$

req resistance

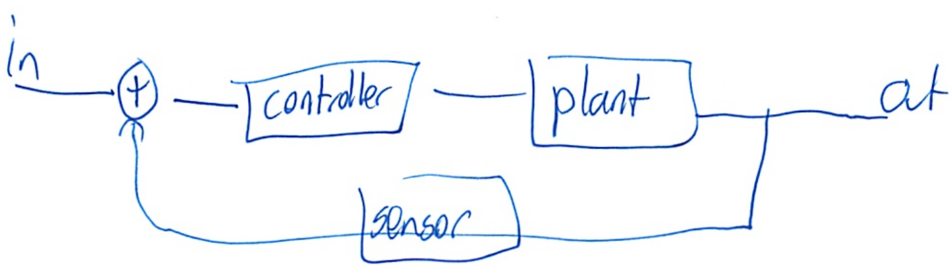
$$V_o = \frac{R_4 + R_5}{R_4} V_+$$

c) Analize circuit

- Simple
- Just show no way to ~~have~~ invert a voltage source
- It can't do this

Control Systems

Simplest



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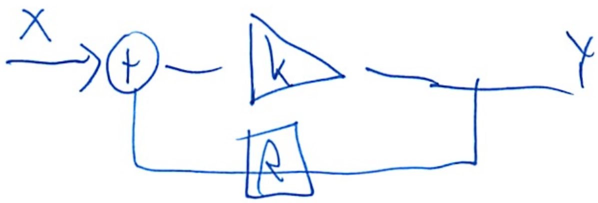
System Functions

Fall 09 ← best exam (one I was doing)



Change variables to make easier

Turn into an equation

$$Y[n] = x[n] \cdot k + y[n-1] \cdot k$$

↑ so is purly n ↑ also goes through gain

Want to analize how behaves w/ unit signal

$$Y[0] = .5\, x[0] + y[-1] \cdot .5$$

↑ always 1 ↑ starts at rest

$$Y[0] = .5 \cdot 1 + .5 \cdot 0 = .5$$

$$Y[1] = .5 \cdot 1 + .5 \cdot .5 = \frac{3}{4}$$

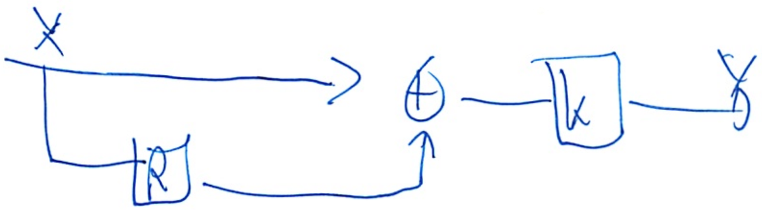
$$Y[2] = .5 \cdot 1 + .5 \cdot \frac{3}{4} = \frac{7}{8}$$

(18)

. . .

So assume for 100 will ~1

B) Now for other circuit



← relable

$Y[n] = x[n] \cdot k + x[n-1] \cdot k$

- no feed back
- feed forward add

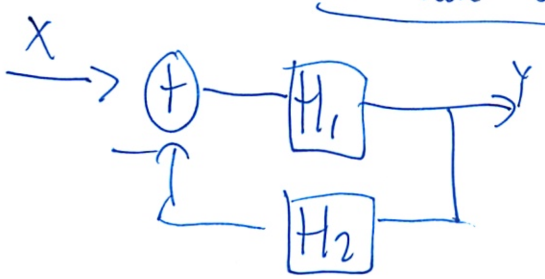
$Y[0] = 1 \cdot .8 + 0 \cdot .8 = .8$

$Y[1] = 1 \cdot .8 + 1 \cdot .8 = 1.6$

$Y[n] =$ " " " " $= 1.6$

↓ always

Blacks' Formula - Feedback Subtract



$$\frac{Y}{X} = \frac{H_1}{1 + H_1 H_2}$$

$H_1 = \frac{A}{B}$

$H_2 = \frac{C}{D}$

(19) C if sensor B

$y[n] = k\,x[n] + k\,x[n-1]$ ← diff eq

$Y = kX + kXR$ ← opp eq

$\frac{Y}{X} = \frac{k + kR}{1}$ ← system function

D) Start fresh

$$\frac{R}{.25R^2 - R + .25R + 1}$$

$R = \frac{1}{z}$

and then the converge/diverge rules

---

3. How to pick right gain
 - Dominate pole (magnitude) – inc if complex $\sqrt{r^2 + i^2}$
 - Osillation does not matter

 - Dom pole ~~[illegible]~~

6.01 Reread Notes

12/12

- Spent most time on circuits in my notes
- Need to learn Thornton + Norton
- for op amps - just practice + it will come back
- do those problems we did in review section again

UC search

by total path cost

Priority queue

test for goal - when take out of agenda

Guarenteed to find shortest

Oh - I was right current ~~φ~~ cost is included in agenda

Midterm 1 Spring 2010 #7

System Function ✓

↙ Thats how I das before

Same mistake!

$$T[n] = C\,I[n] + k_1 C\,I[n-1] - k_2 C\,T[n-1]$$

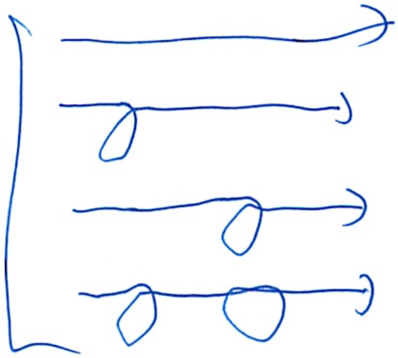
$$T = CI + k_1 C I R - k_2 C T R$$

$$T + k_2 C T R = CI + k_1 C I R$$

$$T(1 + k_2 C R) = I(C + k_1 C R)$$

$$\frac{T}{I} = \frac{C + k_1 C R}{1 + k_2 C R}$$

Possibilities



$$\frac{T}{I} = \frac{C}{(1-k_1 R)(1+k_2 R)}$$

Diff eq

$$T[n] = \overbrace{(k_1 - k_2)\,T[n-1]}^{\text{actually had this except merged}} + \overbrace{k_1 k_2\,T[n-2]}^{\text{plus posibility it goes around both}} + \overbrace{C\,I[n]}^{\checkmark}$$

Midterm 1 Fall 09 #5

$$Y[n] = k_1 k_2 x[n-1] - k_2 y[n-2] - k_1 k_2 y[n-2]$$

$$Y = k_1 k_2 XR - k_2 YR^2 - k_1 k_2 YR^2$$

$$Y + k_2 YR^2 + k_1 k_2 YR^2 = k_1 k_2 XR$$

$$Y(1 + k_2 R^2 + k_1 k_2 R^2) = k_1 k_2 XR$$

$$\frac{Y}{X} = \frac{k_1 k_2 R}{k_1 k_2 R^2 + k_2 R^2 + 1}$$

$$\frac{k_1 k_2 R}{1 + k_2 R^2 (1 + k_1)}$$ ✓ what I had (see I can do it

b) $k_1 = 1$ $k_2 = -2$ start at rest, unit input

what in all world did I do wrong?

Oh is unit just 1 at x=1 not everywhere

✓ yes

$$Y[n] = 1 \cdot -2\, x[n-1] - -2\, y[n-2] - 1 \cdot -2\, y[n-2]$$

$$= -2x[n-1] + 2\, y[n-2] + 2\, y[n-2]$$

copy error

$Y[0] = -2 \cdot 0 + 2 \cdot 0 + 2 \cdot 0 = 0$ ✓

$Y[1] = -2 \cdot 1 + 2 \cdot 0 + 2 \cdot 0 = -2$ ✓

↑ is actual last input?? No

$Y[2] = -2 \cdot \cancel{1}\,0 + 2 \cdot -\cancel{2}\,0 + 2 \cdot 0 = -\cancel{6}\ 0$

$Y[3] = -2 \cdot 0 + 2 \cdot -2 + 2 \cdot -2 = -\cancel{18}\ -8$

$-2 \quad - \quad 12 \quad - \quad 4$

Now try finding for the equivilants & well need to say if eq

d)

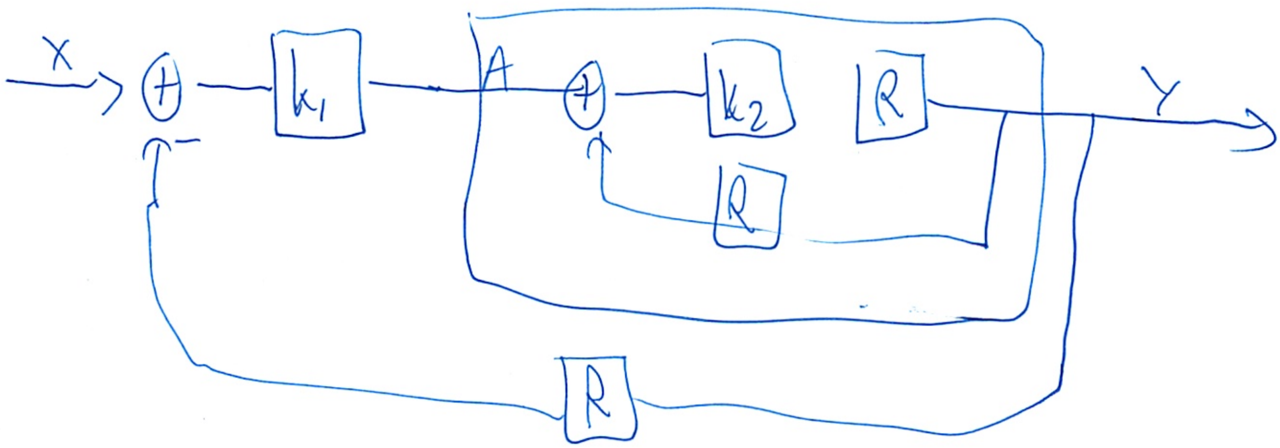
$$Y[n] = k_1 k_2 x[n-1] + k_2 y[n-1] + k_1 k_2 y[n-2]$$

? not eq

$$Y[n] = k_1 k_2 x[n-1] + k_2 y[n-2] + k_1 k_2 y[n-2]$$

same

Now copy 10/11 OH where built original one piece at a time



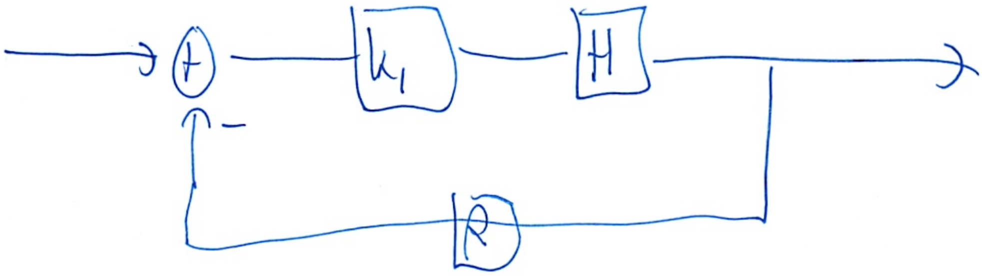
So boxed section

$H = \frac{Y}{A}$ $\quad H_1 = k_2 R$

$H_2 = R$

$$\frac{H_1}{1 + H_1 H_2} \qquad \frac{kR}{1 + (k_2 R)(R)} = \frac{k_2 R}{1 + k_2 R^2}$$

Add the other part



$$H_1 = \frac{k_1 k_2 R}{1 + k_2 R^2}$$

$$H_2 = R$$

$$\frac{Y}{X} = \frac{\dfrac{k_1 k_2 R}{1 + k_2 R^2}}{1 + \left(\dfrac{k_1 k_2 R}{1 + k_2 R^2}\right)\left(R\right)}$$

try own own to simplify

$$\frac{\dfrac{k_1 k_2 R}{1 + k_2 R^2}}{1 + \dfrac{k_1 k_2 R^2}{1 + k_2 R^2}}$$

$$\frac{k_1 k_2 R}{1 + k_2 R^2} \cdot \left(1 , \frac{1 + k_2 R^2}{k_1 k_2 R^2}\right)$$

$$\frac{k_1 k_2 R}{1+k_2 R^2} + \cancel{\frac{(k_1 k_2 R)(1+k_2 R^2)}{(1+k_2 R^2)(k_1 k_2 R^2)}}$$

$$\frac{k_1 k_2 R}{1+k_2 R^2} + \frac{1}{R}$$

need common denom

$$\frac{k_1 k_2 R}{1+k_2 R^2} + \frac{1+k_2 R}{1+k_2 R^2}$$

$$\frac{k_1 k_2 R + 1 + k_2 R}{1+k_2 R^2}$$

$\times$ flipped-ish again — just like my first final review problem

$$\frac{k_1 k_2 R}{k_1 k_2 R^2 + k_2 R^2 + 1}$$

Now check

So what did we do in OH

$$\frac{Y}{X} = \frac{\dfrac{k_1 k_2 R}{1+k_2 R^2}}{1 + \left(\dfrac{k_1 k_2 R}{1+k_2 R^2}\right)\left(\dfrac{R}{1}\right)}$$

✓ had that

$$\frac{\frac{k_1 k_2 R}{1+k_2 R^2}}{1 + \frac{k_1 k_2 R^2}{1+k_2 R^2}}$$ ✓ had

<u>then</u> they multiplied both sides by $1+k_2 R^2$

$$\frac{k_1 k_2 R}{(1+k_2 R^2)(k_1 k_2 R^2)}$$

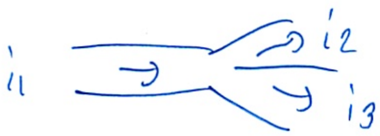
ah soo much better
- why don't I just do it that way?
- Why does my value screw up?

$$\frac{k_1 k_2 R}{\cancel{k_1 k_2 R^2}\, R^2(k_1 k_2 + k_2) + 1}$$

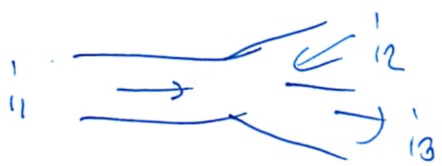
Now let me try mine again

Circuit review of lectures

- current flows in loops
- incompressabble
- Kirchoff Current Law - sum of currents into p = 0



$i_1 = i_2 + i_3$



$i_2 + i_1 = i_3$

- difference in voltdge is what matters

← presure = lines

- Kirchoff's Voltage Law - sum of voltage in closed loop = 0

- What was my fav method again?

NVCC
1. Lable each node
2. Make voltage variables at each node
3. Set one node to ground/0
4. Make current variables for each component
   - lable directions
5. Write $V_+ - V_- = i_k R$ equations

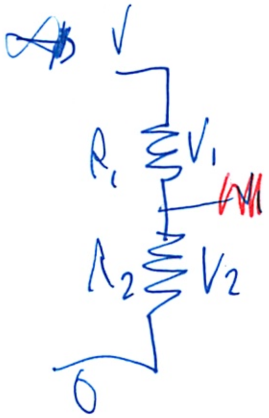
Resistor $V_+ - V_- = i_k R$

V Source $V_+ - V_- = V$

I Source $i_k = c_s$

(Now let me try pratice again)

Voltage Divider



$$I = \frac{V}{R_1 + R_2}$$

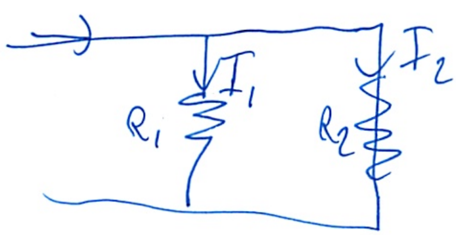
Current scene

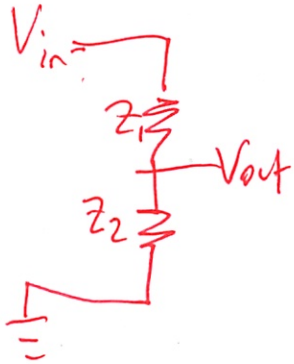
$$V_1 = R_1 I = \frac{R_1}{R_1 + R_2} V$$

actually is this right? perhaps for drop

$$V_2 = R_2 I = \frac{R_2}{R_1 + R_2} V$$

Current divider





$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$

yeah bottom

$$I_1 = \frac{V}{R_1} = \frac{R_2}{R_1 + R_2} I$$

$$I_2 = \frac{V}{R_2} = \frac{R_1}{R_1 + R_2} I$$

6.01 Final Exam: Fall 2009

Name:

Practice 12/12/10

Enter all answers in the boxes provided.
You may use any paper materials you have brought.
You may use a calculator. Open book
No computers, cell phones, or music players.

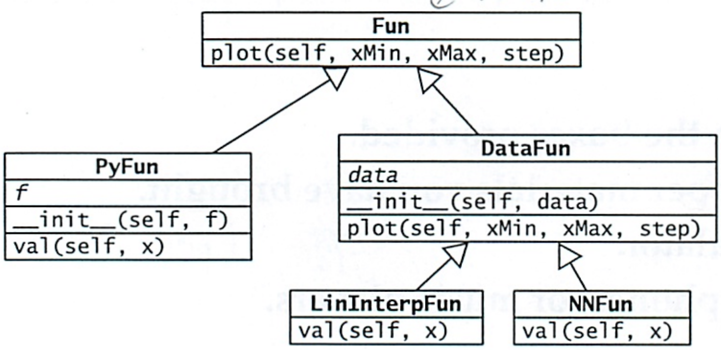
For staff use:

1.	/20
2.	/10
3.	/20
4.	/20
5.	/10
6.	/20
total:	/100

1 Object-Oriented Programming (20 points)

We will build a set of classes for representing functions (that is, mathematical functions, mapping real numbers to real numbers) in Python. Here is a diagram of the class hierarchy. Each box corresponds to a class, with its name shown in bold. Class attributes are shown in italics and methods are shown in regular text with their arguments. Arrows point upward to the superclass of a class. Fun has no superclass.

function



Every instance of a subclass of Fun that we create will have two methods: `val`, which takes an x value and returns the associated y value; and `plot`, which takes a description of the minimum and maximum x values for plotting, and the spacing between plotted points, and makes a plot. Different functions will be represented internally in different ways. In this problem, we will implement the `Fun`, `PyFun`, `DataFun`, and `LinInterpFun` classes; the `NNFun` class is in the diagram to illustrate where we might put a subclass of `DataFun` that uses a different interpolation strategy.

Any qu?

next pg

A. The class Fun is an *abstract superclass*. It won't be useful to make an instance of it, but we can put the `plot` method, which is shared among its subclasses, in it. The `plot` method should create two lists:

- `xVals` is a list whose first value is `xMin`, and whose subsequent values are `xMin + step`, `xMin + step + step`, etc., stopping so that the last value is as large as it can be, but less than `xMax`. `step` will typically be a float.
- `yVals` is a list of the y values of the function, corresponding to the x values in `xVals`. You can use the `val(self, x)` method, which is required to be defined for any actual instance of a subclass of Fun. ← I don't have

could do range but forget so implement

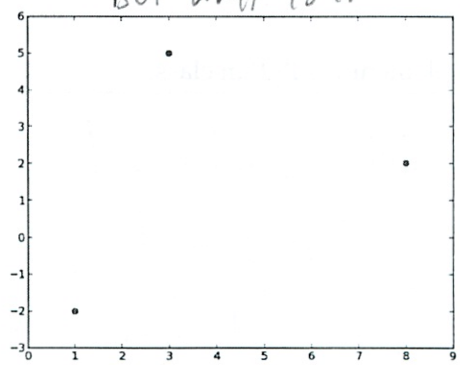
Then, it can call the global function `makePlot` on those lists. Assume `makePlot` is already defined.

So, for example,

`makePlot([1, 3, 8], [-2, 5, 2])` ← that is not a range though

would make the plot on the right.

but what is it?



I don't know why did not get
- just did not understand qu

Implement the `plot` method. Recall that Python's range only works with integer step size.

```
class Fun:
    def plot(self, xMin, xMax, step):
        XVals = myRange(xMin, xMax, step)
        YVal = []
        for x in XVals:
            YVals.append(self.val(x))
    def myRange(min, max, step):
        ans = [min]
        while cur + step <= max:
            ans.append(cur + step)
        return ans
```

cur = ans[-1]

makePlot(XVals, YVals)

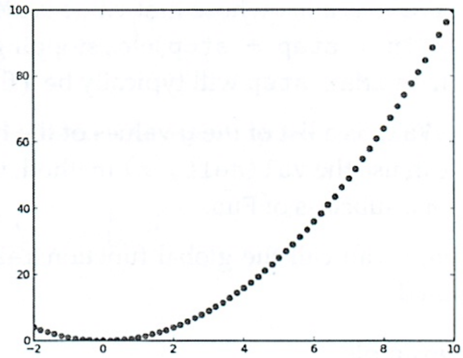
← no not a constant range dch

ans makes a lot more sense

```
xVals = []
Yvals = []
x = xMin
while x <= xMax:
    XVal.append(x)
    YVal.append(self.val(x))
    x += step
makePlot(xvals, yvals)
```

B. The PyFun class is a subclass of Fun. It represents a function just using a Python procedure of a single argument. It should operate as follows:

```
>>> t1 = PyFun(lambda x: x**2)
>>> t1.val(2)
4
>>> t1.val(-3)
9
>>> t1.plot(-2, 10, 0.2)
```



Implement the PyFun class.

```
def __init__(self, f):
    self.f = f
def val (self, x):
    return self.f(x)
```

duh

C. The `DataFun` class is a subclass of Fun, representing functions using a list of (x, y) data points, and using an interpolation rule to evaluate the function at values of x that don't appear in the data set. The data points are not sorted in any particular way. Different subclasses of `DataFun` will provide different interpolation strategies by implementing different `val` methods. `DataFun` is an abstract class, because it does not itself provide a `val` method. It will provide useful `__init__` and `plot` methods, however.

- The `__init__` method should take a list of (x, y) data pairs as input and store it in an attribute called `data`.
- The `plot` method should first plot the function with regularly-spaced x values, using the `plot` method from the parent class, Fun; then it should plot the actual data points stored in the `data` attribute.

Implement the `DataFun` class. ¿ example of atput ?

```
def __init__(self, data):
    Self.data = data

def plot(self, xMin, xMax, step):
    Fun
    ~~Self~~. plot(xMin, xMax, step):
    for x in XVals:
        Y.vals.append(self.val(x))
    make plot (XVals, Y Vals)
```

to call superclass?

XVals=[]

and do the myRange thing — we'd

↑ they did list comprehension and y is in data

make Plot ([x for (x,y) in self.data],
[y for (x,y) in Self.data])

This part of the problem is worth 5 points; we suggest that you do it only after you have finished the rest of the exam.

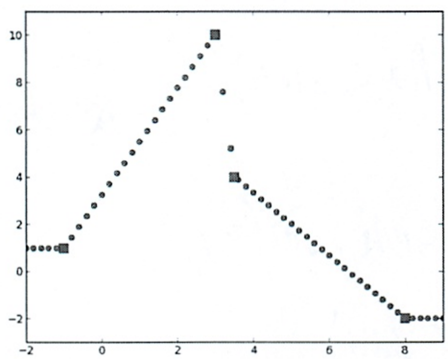
D. The `LinInterpFun` class is a subclass of `DataFun`. Its only method is `val`, which performs linear interpolation. That is, given an x_i value as input, it should look through the data to find the x_{lo} value that is, of all x values less than or equal to x_i, closest to x_i, and the x_{hi} value that is, of all x values greater than or equal to x_i, closest to x_i. Let y_{lo} be the y value associated with x_{lo} and y_{hi} be the y value associated with x_{hi}. The method should return the linear interpolation value of y for input x_i, which is:

$$y = y_{lo} + (x_i - x_{lo})\frac{(y_{hi} - y_{lo})}{(x_{hi} - x_{lo})} .$$

If the query x_i is lower than any x value in the data, then the method should return the y value associated with the smallest x value. Values of x_i that are higher than any x value in the data should be handled analogously. You can assume that all numbers are floats; do not assume that the data are sorted in any way.

Here is an example plot made from an `LinInterpFun` instance. The large squares are the actual stored data points.

```
t3 = LinInterpFun([(3, 10), (-1, 1), (8, -2), (3.5, 4)])
t3.plot(-2, 10, 0.2)
```



Write your answer in the box on the next page.

range ([start], stop, [step])

2 State machines (10 points)

WTF
- bad code

Consider the following program

```
def thing(inputList):
    output = []
    i = 0
    for x in range(3):      (?? every 3 values??
        y = 0                - no 0 to 2
        while y < 100 and i < len(inputList):
            y = y + inputList[i]        - ? does this ever increment
            output.append(y)            - yes past 100
            i = i + 1
    return output
```

A. What is the value of

```
thing([1, 2, 3, 100, 4, 9, 500, 51, -2, 57, 103, 1, 1, 1, 1, -10, 207, 3, 1])
```

[1, 3, 6, 106, 4, 13, 513, 51, 49, 106] ✓

B. Write a single state machine class `MySM` such that `MySM().transduce(inputList)` gives the same result as `thing(inputList)`, if `inputList` is a list of numbers. Remember to include a done method, that will cause it to terminate at the same time as `thing`.

Urg - how need to fix

State = (i, y, x)
Output = value to append

```
class MySM(sm):
    start state = (0,0)
    def getNextValue(self, state, inp):
        ~~i = state[0]~~   ← actually don't need
        y = state[1]
        x = state[2]       they switch
        if x = 3:
            ~~return self.done(state)~~   ← i don't really know look up
        i = i + 1
it will track →  ~~if i > len(inputList):~~
            ~~return self.done(state)~~
        y = y + inp
        if y < 100:
            return ((i, y, x), y)
        else: # y > 100
            x = x + 1
            return ((i, y, x), y)
```

define done seperatly ← did not understand

```
def done(self, state)
    (x,y) = state
    return x >= 3
```

- So done check is run after every getNextValue
done if returns true

Shold also have class heading
class LinIntepFun(DataFun):

Implement the LinInterpFun class.

- find hi + lo

```
def val(self, x):
    xLo = self.findLow(x)
    xhi = self.findHigh(x)
    ylow = self.findValue(xlo)
    yhi = self.findVale(xhi)
    return ylo + (x - xlo) * ((yhi - ylo)/(xhi - xlo))
```

can use min() max()

again use both x, y

~~def sort(self):~~

I don't know how to do sort

```
def findLow(self, xi): best = None
    for x in self.data:
        if x[0] > best and x[0] < xi:
            best = x[0]
    return best
def findHigh(self, xi):
    best = None
    for x in self.data:
        if x[0] < best and x[0] > xi:
            best = x[0]
    return best

def findValue(self, xi):
    i = 0
    for x in self.data:
        if [0] = xi:
            return self.data[i][1]
        i++
```

tuple

Run through on paper

Output [ ]

i = 0

Y = 0

Y = 1

Output = [1]

i = 1

Y = 3

Output [1, 3]

i = 2

~~Output~~

Y = 6

Output [1, 3, 6]

i = 3

Y = 106 ← was under 100 when enter

Output [1, 3, 6, 106]

i = 4 ← ?? x = 1

Y = 0

Y = 4

think get it now

[..., 4, 13, 513

last two

[..., 51, 49, 106]

↓ not defined in notes

C. Recall the definition of `sm.Repeat(m, n)`: Given a terminating state machine `m`, it returns a new terminating state machine that will execute the machine `m` to completion `n` times, and then terminate. sm.repeat(MyNewSM, 3)

Use `sm.Repeat` and a very simple state machine that you define to create a new state machine `MyNewSM`, such that `MyNewSM` is equivalent to an instance of `MySM`.

? I don't understand what they want

```
class ~~MyNewSM~~ Sum (sm):
    start state = 0
    def getNextValue(self, state, inp):
        y = state
        y = y + inp
        if y < 100:
            return (y, y)
        ~~if y ≥ 100:~~ ← ~~sm.done(y)~~
            ~~return (y, y)~~
    def done(self, state):
        return state ≥ 100
```

How exactly does done operate again?

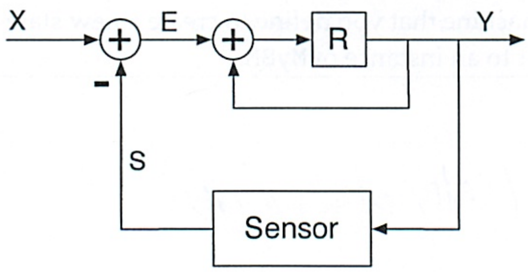
MyNewSM = sm.repeat(Sum(), 3)

? need to include as well

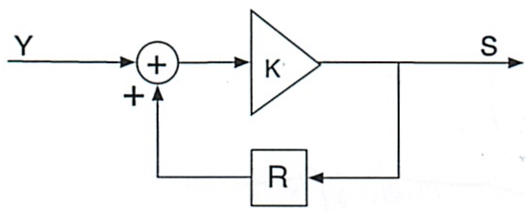
How much do I remember?

3 Linear Systems (20 points)

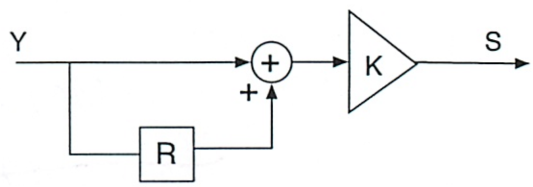
In the following system, we will consider some different possible sensors.



We can buy sensor A or sensor B as shown in the diagrams below. For each of them we can also specify the gain k at the time we order it.



Sensor A



Sensor B

A. Just considering the sensor, not yet connected into the system, if we feed a **step function** (going from 0 to 1) into a sensor A with $k = 0.5$, what will the output value be (approximately) after 100 steps? Assume the system starts at rest.

? how to approach again - system function

A) $S[t+1] = k\,Y[t] + S[t-1]$

$S[t] = k\,y[t-1] + S[t-2]$

$.5$

$S - SR^2 = .5\,YR$

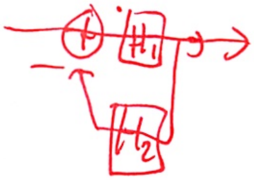
$S(1-R^2) = .5\,YR$

$\frac{S}{Y} = \frac{.5R}{1-R^2}$

? still forget how to ans

See review session ~1

Let me retry w/ Blocks $\frac{H_1}{1+H_1 H_2}$



$\underline{H_1}$

$$Y[n] = X[n-1] + Y[n-1]$$

$$Y = XR + YR$$

$$Y - YR = XR$$

$$Y(1-R) = XR$$

$$\frac{Y}{X} = \frac{R}{1-R}$$

$\underline{H_2}$ sensor A

$$S[n] = k\,Y[n] + k\,S[n-1]$$

$$S = kY + kSR$$

$$S - kSR = kY$$

$$S(1-kR) = kY$$

$$\frac{S}{Y} = \frac{k}{1-kR}$$

Blocks

$$\frac{\frac{R}{1-R}}{1 + \frac{R}{1-R} \cdot \frac{1}{(1-kR)}} = \frac{\frac{R}{1-R}}{\frac{1}{1} + \frac{R}{1-R-kR+kR^2}}$$

$$\frac{R}{1-R} \cdot \left(\frac{1}{1} + \cancel{\frac{1-R-kR+kR^2}{R}} \right)$$

been awhile since I did this

$$\frac{R}{1-R} + \frac{R}{1-R} \cdot \frac{1-R-kR+kR^2}{R}$$

$$\frac{R}{1-R} + \frac{1-R-kR+kR^2}{1-R}$$

common denom, add

$$\frac{1-kR+kR^2}{1-R}$$ why is mine flipped?

Go back + try + find when did in class

Need to be able to do this

✓ did on other paper

try again

$H_1 =$ $y[n] = x[n-1] + y[n-1]$

$$Y = XR + YR$$

$$Y - YR = XR$$

$$Y(1-R) = XR$$

$$\frac{Y}{X} = \frac{R}{1-R}$$

$\underline{H_2}$

$$S[n] = k\,y[n] + k\,s[n-1]$$

$$S = ky + kSR$$

$$S - kRS = ky$$

$$S(1-kR) = ky$$

$$\frac{S}{Y} = \frac{k}{1-kR}$$

$\underline{H}$

$$\frac{H_1}{1+H_1H_2}$$ ← mistake in memorizing formula

$$\frac{Y}{X} \quad \frac{\frac{R}{1-R}}{1+\left(\frac{R}{1-R}\right)\left(\frac{k}{1-kR}\right)}$$

now they multiplied both ~~sides~~ halfs by $1-R$

$$\frac{R}{1-R+\left(\frac{Rk}{1-kR}\right)}$$

multiply both sides by $1-kR$ again - try

$$\frac{R(1-kR)}{(1-R)(1-kR)+Rk}$$

$$\frac{R(1-kR)}{1-R-kR+kR^2+kR}$$

$$\frac{R(1-kR)}{1-R\cancel{-kR}+kR^2}$$

now correct

- just do it that way in future

- Blacks

(w/ a +)

- and get rid by multiplying ~~both sides~~ by denom thing

Why does my flippy thing not work?

B. Just considering the sensor, not yet connected into the system, if we feed a **step function** (going from 0 to 1) into a sensor B with k = 0.8, what will the output value be (approximately) after 100 steps? Assume the system starts at rest.

$S[n] = kY[n] + kY[n-1]$
$= .8$
$= 1.6 \ldots$

See review session

1.6 ✓

C. If you plug sensor A into the overall system, what is the system function relating Y to X? (Leave k as a variable)

Did not do in review

$Y[n] = x[n-1] + Y[n-1] + \text{sensor}$

$S[n] = k\,y[n] + k\,s[n-1]$

$Y[n] = x[n-1] + y[n-1] - k\,y[n] + k\,x[n-1]$ ¿ am I converting this right

~~System function~~ opp eq

$Y = XR + YR - kY + kXR$

$Y - YR + kY = XR + kXR$

$Y(1 - R + k) = X(R + kR)$

perfect spacing

$\frac{Y}{X} = \cancel{\frac{R + kR}{1 - R + k}}$ $\frac{R(1 - kR)}{1 - R + kR^2}$

new qu

D. If we put a sensor of type B into the system, then the overall system function is

$$\frac{R}{kR^2 - R + kR + 1}$$

1. For $k = 0.25$, what are the poles of the system?

$$\frac{R}{.25R^2 + .75R - R + 1} = \qquad \frac{1}{z} = R$$

Replace $R \to \frac{1}{z}$

Multiply by z^2

$$\frac{\frac{1}{z}}{\frac{.25}{z^2} - \frac{.75}{z} + 1}$$

?then what missing someting

$$.25 - .75z + z^2$$ ← you end up w/ this

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

??? remember the formula

$$\frac{.75 \pm \sqrt{.75^2 - 4 \cdot 1 \cdot .25}}{2 \cdot 1} = .375 + .330i$$

Need to convert $\sqrt{.375^2 + .330^2} = .5$

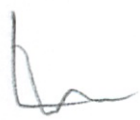
look up + fix - almost have it and other one

$.375 - .330i$

don't care about

Is it stable? Yes converges to 0 ✓ Does it oscillate? Yes ✓

- Can look on exam 2



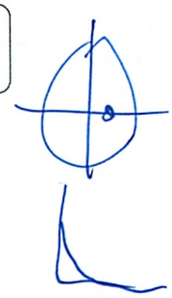
2. for $k = 0.1$, the poles of the system are at 0.77 and 0.13.

dominant

Is it stable? Yes ✓ Does it oscillate? No ✓

increase / decrease monotonically

↳ real



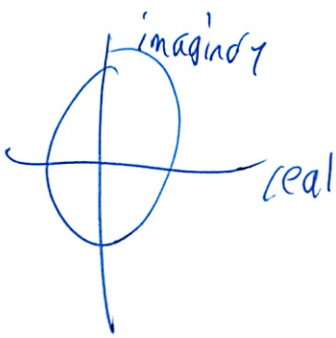
← ~~persistant~~ mag dom pole < 1

What does stable mean? ?: not occilate (~~its not in notes~~)

Now review finding poles

✓ did on other paper

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



$$mag = \sqrt{\text{real}^2 + i^2}$$

parts

then look at lecture notes or midterm 2

3. If you were buying a sensor of type B, which of these gains would give you faster response? Explain.

Scratch Paper

System controlled by mag dom pole

Wait want gain .25 or .1

Higher gain = faster, but more ocillation

-always

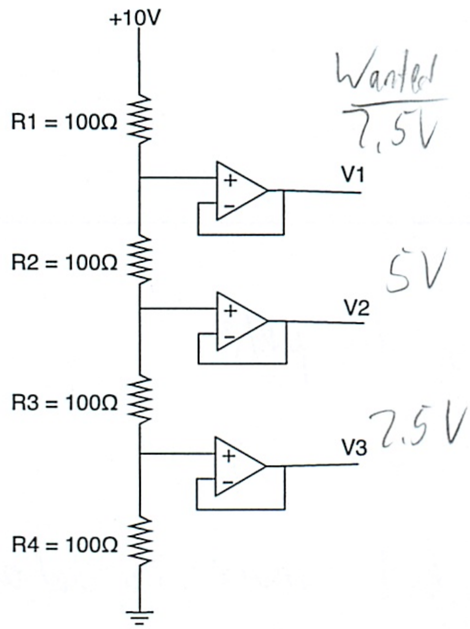
 Lets see if remember better

4 Circuits (20 points)

A. Dana, Emerson, and Flann have a supply of +10 V and want to make buffered supplies of 2.5 V, 5.0 V and 7.5 V for use in their circuit, but they are having a disagreement about how to do it. Here is the circuit Dana suggests:

Oh - dont remember well

Review by doing ans
- even after review session



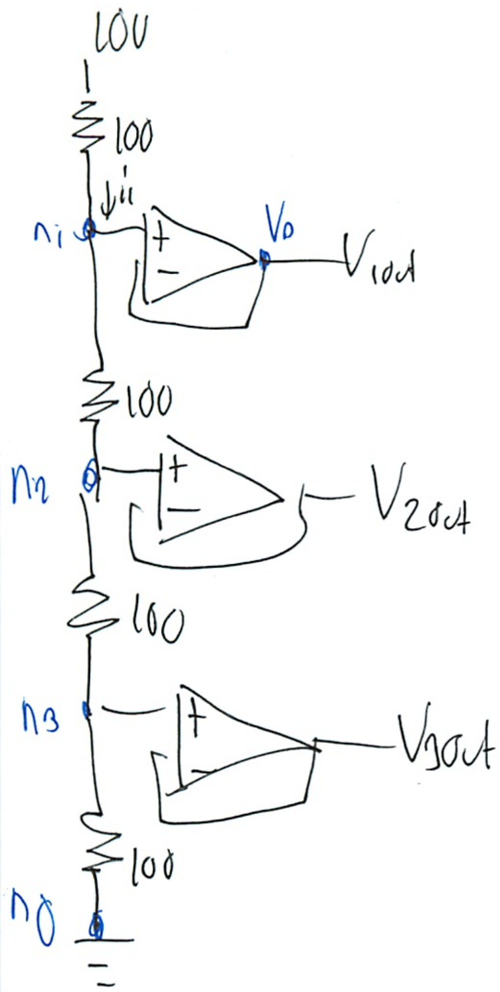
was right
- now confirm in my notes
+ become reaquainted

1. In Dana's circuit, what are the actual values of V_1, V_2, and V_3?

$V_1 =$ 7.5 $V_2 =$ 5 $V_3 =$ 2.5

If they are incorrect, can you change the resistor values to make it work? If so, how?

Correct



$V = IR$

$V_+ = V_-$

$10V - V_1 = i_1 \cdot 100$

(I don't think this is fastest way)

Well have to set = to

~~n_1~~ $= V_1$

$V_1 = V_+ = V_-$

$V_{1\,out}$ = read notes

the normal op amp

$V_{1out} = V_+ = V_- = V_1$

Now V_1 is this voltage divider

shortcut thing

- let me read up on

If I remember this one correctly you start at bottom

Midterm 2 was like this #3

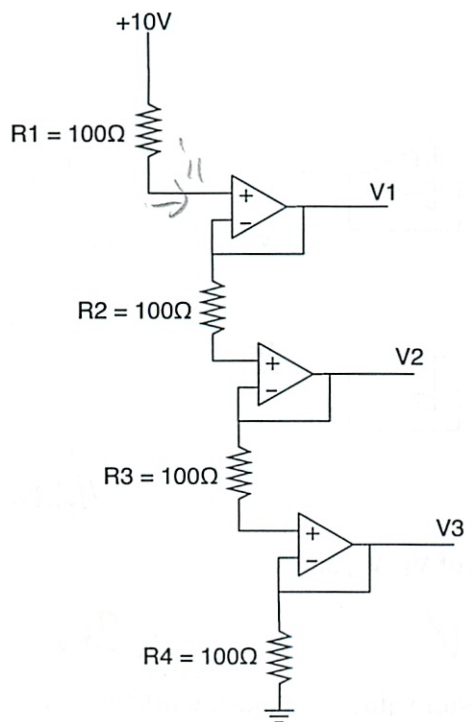
$$V_{end} = \frac{\text{bottom } \Omega}{\text{whole } \Omega} \cdot \text{start } V$$

$$\frac{100\Omega}{400\Omega} \cdot 10V = 2.5V \ 0$$

$$\frac{200\Omega}{400} \cdot 10 = 5V$$

? So combine ones below - and op amp provides seperation/buffering

Here is the circuit that Emerson suggests:



Seperate paper

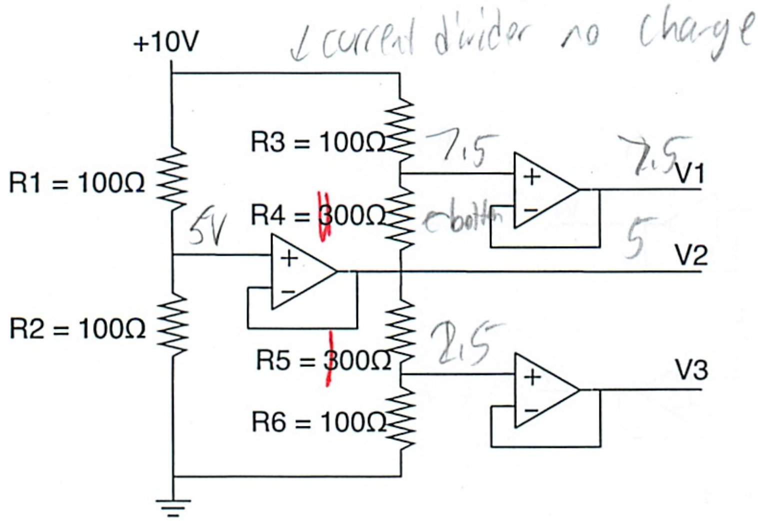
2. In Emerson's circuit, what are the actual values of V_1, V_2, and V_3?

$V_1 =$ ___ $V_2 =$ ___ $V_3 =$ ___

If they are incorrect, can you change the resistor values to make it work? If so, how?

Voltage is the same, but not current

Here is the circuit that Flann suggests:



Seems right but is there a trick

Again - don't get what they did here —OH hmm

3. In Flann's circuit, what are the actual values of V_1, V_2, and V_3?

$V_1 =$ 8.75 $V_2 =$ 5V $V_3 =$ 1.25V

If they are incorrect, can you change the resistor values to make it work? If so, how?

$R_4, R_5 = 100\,\Omega$

2.

Wrong - but what is it

Check op amp sheet

Non inverting amplifier - w/ 0 R_2

But how figure out what each is

(I like building my own circuits - not debugging others)

Well $V_+ = V_- = V_{out}$ w/ these

So maybe it is the same

- yeah it is!

X 10V 10V 10V

Can't fix

Somehow always bumped to 10V

My first intuition was correct

But should be able to do NVCC

(I wish they showed solution on this)

~~[illegible]~~

$10V - V_{1+} = i_1 100$

$$\frac{10V - V_{1+}}{100} = i_1$$

$V_{1+} = V_{1-}$

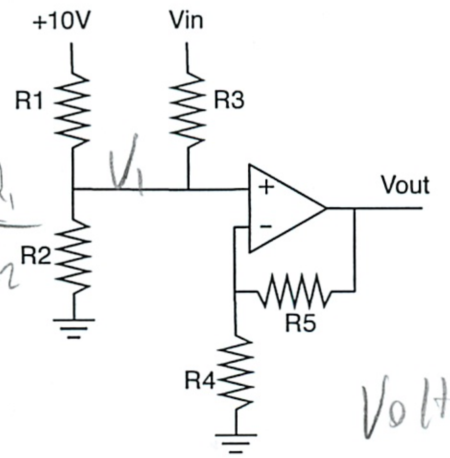
$V_{1+} = V_{1-} = V_{1out}$

?? no confused - skip for now

Did in review
– can I remember

B. Consider the following circuit

$V_1 = \frac{10 \cdot R_1}{R_1 + R_2}$



Voltage adder roughly

1. Write a formula for V_+ (the voltage on the positive input to the op-amp) in terms of V_{in} and the resistor values for this circuit:

– Try NVCC from lecture

first solve each for V_-, V_+ respectively

$$\frac{V_{out} - V_-}{R_5} = \frac{V_- - 0}{R_4}$$

$$R_4(V_{out} - V_-) = R_5 V_-$$

$$V_{out} R_4 - R_4 V_- = R_5 V_-$$

$$V_{out} R_4 = (R_4 + R_5) V_-$$

$$V_- = \frac{V_{out} R_4}{R_4 + R_5}$$

$$\frac{V_1 - V_+}{(R_1 + R_2)} = \frac{V_+ - V_{in}}{R_3}$$

r divider

$$R_3 V_1 - R_3 V_+ = (R_1 + R_2) V_+ - (R_1 + R_2) V_{in}$$

$$R_3 V_1 + (R_1 + R_2) V_{in} = (R_1 + R_2) V_+ + R_3 V_+$$

$$V_+ = V_-$$

$V_+ =$

$$V_+ = \frac{(R_1 + R_2) V_{in} + R_3 V_1}{R_1 + R_2 + R_3}$$

again right in space

$$\cancel{\frac{(R_1 + R_2) V_{in} + R_3 V_1}{R_1 + R_2 + R_3}} = \frac{V_{out} R_4}{R_4 + R_5}$$

but need right V_1

$$\frac{R_3 (10 R_2 + R_1 V_{in})}{R_1 R_3 + R_1 R_2 + R_2 R_3}$$

I don't think I had anything close

2. Write a formula for V_{out} in terms of V_+ and the resistor values for this circuit:

$V_{out} =$

3. For each of these relationships, state whether it is possible to choose resistor values that make it hold in the circuit above. Write **Yes** or **No; it is not necessary to provide the resistor values.**

a. $V_{out} = 2.5 - \frac{3}{16}V_{in}$

b. $V_{out} = 2.5 + \frac{3}{16}V_{in}$

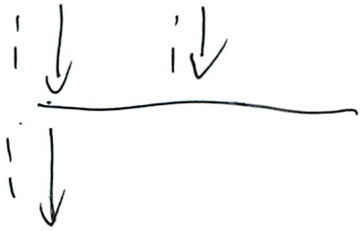
c. $V_{out} = -2.5 + \frac{3}{16}V_{in}$

Let me review w/ review session

$i_2 = i_1 + i_3$

$$\frac{V_+ - 0}{R_2} = \frac{10 - V_+}{R_1} + \frac{V_{in} - V_+}{R_3}$$

Much better
Not trying to force it



$$R_1 R_3 V_+ = R_2 R_3 (10 - V_+) + R_1 R_2 (V_{in} - V_+)$$

Now try ~~own~~ on own

$$V_+ = \frac{R_2 \cancel{R_3} (10 - V_+)}{R_1 \cancel{R_3}} + \frac{\cancel{R_1} R_2 (V_{in} - V_+)}{\cancel{R_1} R_3}$$

$$= \frac{R_2}{R_1}(10 - V_+) + \frac{R_2}{R_3}(V_{in} - V_+)$$

No! How do you get to

$$\frac{R_3 (10 R_2 + R_1 V_{in})}{R_1 R_3 + R_1 R_2 + R_2 R_3}$$

Why am I so bad at circuits
– can't even research ans!

Let me review ans p

$i_4 = i_5$

$$\frac{V_+ - 0}{R_4} = \frac{V_{out} - 0}{R_4 + R_5}$$

req resistance

$$V_{out} = \frac{R_4 + R_5}{R_4} V_+$$

Now why can't I do this

Review circuit problems from past exams

+ redo the Thevin + Norton

5 State estimation (10 points)

We are interested in deciding whether the earth is in one of three states, in any given century: *warming (w), stable (s), cooling(c).*

A. We can do an experiment on an ice sample which gives one of two observations: *melting (m), not melting (n).*

Here are the observation probabilities for the experiment:

$$\Pr(O = m \mid S = w) = 0.9$$
$$\Pr(O = m \mid S = s) = 0.7$$
$$\Pr(O = m \mid S = c) = 0.1$$

Pn = .1
.3
.9

Assume our initial belief state is $\Pr(S = w) = 0.4$, $\Pr(S = s) = 0.5$, $\Pr(S = c) = 0.1$.

1. What would our **belief state** be after doing the experiment and observing n?

w .4 — .9 .36 / .1 ε .04 ε

s .5 — .7 .35 / .3 ε .15 ε

c .1 — .1 .02 / .9 ε .09 ε

? but need to normalize?

.04 + .15 + .9

.28

w/ $\frac{.04}{.28}$ s/ $\frac{.15}{.28}$ c/ $\frac{.09}{.28}$

.14 .535 .32 = 1

dist.DDist({'w' = .14, 's' = .535, 'c' = .32})

think figured it out

Markov chain

B. Now, let's assume that the state of the planet is a Markov process whose transitions can be described, on the scale of centuries, as follows (of course, this is completely climatologically bogus):

new weird way of writing it

		S_{t+1}		
		w	s	c
	w	0.7	0.3	0.0
old S_t	s	0.4	0.2	0.4
	c	0.0	0.3	0.7

1. Circle the following sequences of states that are **possible**.

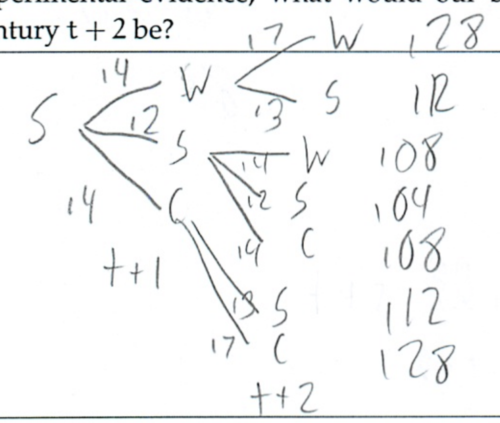
~~**a.** w, s, w, w, c, c, s, w~~

b. c, c, c, s, s, c, s, w ✓

~~**c.** w, s, c, w, s, c, s, w~~

s - not markov stable

2. If we were certain that climate was stable in some century t, and we didn't have any experimental evidence, what would our belief state about the state of the climate in century $t + 2$ be?



No need to normalize
- Should sum to 1

W = .28 + .08 = .36
S = .12 + .04 + .12 = .28 ✓
C = .08 + .28 = .36

 did in review session

6 Search (20 points)

I forget but should be able to re gen what was the solution

A. We want to improve the search performance in the wolf-goat-cabbage problem (summarized below; it is the same as in the tutor problem).

- The farmer has a goat, a wolf and a head of cabbage. They come to a river (they're on the left bank) and need to get everything and everyone to the other side (the right bank).
- There's a boat there that fits at most two of them; the farmer must always be one of the two in the boat.
- If the farmer leaves the goat alone with the cabbage, the goat will eat the cabbage (so that's not a legal state). Similarly, if the farmer leaves the goat alone with the wolf... (so that's not a legal state).

? have no real clue which heuristic would the work

Let $n(s)$ be the number of objects (wolf, goat, cabbage) that are on the incorrect side of the river in state s.

? what would heuristic - do - lowest

1. Andrea suggests that a good heuristic would be $n(s)-1$. Is it admissible? Why or why not?

2. Bobbie suggests that a good heuristic would be $2n(s)-1$. Is it admissible? Why or why not?

3. Casey suggests that a good heuristic would be $3n(s)-1$. Is it admissible? Why or why not?

4. Which heuristic would be likely to reduce the search the most, while retaining optimality of the answer?

# of steps is # of moves
(need to understand what the heuristic is of)

B. We need to travel over a network of roads through the mountains in the snow. Each road has a current condition: *clear*, *slippery*, or *buried*. There are two possible vehicles you can use: a sports car, which can only traverse clear roads or an SUV, which can traverse any road.

You start in the sports car (in location S), but if you are driving one vehicle, and you're in the same location as another vehicle, you can trade vehicles; if you drive your sports car to the location of the SUV (which starts in location A), and trade, then when you move, you will move with the SUV and the sports car will be left at that location.

We will specify the map using the data structure below, which characterizes, for each location, the roads leading out of it. Each road is described by a triple indicating the next location, the length of the road, and the condition of the road.

```
map1dist = {'S' : [('A', 2, 'clear'), ('B', 1, 'slippery')],
            'A' : [('S', 2, 'clear'), ('C', 3, 'clear'), ('D', 10, 'slippery')],
            'B' : [('S', 1, 'slippery'), ('D', 2, 'slippery')],
            'C' : [('A', 3, 'clear')],
            'D' : [('A', 10, 'slippery'), ('B', 2, 'slippery')]}
```

take next lowest cost

We are going to formulate this as a search problem with costs, to be solved using UC search. Let the cost to traverse a road just be the the length of the road times a multiplier: the multiplier is 1 for the sports car and 2 for the SUV. There is a cost of 1 for the action of swapping cars.

The possible actions are to drive on one of the roads emanating from a current location or to swap cars.

don't need to solve yet

1. What information do you need to keep in each state? How will you represent it in Python?

- current location you
- current car
- ~~current loc sports~~
- ~~current loc SUV~~
- ~~cost so far~~

← ~~don't need all of~~ them, but will do

2. How would you represent the starting state (as a Python expression)? [loc, car, sportsLoc, SUVLoc, cost]

['S', 'sports', 'S', 'A', 0]

['S', 'car']

Only 1 place to switch

Back from review session - where did - try again

↓ print documentation ✓

3. What would you pass in as the second argument to ucSearch.search, the goal test, if the goal is to end in location 'D'? ? goalTest

Write Python expression(s)

```
def goalTest(self, state):
    return state[0] == 'D'
```

✓

or w/ lambda

4. Let the actions be described by (action, roadNum), where action is one of 'drive' or 'swapCars', and roadNum is an integer that means which road to drive on out of an intersection. The roadnum can be used as an index into the list of results in map1dist. When action is 'swapCars', then the roadNum is ignored.

just array order

If drivingDynamics is an instance of sm.SM that describes this planning domain, using your state representation, what would the output of this expression be:

```
>>> drivingDynamics.transduce([('drive', 0), ('swapCars', 0), ('drive', 1)])
```

Write a list of states. here they are using code - what would this do

Using review session convention

(S, sports) ← don't forget 1st!

(A, sports)

(A, SUV)

(D, SUV)

? are we using UC

- draw pic
- see (D, SUV) too expensive
- would not be the next one

See pick from review session

no cost

5. From that same start state, what path through state space would be found by breadth-first search, when the goal is to be in location `'D'`? Provide a list of states. end path

S, sports
A, sports
A, SUV
D, SUV

breath first - queue
added in order that is specified

6. From that same start state, what path through state space would be found by uniform-cost search? Provide a list of states.

S, sports
A, sports
A SUV
S SUV
B SUV
D SUV

What is its cost? 13

6.01 Final Exam: Fall 2009

Name: ANSWERS

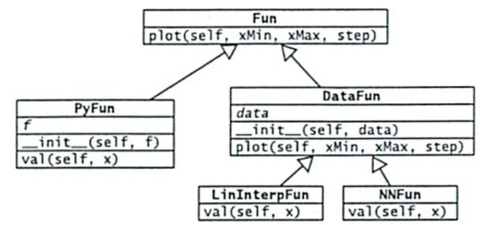
Enter all answers in the boxes provided.
You may use any paper materials you have brought.
You may use a calculator.
No computers, cell phones, or music players.

For staff use:

1.	/20
2.	/10
3.	/20
4.	/20
5.	/10
6.	/20
total:	/100

1 Object-Oriented Programming (20 points)

We will build a set of classes for representing functions (that is, mathematical functions, mapping real numbers to real numbers) in Python. Here is a diagram of the class hierarchy. Each box corresponds to a class, with its name shown in bold. Class attributes are shown in italics and methods are shown in regular text with their arguments. Arrows point upward to the superclass of a class. Fun has no superclass.



Every instance of a subclass of Fun that we create will have two methods: `val`, which takes an x value and returns the associated y value; and `plot`, which takes a description of the minimum and maximum x values for plotting, and the spacing between plotted points, and makes a plot. Different functions will be represented internally in different ways. In this problem, we will implement the Fun, PyFun, `DataFun`, and `LinInterpFun` classes; the `NNFun` class is in the diagram to illustrate where we might put a subclass of `DataFun` that uses a different interpolation strategy.

A. The class Fun is an *abstract superclass*. It won't be useful to make an instance of it, but we can put the `plot` method, which is shared among its subclasses, in it. The `plot` method should create two lists:

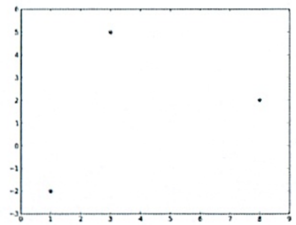
- `xVals` is a list whose first value is `xMin`, and whose subsequent values are `xMin + step`, `xMin + step + step`, etc., stopping so that the last value is as large as it can be, but less than `xMax`. `step` will typically be a float.
- `yVals` is a list of the y values of the function, corresponding to the x values in `xVals`. You can use the `val(self, x)` method, which is required to be defined for any actual instance of a subclass of Fun.

Then, it can call the global function `makePlot` on those lists. Assume `makePlot` is already defined.

So, for example,

`makePlot([1, 3, 8], [-2, 5, 2])`

would make the plot on the right.

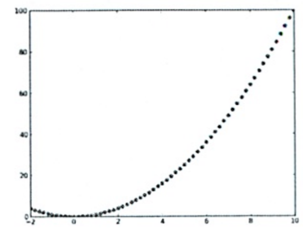


Implement the `plot` method. Recall that Python's `range` only works with integer step size.

```
class Fun:
    def plot(self, xMin, xMax, step):

        xVals = []
        yVals = []
        x = xMin
        while x <= xMax:
            xVals.append(x)
            yVals.append(self.val(x))
            x += step
        makePlot(xVals, yVals)
```


B. The PyFun class is a subclass of Fun. It represents a function just using a Python procedure of a single argument. It should operate as follows:

```
>>> t1 = PyFun(lambda x: x**2)
>>> t1.val(2)
4
>>> t1.val(-3)
9
>>> t1.plot(-2, 10, 0.2)
```



Implement the PyFun class.

```
class PyFun(Fun):
    def __init__(self, f):
        self.f = f
    def val(self, x):
        return self.f(x)
```

C. The DataFun class is a subclass of Fun, representing functions using a list of (x, y) data points, and using an interpolation rule to evaluate the function at values of x that don't appear in the data set. The data points are not sorted in any particular way. Different subclasses of DataFun will provide different interpolation strategies by implementing different `val` methods. DataFun is an abstract class, because it does not itself provide a `val` method. It will provide useful `__init__` and `plot` methods, however.

- The `__init__` method should take a list of (x, y) data pairs as input and store it in an attribute called `data`.
- The `plot` method should first plot the function with regularly-spaced x values, using the `plot` method from the parent class, Fun; then it should plot the actual data points stored in the `data` attribute.

Implement the DataFun class.

```
class DataFun(Fun):
    def __init__(self, data):
        self.data = data
    def plot(self, xMin, xMax, step):
        Fun.plot(self, xMin, xMax, step)
        makePlot([x for (x,y) in self.data],
                 [y for (x,y) in self.data])
```


This part of the problem is worth 5 points; we suggest that you do it only after you have finished the rest of the exam.

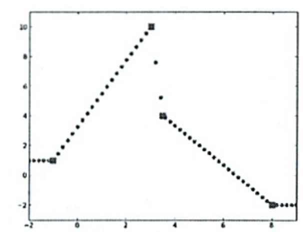
D. The LinInterpFun class is a subclass of DataFun. Its only method is `val`, which performs linear interpolation. That is, given an x_i value as input, it should look through the data to find the x_{lo} value that is, of all x values less than or equal to x_i, closest to x_i, and the x_{hi} value that is, of all x values greater than or equal to x_i, closest to x_i. Let y_{lo} be the y value associated with x_{lo} and y_{hi} be the y value associated with x_{hi}. The method should return the linear interpolation value of y for input x_i, which is:

$$y = y_{lo} + (x_i - x_{lo})\frac{(y_{hi} - y_{lo})}{(x_{hi} - x_{lo})} .$$

If the query x_i is lower than any x value in the data, then the method should return the y value associated with the smallest x value. Values of x_i that are higher than any x value in the data should be handled analogously. You can assume that all numbers are floats; do not assume that the data are sorted in any way.

Here is an example plot made from an LinInterpFun instance. The large squares are the actual stored data points.

```
t3 = LinInterpFun([(3, 10), (-1, 1), (8, -2), (3.5, 4)])
t3.plot(-2, 10, 0.2)
```



Write your answer in the box on the next page.

Implement the LinInterpFun class.

```
class LinInterpFun(Fun):
    def val(self, x):
        xvals = [dx for (dx,dy) in self.data]
        xlo = min(xvals)
        xhi = max(xvals)
        if x <= xlo: return xlo
        if x >= xhi: return xhi
        for (dx, dy) in data:
            if dx < x and dx >= xlo: (xlo, ylo) = (dx, dy)
            if dx > x and dx <= xhi: (xhi, yhi) = (dx, dy)
        return ylo + (x - xlo) * (yhi - ylo)/(xhi - xlo)
```


2 State machines (10 points)

Consider the following program

```
def thing(inputList):
    output = []
    i = 0
    for x in range(3):
        y = 0
        while y < 100 and i < len(inputList):
            y = y + inputList[i]
            output.append(y)
            i = i + 1
    return output
```

A. What is the value of

`thing([1, 2, 3, 100, 4, 9, 500, 51, -2, 57, 103, 1, 1, 1, 1, -10, 207, 3, 1])`

```
[1, 3, 6, 106, 4, 13, 513, 51, 49, 106]
```

B. Write a single state machine class MySM such that `MySM().transduce(inputList)` gives the same result as `thing(inputList)`, if `inputList` is a list of numbers. Remember to include a done method, that will cause it to terminate at the same time as `thing`.

```
class MySM(sm.SM):
    startState = (0,0)
    def getNextValues(self, state, inp):
        (x, y) = state
        y += inp
        if y >= 100:
            return ((x + 1, 0), y)
        return ((x, y), y)
    def done(self, state):
        (x, y) = state
        return x >= 3
```

B. Just considering the sensor, not yet connected into the system, if we feed a **step function** (going from 0 to 1) into a sensor B with $k = 0.8$, what will the output value be (approximately) after 100 steps? Assume the system starts at rest.

1.6

C. If you plug sensor A into the overall system, what is the system function relating Y to X? (Leave k as a variable)

$$\frac{Y}{X} = \frac{R(1-kR)}{1-R+kR^2}$$

D. If we put a sensor of type B into the system, then the overall system function is

$$\frac{R}{kR^2 - R + kR + 1}$$

1. For $k = 0.25$, what are the poles of the system?

$$\frac{1}{8}(3 \pm \sqrt{7}j)$$

Is it stable? Yes Does it oscillate? Yes

2. for $k = 0.1$, the poles of the system are at 0.77 and 0.13.

Is it stable? Yes Does it oscillate? No

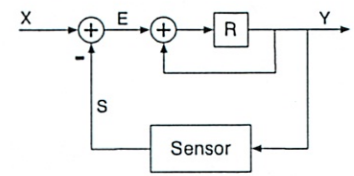
C. Recall the definition of `sm.Repeat(m, n)`: Given a terminating state machine `m`, it returns a new terminating state machine that will execute the machine `m` to completion `n` times, and then terminate.

Use `sm.Repeat` and a very simple state machine that you define to create a new state machine `MyNewSM`, such that `MyNewSM` is equivalent to an instance of `MySM`.

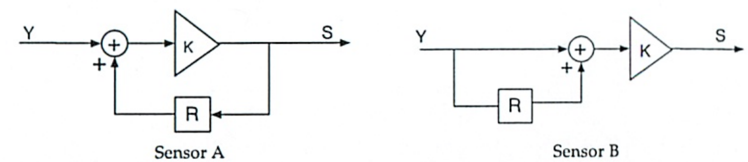
```
class Sum(sm.SM):
    startState = 0
    def getNextValues(self, state, inp):
        return (state + inp, state + inp)
    def done(self, state):
        return state > 100

myNewSM = sm.Repeat(Sum(), 3)
```


3 Linear Systems (20 points)

In the following system, we will consider some different possible sensors.



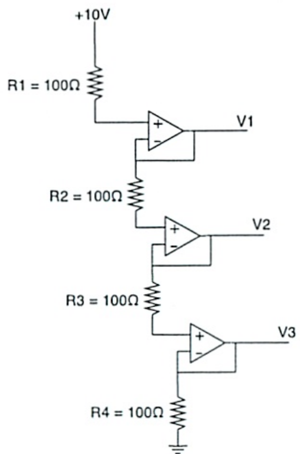
We can buy sensor A or sensor B as shown in the diagrams below. For each of them we can also specify the gain k at the time we order it.



A. Just considering the sensor, not yet connected into the system, if we feed a **step function** (going from 0 to 1) into a sensor A with k = 0.5, what will the output value be (approximately) after 100 steps? Assume the system starts at rest.

3/4, 7/8, 15/16, ..., 1

Here is the circuit that Emerson suggests:



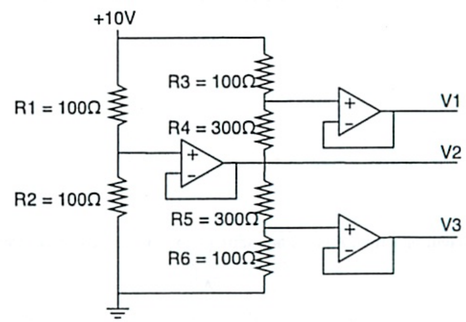
2. In Emerson's circuit, what are the actual values of V_1, V_2, and V_3?

$V_1 =$ 10 V $V_2 =$ 10 V $V_3 =$ 10 V

If they are incorrect, can you change the resistor values to make it work? If so, how?

No.

Here is the circuit that Flann suggests:



3. In Flann's circuit, what are the actual values of V_1, V_2, and V_3?

$V_1 =$ 8.75 V $V_2 =$ 5 V $V_3 =$ 1.25 V

If they are incorrect, can you change the resistor values to make it work? If so, how?

Set $R_4 = 100\ \Omega$ and $R_5 = 100\ \Omega$

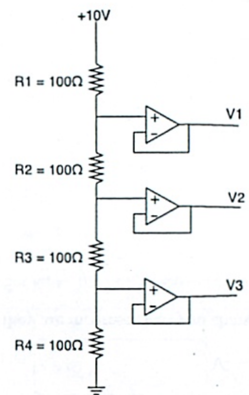
3. If you were buying a sensor of type B, which of these gains would give you faster response? Explain.

Pick k = 0.25 because it converges faster.

Scratch Paper

4 Circuits (20 points)

A. Dana, Emerson, and Flann have a supply of +10 V and want to make buffered supplies of 2.5 V, 5.0 V and 7.5 V for use in their circuit, but they are having a disagreement about how to do it. Here is the circuit Dana suggests:



1. In Dana's circuit, what are the actual values of V_1, V_2, and V_3?

V_1 = 7.5 V V_2 = 5.0 V V_3 = 2.5 V

If they are incorrect, can you change the resistor values to make it work? If so, how?

Correct

5 State estimation (10 points)

We are interested in deciding whether the earth is in one of three states, in any given century: *warming (w), stable (s), cooling(c)*.

A. We can do an experiment on an ice sample which gives one of two observations: *melting* (m), *not melting* (n).

Here are the observation probabilities for the experiment:

$$\Pr(O = m \mid S = w) = 0.9$$
$$\Pr(O = m \mid S = s) = 0.7$$
$$\Pr(O = m \mid S = c) = 0.1$$

Assume our initial belief state is $\Pr(S = w) = 0.4$, $\Pr(S = s) = 0.5$, $\Pr(S = c) = 0.1$.

1. What would our **belief state** be after doing the experiment and observing n?

$\left(\frac{1}{7}, \frac{15}{28}, \frac{9}{28}\right)$

B. Now, let's assume that the state of the planet is a Markov process whose transitions can be described, on the scale of centuries, as follows (of course, this is completely climatologically bogus):

		S_{t+1}		
		w	s	c
	w	0.7	0.3	0.0
S_t	s	0.4	0.2	0.4
	c	0.0	0.3	0.7

1. Circle the following sequences of states that are **possible**.

a. w, s, w, w, c, c, s, w Not possible

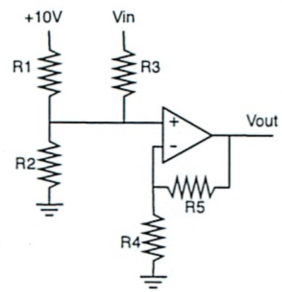
b. c, c, c, s, s, c, s, w Possible

c. w, s, c, w, s, c, s, w Not possible

2. If we were certain that climate was stable in some century t, and we didn't have any experimental evidence, what would our belief state about the state of the climate in century t + 2 be?

$t = 0: \quad (0, 1, 0)$
$t = 1: \quad (0.4, 0.2, 0.4)$
$t = 2: \quad (0.36, 0.28, 0.36)$

B. Consider the following circuit



1. Write a formula for V_+ (the voltage on the positive input to the op-amp) in terms of V_{in} and the resistor values for this circuit:

$V_+ =$

$$\left(\frac{R_3(10R_2 + R_1V_{in})}{R_1R_3 + R_1R_2 + R_2R_3}\right)$$

2. Write a formula for V_{out} in terms of V_+ and the resistor values for this circuit:

$V_{out} =$

$$\left(\frac{R_4 + R_5}{R_4}\right)V_+$$

3. For each of these relationships, state whether it is possible to choose resistor values that make it hold in the circuit above. Write Yes or No; **it is not necessary to provide the resistor values.**

a. $V_{out} = 2.5 - \frac{3}{16}V_{in}$ No

b. $V_{out} = 2.5 + \frac{3}{16}V_{in}$ Yes

c. $V_{out} = -2.5 + \frac{3}{16}V_{in}$ No

3. What would you pass in as the second argument to `ucSearch.search`, the goal test, if the goal is to end in location `'D'`?

Write Python expression(s)

```
lambda s: s[0] == 'D'
```

4. Let the actions be described by `(action, roadNum)`, where `action` is one of `'drive'` or `'swapCars'`, and `roadNum` is an integer that means which road to drive on out of an intersection. The `roadnum` can be used as an index into the list of results in `map1dist`. When `action` is `'swapCars'`, then the `roadNum` is ignored.

If `drivingDynamics` is an instance of `sm.SM` that describes this planning domain, using your state representation, what would the output of this expression be:

```
>>> drivingDynamics.transduce([('drive', 0), ('swapCars', 0), ('drive', 1)])
```

Write a list of states.

```
[('S', 'car'), ('A', 'car'), ('A', 'suv'), ('C', 'suv')]
```


5. From that same start state, what path through state space would be found by breadth-first search, when the goal is to be in location `'D'`? Provide a list of states.

```
[('S', 'car'), ('A', 'car'), ('A', 'suv'), ('D', 'suv')]
```

6. From that same start state, what path through state space would be found by uniform-cost search? Provide a list of states.

```
[('S', 'car'), ('A', 'car'), ('A', 'suv'), ('S', 'suv'), ('B', 'suv'), ('D', 'suv')]
```

What is its cost? 13

6 Search (20 points)

A. We want to improve the search performance in the wolf-goat-cabbage problem (summarized below; it is the same as in the tutor problem).

- The farmer has a goat, a wolf and a head of cabbage. They come to a river (they're on the left bank) and need to get everything and everyone to the other side (the right bank).
- There's a boat there that fits at most two of them; the farmer must always be one of the two in the boat.
- If the farmer leaves the goat alone with the cabbage, the goat will eat the cabbage (so that's not a legal state). Similarly, if the farmer leaves the goat alone with the wolf... (so that's not a legal state).

Let $n(s)$ be the number of objects (wolf, goat, cabbage) that are on the incorrect side of the river in state s.

1. Andrea suggests that a good heuristic would be $n(s)-1$. Is it admissible? Why or why not?

Yes, always less than the number of steps to go.

2. Bobbie suggests that a good heuristic would be $2n(s)-1$. Is it admissible? Why or why not?

Yes, always less than or equal the number of steps to go.

3. Casey suggests that a good heuristic would be $3n(s)-1$. Is it admissible? Why or why not?

No, on the first step, $3n(s) - 1 = 9$ but there are 7 steps to go.

4. Which heuristic would be likely to reduce the search the most, while retaining optimality of the answer?

Use Bobbie's, $2n(s) - 1$, it's the largest admissible heuristic.

B. We need to travel over a network of roads through the mountains in the snow. Each road has a current condition: *clear*, *slippery*, or *buried*. There are two possible vehicles you can use: a sports car, which can only traverse clear roads or an SUV, which can traverse any road.

You start in the sports car (in location S), but if you are driving one vehicle, and you're in the same location as another vehicle, you can trade vehicles; if you drive your sports car to the location of the SUV (which starts in location A), and trade, then when you move, you will move with the SUV and the sports car will be left at that location.

We will specify the map using the data structure below, which characterizes, for each location, the roads leading out of it. Each road is described by a triple indicating the next location, the length of the road, and the condition of the road.

```
map1dist = {'S' : [('A', 2, 'clear'), ('B', 1, 'slippery')],
            'A' : [('S', 2, 'clear'), ('C', 3, 'clear'), ('D', 10, 'slippery')],
            'B' : [('S', 1, 'slippery'), ('D', 2, 'slippery')],
            'C' : [('A', 3, 'clear')],
            'D' : [('A', 10, 'slippery'), ('B', 2, 'slippery')]}
```

We are going to formulate this as a search problem with costs, to be solved using UC search. Let the cost to traverse a road just be the the length of the road times a multiplier: the multiplier is 1 for the sports car and 2 for the SUV. There is a cost of 1 for the action of swapping cars.

The possible actions are to drive on one of the roads emanating from a current location or to swap cars.

1. What information do you need to keep in each state? How will you represent it in Python?

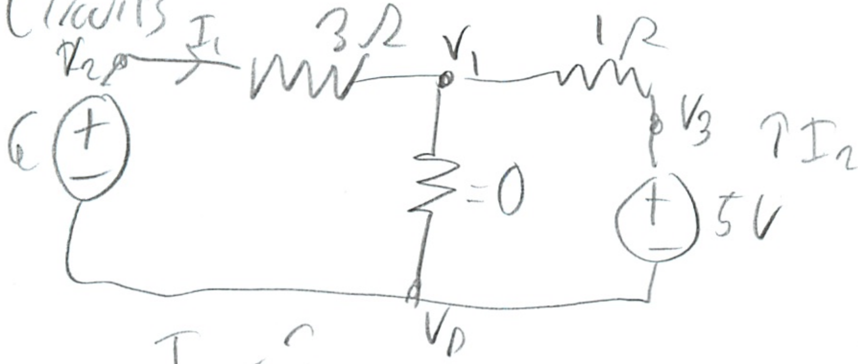
Our location and which vehicle we are using: `(loc, car)`
We don't need to keep in the state where the other vehicle is. Once we change vehicles, we don't ever change back.

2. How would you represent the starting state (as a Python expression)?

`('S', 'car')`

6.01 Midterm 2 Spring 09

1. Circuits



$I_1 = ?$

do full formal way

$V_2 - V_0 = 6V$

$V_2 - V_1 = I_1 \, 3\Omega$

$\frac{V_2 - V_1}{3} = I_1$

$V_3 - V_0 = 5V$

$V_3 - V_1 = I_2 \, 1\Omega$

$\frac{V_3 - V_1}{1} = I_2$

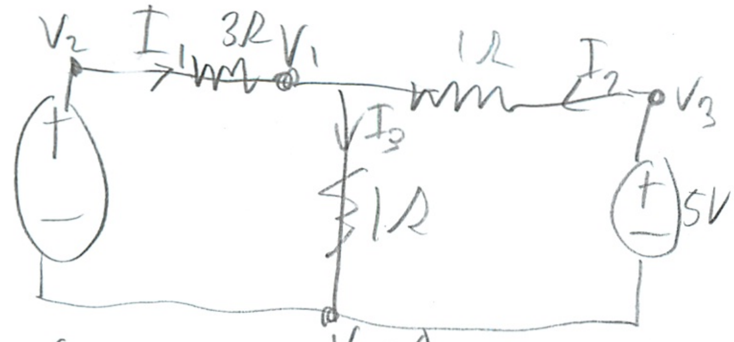
$V_1 = V_0$ here *

$6V = I_1 3\Omega$

$I_1 = 2A$ ✓

a bit long but right

b)



$V_2 = 6V$ $\quad$ $V_0 = 0$

← oh yeah duh

$V_3 = 5V$

$V_3 - V_0 = V_3 - 0 = V_3$

← I may not be 2

$V_2 - V_1 = I_1 \, 3\Omega$

$\dfrac{V_2 - V_1}{3} = I_1$ ← most write like this

oh yeah $I_1 + I_2 = I_3$

$\dfrac{V_3 - V_1}{1} = I_2$

$\dfrac{V_1 - V_0}{1} = I_3$

$\dfrac{V_2 - V_1}{3} + \dfrac{V_3 - V_1}{1} = \dfrac{V_1 - 0}{1}$

$\dfrac{6V - V_1}{3} + 5V - V_1 = V_1$

$2V + 5V = V_1 + V_1 + \dfrac{V_1}{3}$

$7V = \dfrac{7}{3} V_1$

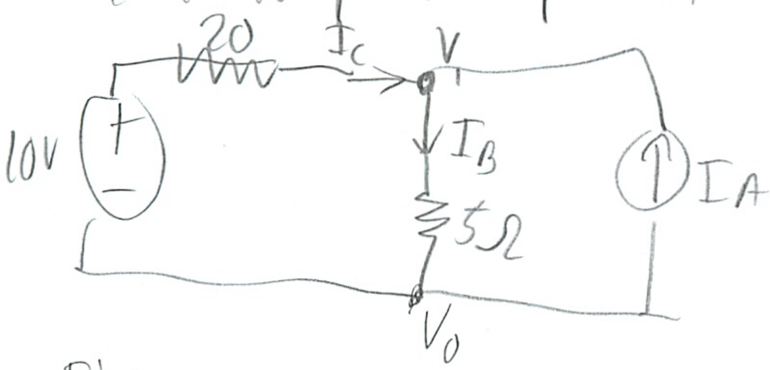
$\cdot\, 3/7$

$V_1 = 7 \cdot \frac{3}{7} = 3V$ ✓

See I can do it – all by myself

but what about an op-amp one

6.01 Final
Fall 08 #6
- key final practice problem!



Find I_C if $I_A = 0$

- think I know it better now

$$\frac{10V - V_1}{20} = I_C$$

$$\frac{V_1 - 0}{5} = I_B$$

realized just plug it in

$$I_A + I_C = I_B$$

$$\underset{\text{told}=0}{I_A} + \underbrace{\frac{10V - V_1}{20}}_{\text{find}} = \frac{V_1 - 0}{5}$$

first need to find V_1

$$50V - 5V_1 = 20V_1$$

$$50 = 25V_1$$

$$2 = V_1$$

really long - but thats ok

$$I_C = \frac{10-2}{20} = \frac{8}{20} = \frac{4}{10} = \frac{2}{5} A$$

✓ did not get before

b) Find i_B if $I_A = 5A$

$$5A + \frac{10 - V_1}{20} = \frac{V_1 - 0}{5}$$ ← may have charged

$$25 + 50 - 5V_1 = 20V_1$$

$$75 = 25V_1$$

$$V_1 = 3$$ ← wolfram alpha says $V=22$

So this was problem - bad algebra

$$I_B = \frac{3}{5} A$$ 4.4 $= \frac{22}{5}$

← seems funny $5 - .6 = 4.4$

what abat other way

$$5 + \frac{10-3}{20}$$

$$5.35$$

c) Find I_A so $I_C = 0$

$$I_A + 0 = I_B = \frac{V_1 - 0}{5}$$

$$0 = \frac{10V - V_1}{20}$$

$$0 = 10V - V_1$$

$$V_1 = 10V$$

$I_B = \frac{10}{5} = 2$

$I_A = 2A$ A

much less of a disaster than last time

but why part B wrong?

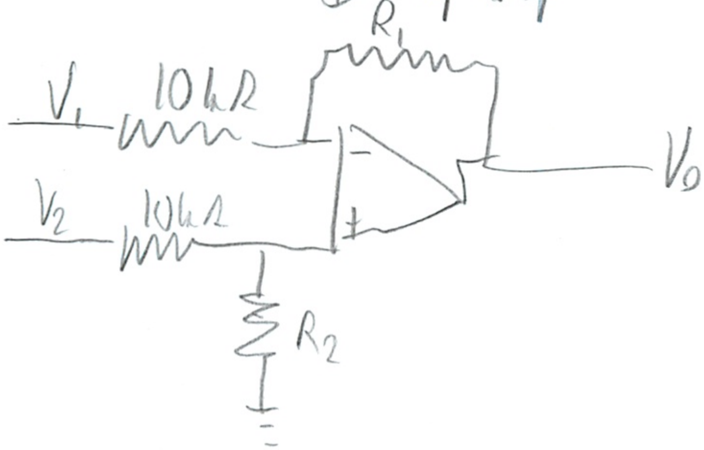
Oh I also did something w/ current dividers

On seperate page

- I like my ans here better

Fall 08 Final

d Opamp



Fill in table

- First check notes for which → subtractor
- Find R_1, R_2 to satisfy

First let me try to find eq on my own

$$\frac{V_1 - V_-}{10k\Omega} = \frac{V_- - V_0}{R_1}$$

be sure to go right direction

$$\frac{V_2 - V_+}{10k\Omega} = \frac{V_+ - 0}{R_2}$$

then solve each for V_-, V_+ respectfully

$$V_1 R_1 - V_- R_1 = 10k\, V_- - 10k\, V_0$$

$$10k V_- + V_- R_1 = V_1 R_1 + 10k V_0$$

$$V_-(10k + R_1) = V_1 R_1 + 10k V_0$$

$$V_- = \frac{V_1 R_1 + 10k V_0}{10k + R_1}$$

$V_+ =$

$$R_2 V_2 - R_2 V_+ = 10k\, V_+$$

$$10k\, V_+ + R_2 V_+ = R_2 V_2$$

$$V_+ = \frac{R_2 V_2}{(10k + R_2)}$$

$V_- = V_+$

$$\frac{V_1 R_1 + 10k\, V_0}{10k + R_1} = \frac{R_2 V_2}{(10k + R_2)}$$

? now what

V_0 - in terms of V_1, V_2, R_1, R_2

$$\frac{10k\, V_0}{10k + R_1} = \frac{R_2 V_2}{10k + R_2} - \frac{V_1 R_1}{10k + R_1}$$

$$10k\, V_0 = \frac{R_2 V_2 (10k + R_1)}{10k + R_2} - \frac{V_1 R_1 \cancel{(10k + R_1)}}{\cancel{10k + R_1}}$$

$\overline{10k}$

$$V_0 = \frac{R_2 V_2 (10k + R_1)}{(10k + R_2)\, 10k} - \frac{V_1 R_1}{10k}$$

- If all 10k then should $= V_2 - V_1$

Test by setting $R_1 = R_2 = 10k$

$$\frac{\cancel{10k}\, V_2\, \cancel{(10k + 10k)}}{\cancel{(10k + 10k)}\, \cancel{10k}} - \frac{V_1\, \cancel{10k}}{\cancel{10k}}$$ checks out

Ok now back to our regularly scheduled problem

$V_0 = 2V_2 - 2V_1$

so want

$$\frac{R_2 (10k + R_1)}{(10k + R_2)\, 10k} = 2$$

(connected)

$$\frac{R_1}{10k} = 2$$

easier start here

$R_1 = 20k$

now back

$$\frac{R_2 (10k + 20k)}{(10k + R_2)\, 10k} = 2$$

$$\frac{3\cancel{0}k\, R_2}{\cancel{10}k\, (10k + R_2)} = 2$$

Took me 4 pages but is correct

$$\frac{3R_2}{(10k + R_2)} = 2$$

could have g+V

wolfram solve

$x = 20{,}000 = 20k$

$V_0 = 2V_2 - V_1$

$\frac{R_1}{10k} = 1$

$R_1 = 10k$

$\frac{R_2(10k + \overset{R_1}{10k})}{(10k + R_2)\,10k} = 2$

$\frac{2R_2}{(10k+R_2)} = 2$

$2R_2 = 20k + 2R_2$ ← oh here how to solve by hand

$0R_2 = 20k$

$R_2 = \infty$ - anything?

$V_0 = V_2 - 2V_1$

$\frac{R_1}{10k} = 2$

$R_2 = 20k$

$\frac{R_2(10k + 20k)}{(10k + R_2)\,10k} = 1$

$\frac{3R_2}{(10k+R_2)} = 1$

$3R_2 = 10k + R_2$

$2R_2 = 10k$

$R_2 = 5k$ ✓

$V_0 = 4V_2 - 2V_1$

$\frac{R_1}{10k} = 2$

$R_F = 20k$

$\frac{R_2(10k + 20k)}{(10k + R_2)10k} = 4$

$\frac{3R_2}{(10k + R2)} = 4$

$3R2 = 40k + 4R^2$
$-4R^2 \qquad -4R^2$

$-R_1 = 40k$

$R_1 = -40k$

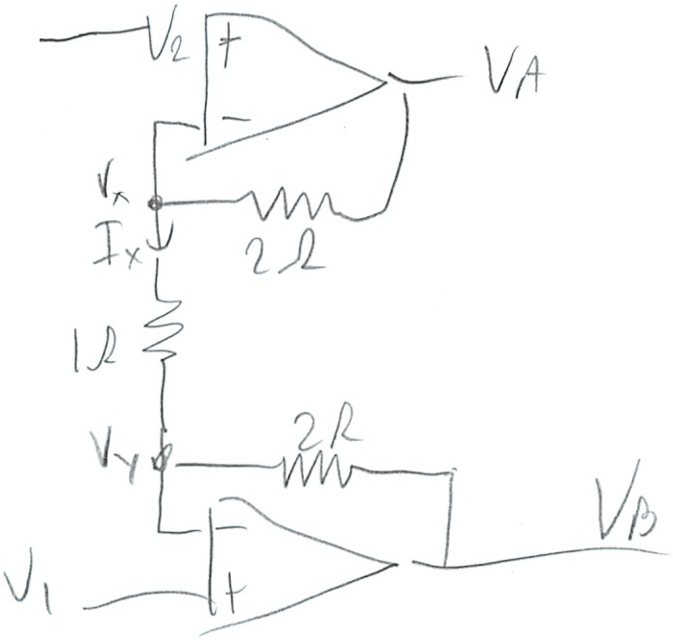
impossible

0

Good - getting the hang of circuits

Nano Quiz 10

- may fav problem - can I remember???



$V_+ = V_-$

a) Determine I_x when $V_1 = 1V$ $V_2 = 2V$

$$\cancel{V_2 = V_+ = V_-}$$

$$\cancel{\frac{V_A - V_-}{2} = I_x}$$

$$V_2 = V_x$$

$$\frac{V_A - V_x}{2} = I_x$$

$$\frac{V_x - V_y}{1} = I_x$$

direction is critical!

~~What~~ $\frac{V_Y - V_B}{2} = I_X$

Which dir is current flowing in?

$V_1 = V_Y$

$$\frac{V_A - V_X}{2} = \frac{V_X - V_Y}{1} = \frac{V_Y - V_B}{2}$$

$V_X = V_2$

$V_Y = V_1$

$$\frac{V_A - V_2}{2} = V_2 - V_1 = \frac{V_1 - V_B}{2} = I_X$$

$$\frac{V_A - 2}{2} = 2 - 1 = \frac{1 - V_B}{2} = I_X$$

$1 = I_X$ ✓

I think I did way too much there

b) Determine V_A when $V_1 = 1$ $V_2 = 2$

? So use same formula

- nothings changed - can use old #

$$\frac{V_A - 2}{2} = 1$$

$$V_A - 2 = 2$$

$$V_A = 4$$

It seems like each time around I solve it differently - they used too many diff methods

c) Determine an expresson for V_A in terms V_1, V_2

$$\frac{V_A - V_2}{2} = V_2 - V_1$$

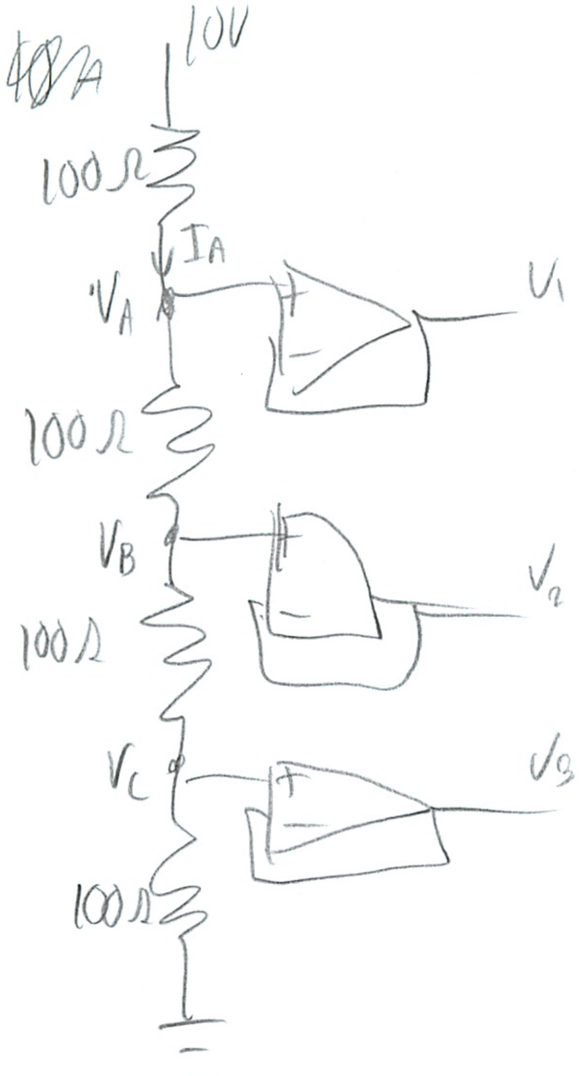
$$V_A - V_2 = 2(V_2 - V_1)$$

$$V_A = 2(V_2 - V_1) + V_2$$

$$V_A = 2V_2 - 2V_1 + V_2$$

$$V_A = 3V_2 - 2V_1$$

I seem to be getting this circuit thing!



$$\frac{10V - V_A}{100} = I_A$$

$V_1 = V_A$ buffered

$$\frac{V_A - V_B}{100} = I_B$$

$I_A = I_B$ same current!

$$\frac{V_B - V_C}{100} \qquad V_2 = V_B$$

$$\frac{V_C - 0}{100} \qquad V_3 = V_C$$

$$\frac{10V - V_A}{100} = \frac{V_A - V_B}{100} = \frac{V_B - V_C}{100} = \frac{V_C}{100}$$

Right???

- no where to confirm

← Voltage divider thing

$$10 \cdot \frac{100}{400} = V_C = 2.5$$

etc

- try others

Emerson

Oh here I_s not the same

$\cancel{V}$

What is it w/ currents + op amps again?

~~VA~~ I at $V_+, V_- = 0$ (draws no current)

It generated needed output current

$$\frac{10V - V_A}{100} = I_1 \quad \text{but } I_1 = 0$$

$$V_A = V_+ = V_- = V_1$$

$$\frac{V_A - V_B}{100} = I_{Br} \text{ from op amp}$$

So what ever so $V_A = V_B$

$\cancel{10 = 10}$

...

Somehow all are 10 V

No way to fix

Well V_1 always 10 V - thats whats coming in

- ? no voltage drop over resistor?

$V = IR$

$10 = \underline{0} \cdot 100$

↑ since no current

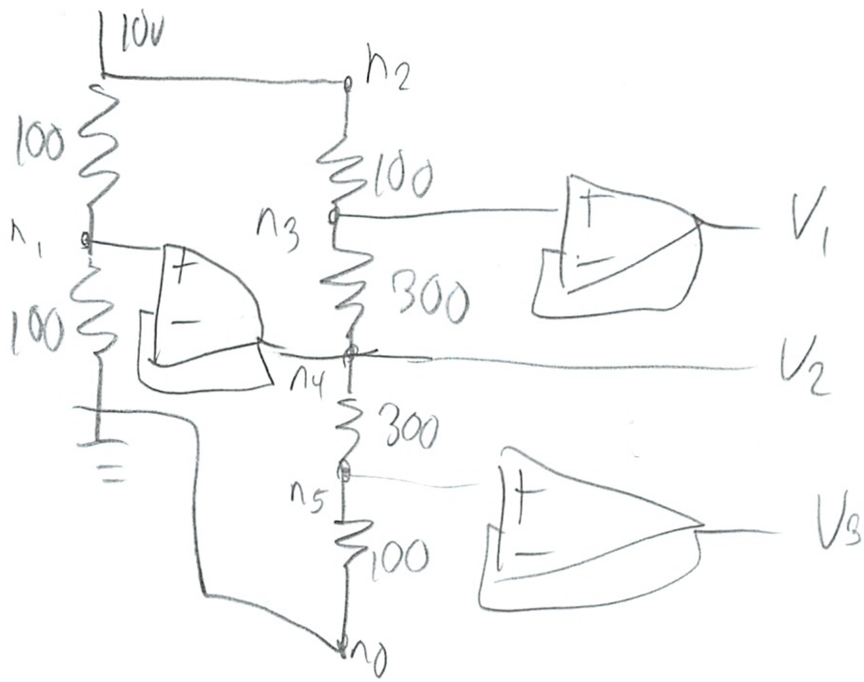
Or whatever current so 10V

Then next

Same as above

(still don't really get - but ship)

Flann



$$\frac{10 - V_1}{100} = \frac{V_1 - 0}{100}$$

$V_1 = 5$

↓ opamp draws no voltage

$$\frac{n_2 - n_3}{100} = \frac{n_3 - n_4}{300}$$

$n_4 = 5V$ from opamp

$n_2 = 10V$ (source)

$$\frac{10v - n_3}{100} = \frac{n_3 - 5V}{300}$$ ✓

← Wolffram alpha $= \frac{35}{4} = 8.75$

find n_3

~~$300 - 300 n_3 = 100 n_3 - 500$~~

$+300 \qquad\qquad +500$

So problem is in solving

but got circuits

~~$800 = 400 n_3$~~

~~$2 = n_3$~~ should be 8.75

? does current go out w/ V_2

— no — nothing is hooked up

?

fix this now

what am I doing wrong?

can't do that distribution of division ~~multiplication~~

let me try something else

$$\frac{10 - n_3}{100} = \frac{n_3 - 5}{300}$$

$\cdot 300 \qquad \cdot 300$

$30 - 3n_3 = n_3 - 5$

$+3n_3 \qquad +5$

$35 = 4n_3$

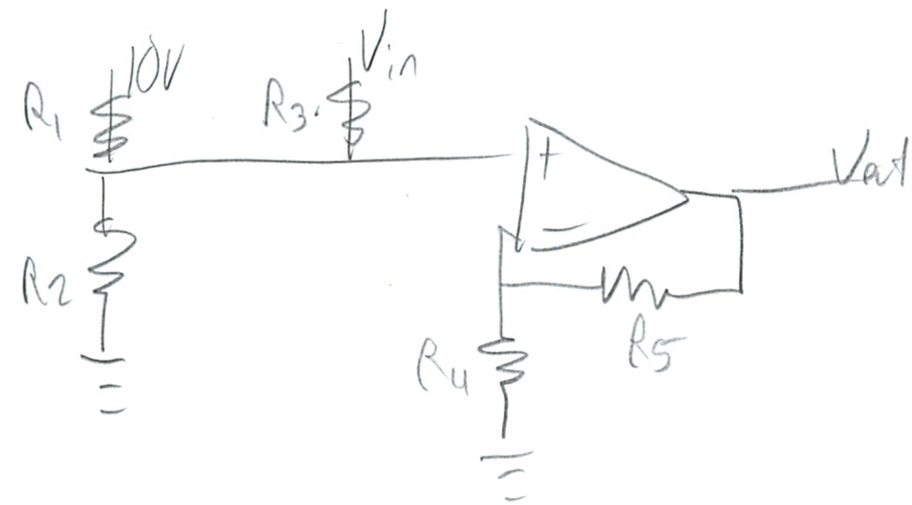
$\frac{35}{4}$ ✓

why can't I get the simple algebra down

— also in Blacks formula

— and in 14.01

B 3rd time



Formula for V_+

Which way current ↓ ↓

↓

$$\frac{10V - V_+}{R_1} + \frac{V_{in} - V_+}{R_3} = \frac{V_+ - 0}{R_2}$$

Solve for V_+

Again w/ denominators

oh right - get common denom

get a common denom!
get the algebra down!

$$\frac{R_3(10V - V_+)}{R_1R_3} + \frac{R_1(V_{in} - V_+)}{R_3R_1} = \frac{V_+}{R_2}$$

$$\frac{10V\,R_3 - V_+\,R_3 + R_1V_{in} - V_+\,R_1}{R_1R_3} = \frac{V_+}{R_2}$$

? now can cross multiply?

Well - what do we want - alll V_+ on 1 side of page

$$\frac{V_+}{R_2} + \frac{V_+ \cancel{R_3}}{R_1 \cancel{R_3}} + \frac{V_+ \cancel{R_1}}{\cancel{R_1} R_3} = \frac{10V R_3 + R_1 V_{in}}{R_1 R_3}$$

? now need common denom

$$\frac{V_+ \cdot R_1 \cdot R_3}{R_2 \cdot R_1 \cdot R_3} + \frac{V_+ R_2 R_3}{--} + \frac{V_+ R_1 R_2}{+ \ldots} = \frac{10V R_3 + R_1 V_{in}}{R_1 R_3}$$

$\circ\ R_1 R_2 R_3$

$$V_+ (\ldots) = \frac{(10V R_3 + R_1 V_{in}) \cancel{R_1} R_2 \cancel{R_3}}{\cancel{R_1} \cancel{R_3}}$$

$$V_+ (\ldots) = 10V R_2 R_3 + R_1 R_2 V_{in}$$

$$V_+ = \frac{10V R_2 \cdot R_3 + R_1 R_2 V_{in}}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

$$= \frac{R_3 (10V R_2 + V_{in} R_1)}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

? how did I switch those two?
- but much nicer!

Now V_{out} in terms V_+

$$V_+ = V_-$$

$$\frac{V_- - 0}{R_4} = \frac{V_- - V_{out}}{R_5} = \cancel{V_{out}} \quad \frac{V_{out} - 0}{R_4 + R_5}$$

(must be some op amp process

$$V_{out} = \frac{R_4 + R_5}{R_4} V_+$$

(I don't care about this anymore