Electrical Engineering

Quals Questions

1995

[2211] MON 01/30/95 09:01 FROM shankle@EE.Stanford.EDU "Diane J. Shankle":
[Mary Gray Baker <mgbaker@plastique.Stanford.EDU>: EE quals question;
135 LINES

ived: by Forsythe.Stanford.EDU; Mon, 30 Jan 95 09:01:52 PST
Received: by EE.Stanford.EDU (5.67b8/25-eef) id AA23158; Mon,
30 Jan 1995 09:01:55 -0800
Date: Mon, 30 Jan 95 9:01:55 PST
From: "Diane J. Shankle" <shankle@EE.Stanford.EDU>
To: Hf.djs@forsythe.Stanford.EDU
Subject: [Mary Gray Baker <mgbaker@plastique.Stanford.EDU>: EE quals question
and solution]
Message-Id: <CMM.0.90.0.791485315.shankle@EE.Stanford.EDU>

For your file
Diane

CS

Return-Path: <mgbaker@plastique.Stanford.EDU>
Received: from plastique.Stanford.EDU by EE.Stanford.EDU with SMTP (5.67b8/25-ee
Received: by plastique.Stanford.EDU (4.1/25-LAGUNITA-eef) id AA28334; Fri, 27 J
Date: Fri, 27 Jan 95 18:13:31 PST
From: Mary Gray Baker <mgbaker@plastique.Stanford.EDU>
Message-Id: <9501280213.AA28334@plastique.Stanford.EDU>
To: shankle@ee.Stanford.EDU
Subject: EE quals question and solution
Cc: mgbaker@plastique.Stanford.EDU

Diane,

ce I can't come to the EE quals meeting, I hope it's okay that I
d you my questions and solutions by email.

Thanks,
Mary
mgbaker@cs

****
Since I was instructed that the goal of these exams is to test a student's potential in the area, and not their actual background, I placed a lot of weight on how the student reasoned about the problems, rather than placing all the weight on the actual answers they came up with.

I also asked about their backgrounds first, so that I could give them questions that wouldn't be frightening but for which they wouldn't know the answers from memory. So different students were asked at least two of the following questions, but they weren't all asked the same questions necessarily. There are lots of different facets to the questions, and their scores depended in part on how much guidance they needed.

1) Describe how you'd implement process migration in a network of workstations.

swer: I looked for a description of the process state that would d to be transferred (process control block, open file information, c.) They also needed to describe how the process's address space would be transferred (paged out some place and then demand-paged in again, transferred directly, etc.). Then I asked them about how they would handle it if the source machine's file cache contained modified file data for the process. Those who just wanted to transfer over the modified pages didn't get full points, because it meant they weren't thinking about how to handle file cache consistency in a distributed system. Those who mentioned writing the data back to the file server did better. There were also plus points for those who enquired about resources in the network, such as whether the source and destination machines could run the same binaries, etc.

2) Given the following two fault-tolerant architectures, compare them in terms of efficiency in the absence of faults and in the presence of faults. Then compare them in terms of the types of hardware and software faults they could detect and/or survive.

Answer: [For this problem I described varying amounts of the set-up for those students with more or less background.] The first architecture is a Stratus-like one that uses lock-step synchronization for its replicated processors. (Both processors run the same replicated process instruction-by-instruction in lock-step.) I added comparison hardware that allows you to compare results between the two processors. The other architecture was more TARGON-like. Again the processors are replicated, but you use a primary/backup process-pair scheme. The replicated processor can run other stuff unless the primary process fails. The primary process's state is periodically checkpointed, and there's a log of its activities after the checkpoint. Both the checkpoint and the log are available to the backup processor in the event of a failure.

They needed to mention that the lock-step system is much more wasteful of resources in the absence of failures. For more points they needed to mention that the process-pair system would take longer to fail over to the backup process in the event of a failure, since it has to process a log from the last checkpoint.

They got plus points for thinking through all the types of hardware and software faults that could occur. If they didn't do this, I helped. They needed to mention that the lock-step system would detect transient hardware problems that cause incorrect results and that the process/pair scheme would not find all of these. They needed to mention that the lock-step scheme might not survive transient software problems, since it's really running in lock-step and both processors would execute the same bug. In contrast, the process-pair scheme might fail over to the backup processor which might escape the bug if it's a transient timing-dependent one that's not triggered by the checkpoint state and log.

3) Would TCP's techniques for handling congestion on a wired Internetwork work well in a wireless environment?

Answer: [Depending on a student's background I described more or less of how TCP works. I also described more or less of the behavior of the wireless medium for those that needed it. For the wireless network I assumed a packet network.]

They needed to explain why acknowledgement timeouts and exponential back-offs on retransmission would help in a congested wired network. They then needed to explain why TCP would think that lost packets in a wireless network looked like congestion when it isn't necessarily. Avoiding the back-off and just retransmitting those lost packets as soon as possible is good. Plus points went to those who mentioned the problems for TCP due to increased variance in latencies in the wireless network.

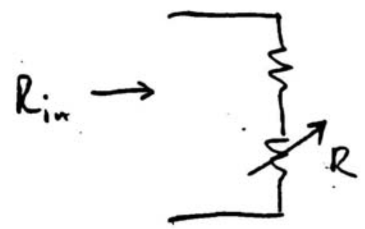
4) Discuss the benefits of location-transparency in a traditional ributed system and whether location-transparency is entirely beneficial in a mobile/wireless environment.

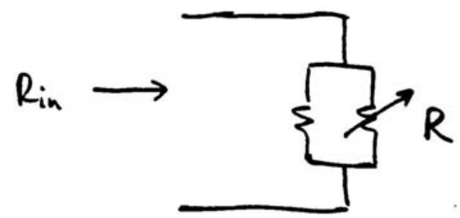
Answer: They needed to mention the usual virtues of location transparency (users/applications shouldn't have to know where resources are but simply what they're called). In a mobile/wireless environment, though, there are applications that want to know where you are. For example, consider a wireless network in a museum. If you're by the Rembrandt, then you'd like your PDA to tell you about the Rembrandt and not the Goya. This question was asked of only a few people. Nobody got the whole answer. I gave some points, though, for people who mentioned that knowing where some resources are in a mobile/ wireless environment may help you or your software make intelligent choices about what to use.

Print requested by HF.DJS on 01/30/95 at 10:59:00 from HF.DJS's message file.

Stephen Boyd

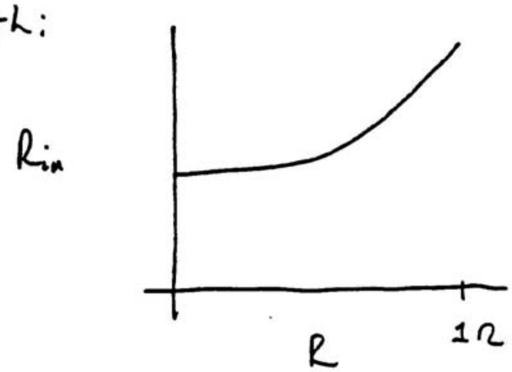
(1) Sketch R_{in} vs. R for:





$0 \leq R \leq 1\Omega$

(2) Design a circuit made of constant resistors and <u>one</u> variable resistor R with:



Discuss.

1995 Electrical Engineering Department PhD Qualifying Exam
Solid State Questions by Prof. C. Chang-Hasnain leave

1. For a typical p-i-n diode with an abrupt doping profile of N_A for the p-side and N_D for the n-side, sketch

(a) the space charge distribution

(b) electric field distribution

(c) the energy band diagram indicating the conduction band edge E_C and the valence band edge E_V

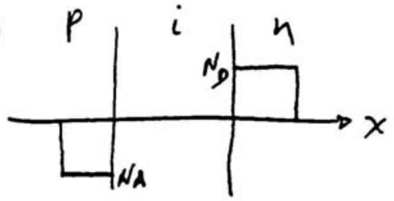
(d) discuss what changes if an extra and equal amount of electrons and holes are generated in the space charge region.

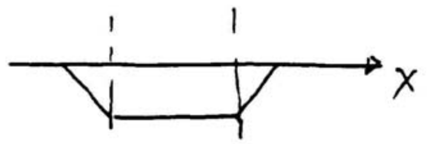
(e) discuss what happens to this device's IV characteristics when it is exposed to light. What happens as the light intensity increases?

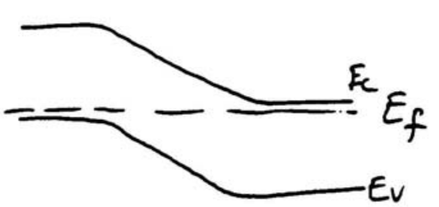
(f) What happens to its IV curve as a function of device temperature?

(g) If the device is exposed to light, what happens to its IV curve as a function of the wavelength of the illumination?

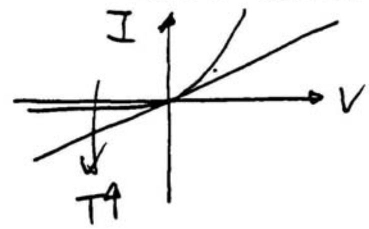
Answers:

(a)


(b)


(c)


(f) As T↑, the pin diode looks more and more like an intrinsic semiconductor → looks like a resistor



(d) negative (drift) Current is generated by the extra ~~g~~ chages.

(e)


(g) If photon energy ($h\nu = \frac{hc}{\lambda}$) is greater than the bandgap of the semiconductor, then there is photo current; otherwise, signal

J. CIOFFI

Quals '95

x is a random variable such that $\Pr\{x=+1\} = \frac{1}{2}$ and $\Pr\{x=-1\} = \frac{1}{2}$. x is added to independent zero-mean Gaussian random variable n to obtain y:

$$y = x + n \qquad E[n^2] = \sigma_1^2$$

(1) 1). What is $E[y]$?

(1) 2). What is $E[y^2]$ and $\sigma_y^2 = E\left[(y - E[y])^2\right]$?

(1) 3). Find $E[y/x]$.

(1) 4). Find $E[y^2/x]$.

(1) 5). Find $\sigma^2_{y/x}$

(2) 6). Determine a rule that uses an observed value of y to decide whether $x = +1$ or -1 such that the probability of error is minimized.

(3) 7) Suppose a second observation $y_2 = x + n_2$ is available where n_2 is zero mean-Gaussian with $E[n_2^2] = \sigma_2^2$ and $E[n_1 \cdot n_2] = 0$. Revise your answer to question 6.

```
oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo
Message 73 (1298 chars)
  urn-Path: <fely@gloworm.Stanford.EDU>
Received: from gloworm.Stanford.EDU by EE.Stanford.EDU with SMTP (5.67b8/25-eef) id AA01524; Mon, 30 Jan 1995 :
Received: from Zotz.Stanford.EDU by gloworm.Stanford.EDU with SMTP (5.67b8/25-eef) id AA06171; Mon, 30 Jan 199!
Received: from [0.0.0.0] by zotz.Stanford.EDU (5.67b8/)
        id AA21212; Mon, 30 Jan 1995 10:15:57 -0800
From: fely@gloworm.Stanford.EDU
Message-Id: <199501301815.AA21212@zotz.Stanford.EDU>
To: shankle@ee.Stanford.EDU
Cc: fely@gloworm.Stanford.EDU
Subject: Quals question from Prof. Dutton      Circuits
Date: Mon, 30 Jan 95 10:15:56 -0800


1) What is it about semiconductors that requires
   the use of Quantum Mechanics?
(Discussion of band theory and where it comes from)

2) What experiments can you think of that show
   that QM real exists?
(Discussion of various real experiments...simple
 non-linear current-voltage curves is not sufficient)

3) Given that electrons according to QM are to behave
   both as particles and waves, in a semi-conductor
   what makes it so difficult to observe the waves?
(Consider for example a resistor with current flowing
in it.  Why will it be extremely difficult to see the
waves?  Is there some other kind of device where
the wave properties will be more observable and why?)
```

Subject: Re: 1995 Quals Questions

This year's quals question(s):
1) What is an interupt?
2) Suppose the probability of an interupt arising during the exection of any instruction is 0.001. What's the probability that one or more interupts arise in the next 1000 instructions?
3) What's Non Restoring division?
4) What's Booth's method of multiplication?
5) What's floating point underflow?

Answer to (2) is 1-(1-.001)exp1000 or about .63
For all other answers see ee182 text(or any introductory text on Computer design/architecture)

Mike Flynn

$1-(1-0.001)^{1000}$

R

OFFICE MEMORANDUM ◇ STAR LABORATORY

February 23, 1995

To: Diane Shankle

From: Tony Fraser-Smith   Electromagnetics

Subject: Ph.D. Quals Question, 1995

Question: Suppose an earthquake occurs in the earth at a depth of d meters (Figure 1). Although we have no idea what kind of electromagnetic signals, if any, are generated in the earth by earthquakes, let us assume that they do produce electromagnetic fields and that these fields have the same amplitude at all frequencies. Given the electrical conductivities (σ) shown in the figure, and given also that the skin depth δ at 1 Hz is 1.6 km for $\sigma = 0.1$ S/m, what frequencies are likely to be observed on the surface for earthquakes in California? Is there any delay? Are there any ways by which the seismic changes in the earth associated with earthquakes might generate electromagnetic signals?

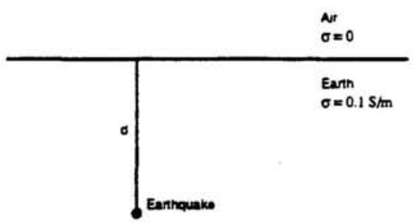


Figure 1. Earthquakes in California typically occur at depths (d, in meters) of around 10 km

Answer: After a brief discussion of good conductors and poor conductors, leading to the conclusion that the above problem must treat the earth as a good conductor ($\sigma/\omega\epsilon \gg 1$, where ω is the angular frequency and ϵ is the permittivity), the student must either remember or derive an expression for the attenuation of electromagnetic fields in a conducting medium in terms of the skin depth, i.e., $\delta = [2/(\omega\mu\sigma)]^{1/2}$, where μ is the permeability. In addition, the student should demonstrate some knowledge of how (1) the wave propagates with phase velocity $v = \omega/\beta = \omega\delta$, (2) it has a wavelength $\lambda = 2\pi\delta$, and (3) it is exponentially attenuated with attenuation constant $\alpha = 1/\delta$. Given the preceding information, it is easy to show that the phase velocity has a $\omega^{1/2}$ frequency dependence (*dispersion*!), meaning that it propagates more slowly as the frequency gets smaller.

With the information given in the problem, em signals with frequencies above 1 Hz will be severely attenuated as they propagate a distance of 10 km to the surface. On the other hand, for $f = 0.01$ Hz, it is easy to derive a skin depth of 16 km from the information given, showing that em signals will not be severely attenuated for frequencies less than about 0.01 Hz. Thus measurements at frequencies less than about 0.1 Hz appear most desirable if em signals from earthquakes are to be detected (more specifically, the frequency for which $\delta = 10$ km is close to 0.3 Hz).

Consideration of the phase (and group) velocity indicate delays of about 1 sec for the signals to reach the surface, which are not likely to be significant. Pressure changes in the earth associated with the earthquake seismic waves might produce electric charges through the piezoelectric effect, and the charge distributions might radiate em waves (very speculative). If the charge is on the surface the em waves will not be heavily attenuated and high frequencies may be observed.

$k \approx \beta + i\alpha$. $\delta = \frac{1}{\alpha}$

$v_{ph} = \omega/\beta = \omega\delta = \sqrt{\frac{2\omega}{\mu\sigma}}$

Message 64 (1594 chars)
Return-Path: <hector@DB.Stanford.EDU>
Received: from Coke.Stanford.EDU by EE.Stanford.EDU with SMTP (5.67b8/25-eef) id AA04126; Fri, 27 Jan 19
Received: by Coke.Stanford.EDU (5.57/25-DB-eef) id AA27352; Fri, 27 Jan 95 12:06:21 -0800
Message-Id: <9501272006.AA27352@Coke.Stanford.EDU>
To: shankle@ee.Stanford.EDU
Subject: qual question
Date: Fri, 27 Jan 95 12:06:20 -0800
From: hector@DB.Stanford.EDU
X-Mts: smtp

EE Qual Question cS
Hector Garcia-Molina, 1995

You wish to compare two files stored on separate computers, to see if they are identical.

PART I: How could you compare the files?

POSSIBLE ANSWER:
(1) Read file on one machine, send all bytes across network, do a byte by byte compare
(2) Compute a "check sum" or signature at one machine, send it across network, and compare to signature of other file.
(3) Assuming files were identical initially, keep a log of changes. Then compare logs.
(4) Compress the file before sending across network.

PART II: For strategy (2) above, compute the probability that the test "fails". Assume each file has p bits, signature is s bits.

POSSIBLE ANSWER:
Consider a given file X with signature Sx being compared against a file Y. There are 2**p possible Y files. Of these, 2**p/2**s have the same signature as Sx. Of these, (2**p/2**s) - 1 will cause our test to fail. (The remaining one with Sx signature is identical to X so the test does not fail.) Thus, the probability that our test gives an incorrect answer is [(2**p/2**s) - 1]/(2**p). If p is substantially larger than s, this simplifies to 1/(2**s).

1995 PhD Quals Question
J. S. Harris

1. (I have a LED demo with a Red, Green & Blue LED which I show to the student) Can you describe what a light emitting diode (LED) is and how it works?

1A. A LED is a p/n junction diode which is operated in forward bias such that electrons and/or holes are injected as minority carriers into the opposite conductivity type material where electrons and holes recombine radiatively to give off spontaneously emitted light.

2. What is different about the 3 LEDs I showed you, what is important and does the semiconductor have to be a direct bandgap semiconductor?

2A. Because of the different colors, the photons must be emitted from transitions with different energies, thus the diodes are made with different materials with different energy bandgaps. Thus it is important to choose a material with the right energy bandgap to give off the desired color and that it have an efficient radiative transition path. The material does not have to be direct bandgap, although these are by far the most efficient. If an indirect gap material is used, you must incorporate an optically efficient trap.

3. (I now show the student a Red semiconductor laser pointer) How does this semiconductor laser differ from the LEDs which we just discussed?

3A. The laser is also a p/n junction diode operating in the same basic manner as the LED except that it is inside a Fabry-Perot cavity which provides optical feedback and when the number of injected carriers is high enough (threshold current), a population inversion is reached and this, combined with the feedback produces stimulated emission and an optical oscillator or laser. Below threshold, the laser is an LED--it emits only spontaneous, not stimulated photons.

4. Why is the laser output so directional and does it have to be made from a direct bandgap material?

4A. The laser output is largely controlled by the optical feedback from the Fabry-Perot cavity, which only occurs over a very narrow angular range. Photons not emitted directly down the optical axis experience no feedback and gain. In contrast to the LED, which can be made with an optically efficient trap in an indirect bandgap semiconductor, a laser can only be made with a direct bandgap material because the trap transition saturates and cannot achieve a population inversion. ☆

5. Would one expect the optical output of the LED and laser to behave differently as a function of temperature?

5A. Yes. The LED output will "change color" or the peak of the output will shift to longer wavelength because the photon energy is directly related to the bandgap, which decreases in energy with increasing temperature. The laser output is controlled by the optical feedback, hence, the Fabry-Perot cavity resonant wavelength. Since the linear thermal expansion coefficient is very small compared to the bandgap shift, the laser output remains at the same wavelength until there is insufficient gain at this wavelength and then the laser either stops oscillating or it "jumps" to a completely different wavelength where there is another Fabry-Perot resonance and sufficient gain to oscillate at this new wavelength.

band gap decrease with increasing temperature.

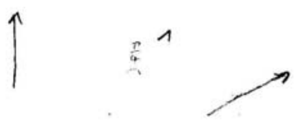
5. (I now put a polarizer in front of the laser and rotate it back and forth by 90° and in one orientation, there is virtually no light and the other, ~100% of the light) What does this demonstration tell you about the laser and what might be the reason for this?

5A. The laser output is polarized along either the horizontal or vertical plane of the laser. Since the Fabry-Perot cavity controls the output, either the cavity shape or the reflectivity of the mirrors is different for TM vs TE polarized light and one mode is strongly favored.

6. (I then put a second polarizer <u>between</u> the laser and first polarizer which is in the position where there is no transmitted light. When this second polarizer is either parallel to or perpendicular to the first polarizer, there is no change, but when it is rotated 45°, to the first polarizer, 25% of the light is now transmitted through both polarizers.) Can you explain why is there output from the laser after passing through the two polarizers at 45° to each other?

6A. When the first polarizer is at 90° to the laser polarization, there is no transmission because there is no component of electric field parallel to the linear polarizer and the new polarizer doesn't change anything when it's either parallel or perpendicular to the first polarizer. However, when the second polarizer is placed at 45° to the laser polarization, there is a $1/\sqrt{2}$ E component that is parallel to the polarizer axis which is transmitted through this new polarizer. The beam is now linearly polarized at 45° relative to both the laser and original polarizer axes and when it now reaches the original polarizer, there is again a $1/\sqrt{2}$ E field component parallel to the polarizer axis and this is transmitted, thus an optical output of 25% of the laser is observed.

Electrical field is $\frac{1}{2}$. energy is $\frac{1}{4}$



Qualifying Exam Question (1995)

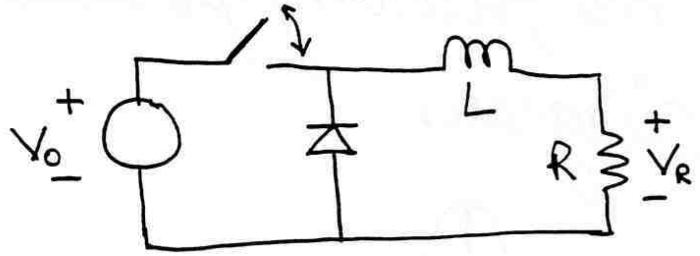
Professor S. E. Harris

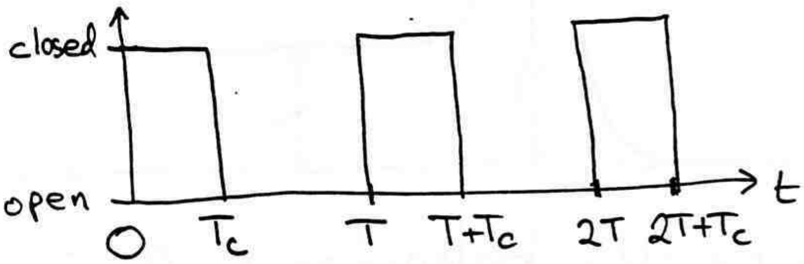
The candidate was told that the exam would have two portions, a qualitative portion discussing heat flow and a quantitative portion on mechanics.

The heat flow question began by asking the candidate to name and briefly describe the constants of a material which one needs to know to describe heat flow. The expected answer was the thermal conductivity, the specific heat, and perhaps the mass density. The candidate was then shown a rough sketch of a long bar to which a square wave of temperature vs. time was applied at the input. He/She was asked to roughly describe the temperature as a function of time at the end of the bar. The question was then modified to have a sinusoidal temperature applied at the input. The expected answer was periodicity and broadening in the first case and a perfect sinusoid in the second case. The candidate was asked for the nature of the partial differential equation describing heat flow; i.e., second derivative in space and first derivative in time.

In the mechanics portion of the exam, the candidate was asked to write the differential equation for a particle which falls under the influence of gravity and a frictional force which is oppositely directed to its velocity. The expected answer was the differential equation for velocity or position as a function of time, followed by the solution which checked the boundary condition. The candidate was asked if there was a terminal velocity. The frictional force was then changed to a force proportional to the square of velocity and, again, the candidate was queried as to the existence of a terminal velocity. The final question was whether, if the same particle was dropped from an airplane moving at a horizontal velocity V_x , how the previous answer would change. The expected answer was that the behavior in the vertical direction was unchanged and that the x component of velocity would damp out.

Prof. Martin Hellman 1995 Quals





Duty Cycle $\equiv T_c/T \equiv \rho$

How does V_R vary with ρ?

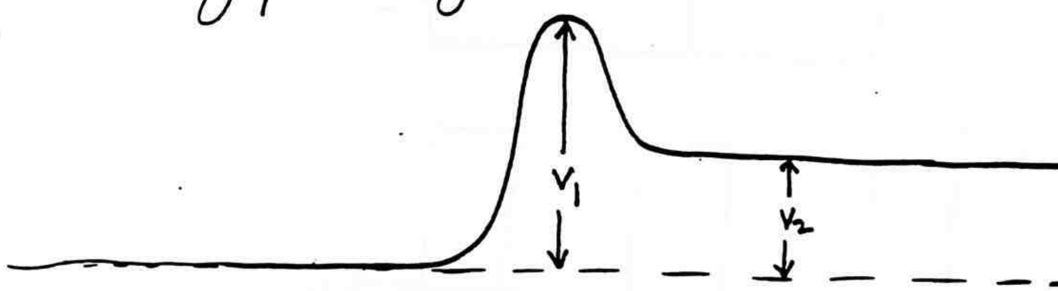
---

1. Consider extreme cases: $\rho=0 \Rightarrow V_R=0$
   $\rho=1 \Rightarrow V_R=V_0$(ss) Hmm... Maybe $V_R=\rho V_0$?
2. But V_R is really a fnctn of time. What single number might characterize it? Avg (DC value)? RMS??
3. Again consider extreme cases $\tau = L/R \to 0$ & $\to\infty$. 0 is easiest $\to V_R(t)=V_0$ when switch closed & $V_R(t)=0$ when open
   $\bar{V}_R=\rho V_0$.
4. $\tau\to\infty$ harder, but get similar using RL ckts.

ITEMS

who is he?

Consider the following potential energy diagram:



(a) Describe the behavior of a particle traveling from left to right, interacting with this potential

(b) Give some examples where we might encounter this potential.

(c) What effect would thermal excitation of the particles (Temp> have?

(d) What is the effect of the curvatu in the diagram?

Answers

(a) For $E < V_2$ perfect reflection with $\vec{V}_{final} = -\vec{V}_{initial}$

For $V_2 < E \leq V_1$ some reflection and some transmission

$$\vec{V}_{reflected} = -\vec{V}_{initial}$$

$$\vec{V}_{transmitted} = \sqrt{V_i^2 - \frac{2V_2}{m}}^{\,1/2}\,\hat{x}$$

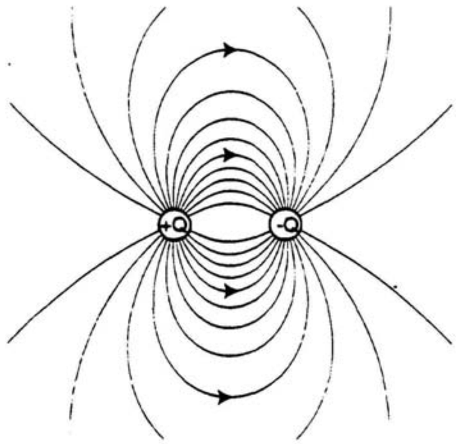
For $E > V_1$ some reflection & some transmission; Transmission probability $\to 1$ as $E \to \infty$.

(b) Shottky barrier, narrow base BJT, HBT, ...

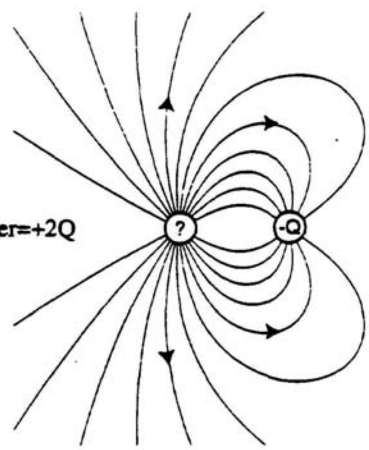
(C) Fermi Dirac Statistics $\Rightarrow$ high energy tails & higher transmission probability

(d) Hard question; in words high transmission implies "good $\vec{k}$ matching. For abrupt boundaries the discontinuity lead to large scattering probabilities due to the wavefunction matching. Smoother boundaries allow for "softer" matching & $\therefore$ high transmission probabilities.

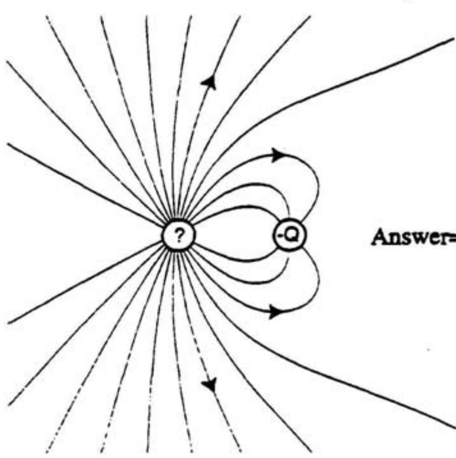
JANUARY 1995 PROFESSOR INAN



PhD QUALS QUESTION #1



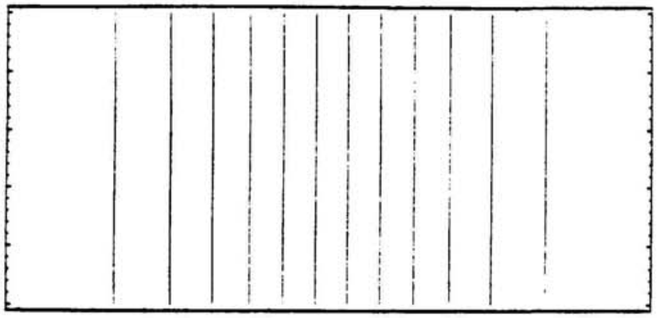
Answer=+2Q

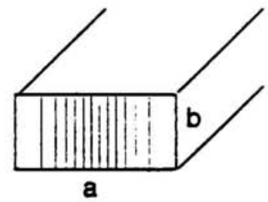


Answer=+4Q

In this problem, we are exploring electric flux, charges and Gauss' Law. The unknown charge can be found by simply visualizing Gaussian surfaces surrounding each charge and counting the number of flux lines. A Gaussian surface enclosing both charges would also work, when one counts the number of lines escaping versus total number of lines, thereby finding net charge. It is also possible to 'draw' equipotential lines and estimate Q by measuring the point of zero potential between the lines.

JANUARY 1995 PROFESSOR INAN Electromagnetics PhD QUALS QUESTION #2

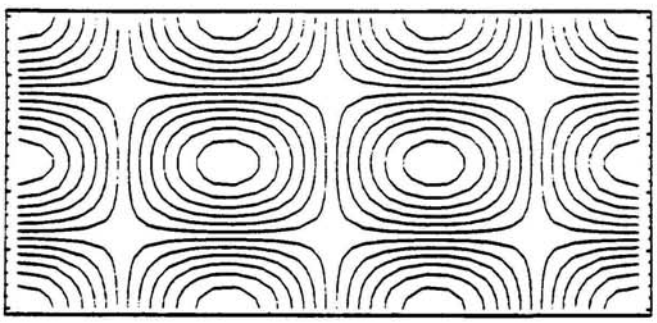




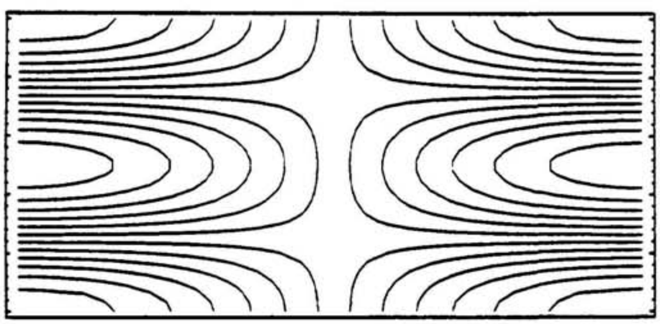
E or H ?

$TE_{??}$ or $TM_{??}$

(I also show the students an actual metallic waveguide)



In this problem, we are exploring boundary conditions for electric and magnetic fields. With a solid understanding of Maxwell's Equations, the solution is straightforward. One has to understand the equations in terms of electric field lines encircling magnetic field lines and vice versa.

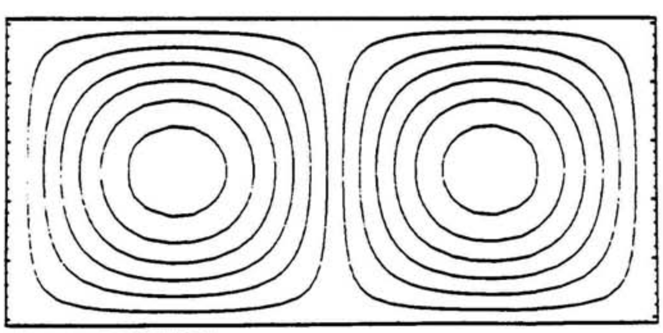


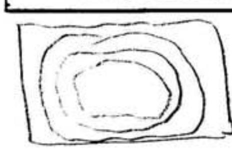
Answers:

E, E, E, H

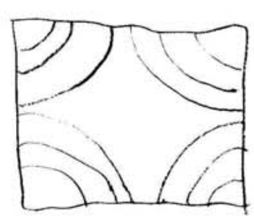
TE_{10}, TE_{32}, TE_{12}, TM_{21}

perpendicular to each oth





TM_{11}



TE_{11}

Prof. Leonid Kazovsky
physics

Ph.D. Quals. January 1994. 5

A DBR laser has two sections: the active, or gain section, and a grating section, as shown in Fig. 1 below:

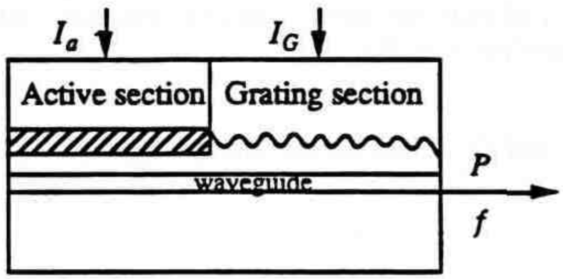


Fig. 1.

Assume that (a) the laser linewidth is zero when I_a and I_G are fixed; (b) the current through the active section sets the laser output power P, and has no influence on the laser frequency f_L; and (c) the current through the grating section changes the laser frequency f_L at the rate $100 MHz / mA$, and has no influence on the laser output power.

Consider an experiment shown in Fig. 2 below:

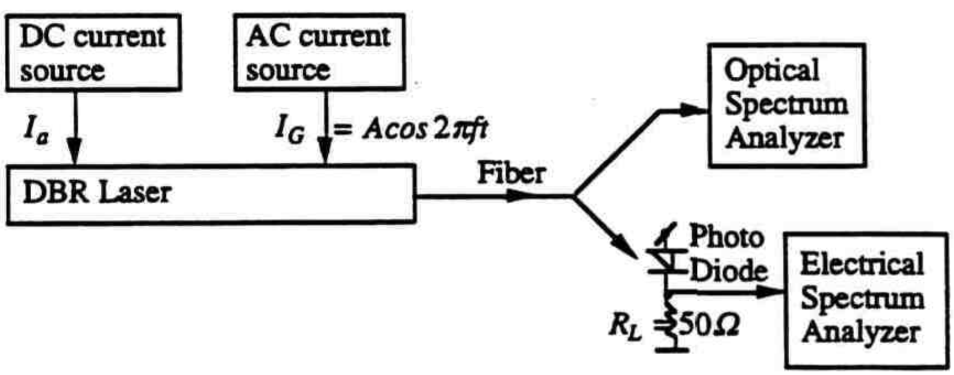


Fig. 2.

Neglect all noises.

Questions:

1. Let $f = 1KHz$ (f is the frequency of the AC current source in Fig. 2) and $A = 1mA$ (A is the amplitude of the AC current source in Fig. 2). Neglecting fiber dispersion, sketch the power spectral densities displayed by the two spectrum analyzers in Fig. 2.

2. Let $f = 10GHz$ and $A = 0.1mA$. Neglecting fiber dispersion and attenuation, sketch the power spectral densities displayed by the two spectrum analyzers in Fig. 2.

3. Repeat (1) and (2) above for the case of ***dispersive*** fiber.

The following was my quals question:
-ttach a spring to a capacitor then apply a voltage to the capacitor and describe the motion of the capacitor ;
aining force.e srping re--More--
i expected the students to set up an equation for the balance of forces and describe instabilities in the motic
The problem was given in terms of a micromachined implementation with cantilevers and parallel plates.

Pierre Khuri-Yakub physics 起重机
>

```
Mime-Version: 1.0
Date: Thu, 16 Mar 1995 08:49:34 -0800
To: shankle@ee.Stanford.EDU
From: goodman@ee.stanford.edu (Joseph W. Goodman)
Subject: EE quals question from David Luckham

>Date: Wed, 15 Mar 95 19:14:14 PST
>From: dcl@hawk.Stanford.EDU (David Luckham)
>To: goodman@soe.Stanford.EDU
>Cc: suvan@hawk.Stanford.EDU
>Subject: EE quals
>
>Joe,
>I do not pose problems requiring solution.
>
>- David
>
>David Luckham: Area: Programming Languages and Methodology.
>
>In the 12 minutes available the candidiate is asked to define or
>describe common concepts and features of modern programming
>languages and their purposes. Typical examples might include,
>but are not limited to,  strong typing, features of various module
>constructs, and simple principles and techniques for constructing
>concurrent and
>multi-task programs. The candidate is expected to be able to illustrate
>his/her answers with examples from well-known programming languages of
>their choice such as Pascal, C++ and Ada, as appropriate. Other topics
>of questions may include, for example,  methodology of  testing and
>verifying programs,
>and features of well-known event-based simulation languages.
>The examination attempts to ascertain the candidate's basic knowledge of the
>area, and does not require the candidate to perform problem-solving under
>stress.
>
```

c s

Subject: 1994/95 EE quals question

1994/95 EE PhD quals question

Marc Levoy CS

My overall strategy was to ask a question just beyond the material they were expected to know, then watch them bridge the gap using what they know, first principles, and reasoning.

Q. What steps are required to geometrically transform (i.e. warp) an image?

A. input discrete image -> reconstruct -> transform (warp) ->
bandlimit for new sampling rate -> resample -> output discrete image

(Hints provided as necessary.)

Q. Describe a typical approximation for two cases: enlarging and reducing

A. Enlarging: bilinear interpolation between samples of the original
Reducing: box filter averaging down of samples of the original

(Any reasonable approximations were accepted.)

Q. Many researchers are interested in performing image warps on compressed data, e.g. JPEG. Can one warp an image in the frequency domain? If so, which kinds of warps? If not, why not?

A. translation = multiplication by a complex exponential,
scaling = scaling, rotation = rotation, shears are also possible,
projective mappings (e.g. perspective) are not, unfortunately for graphics

(I was more interested in how well students classified warps and could reason from their knowledge of Fourier analysis than whether or not they produced this particular list of answers.)

R>

(c) Let's say we go for 20 GHz and get 100 b/sec data.

What rate will we get if we now increase the power from 50 watts to 200 watt

data rate is directly proportional to transmission Power.

[400 b/sec] $\propto P_t$

(d) When we changed from 2 GHz to 20 GHz what did we do ~~to~~ to the required accuracy needed to point the spacecraft antenna?

beam width $\alpha_x = \frac{\lambda}{D_x}$ $\alpha_y = \frac{\lambda}{D_y}$

I understand why but is there a concept to describe the accuracy?

At 2 GHz we needed ± 1 degree accuracy, at 20 GHz ... [0.1° accuracy]

(e) Say it rains over the Earth receive antenna. (Temp 50°K and 30 Meter Diameter) The rain absorption is 3 dB. Before rain data rate is 100 b/sec. During rain it is?

rain loss should hit us twice one by reduce signal power. one by add noise

$\Delta T \rightarrow$ (200/50 ⇒ 4) Abs = 2 [Bit 100/8] $= 12.5$

?

(f) Super modulation ~~[illegible]~~ improves from 10 dB Eb/No ~~[illegible]~~ to 4 dB Eb/N

what is the increase in 100 b/sec Data [⇒ 400 b/

6 dB = 4 times

without rain. temperature is 50K°

with 3dB loss. (3dB ⇒ 2)

$T_{eff} = 50 + \frac{290(2-1)}{2} \approx 200°K$. temperature increase 4 times.

Quals question from: Bruce Wagner 1/2

A spacecraft is on the way to Mars. When it passes by the moon it is able to transmit 1 Million bits/sec to the 30 Meter antenna at Goldstone. It has a 50°K noise temp.

The Spacecraft has a 3 Meter Antenna and transmits 50 watts.

(a) At Mars how many bits per second can it transmit? Mars is 1000 time farther than the moon. [1 bit/sec]

$\propto \frac{1}{R^2}$

(b) We want to increase the data rate without increasing antenna sizes or transmit power. The present frequency is 2 GHz. We can go to either 200 MHz or 20 GHz. What ~~power~~ data rate results for each frequency? [100 b/s @ 20 GHz, .01 @ 200 MHz]

$\propto \frac{1}{\lambda^2} = f^2$

Date: Wed, 15 Mar 1995 01:22:52 PST
From: PIERO PIANETTA AT SSRL <pianetta@ssrl01.slac.stanford.edu>
To: shankle@ee.stanford.edu
Subject: RE: 1995 Quals Question

Devices

Question:
(a) Assume that a very sharp probe is held less than 100 Angstroms away from a clean semiconductor surface. Describe how the semiconductor bands would react to this probe. What happens when a bias is put between the probe and semiconductor.
(b) Now assume that photons with energy sufficient to eject photoelectrons are incident on the semiconductor surface and the probe is biased positively. Describe how the photoemitted electrons would react to the biased probe.

Answers:
(a) An acceptable analysis would be to use an analogy of an MOS capacitor since the gap between the probe and semicondcutor is in fact an insulator. Some students also got into the complications added by the sharp tip.

why?

(b) This situation could be analyzed assuming the tip of the probe is a point charge and then the method of images could be applied to determine the profile of the electric field which then could be used to infer the area over which the photoelectrons would be collected.

method of image should only be used for metal boundary condition?

Fabian

1995 Quals Questions - Pease

physics

1. Define Inductance.
2. Write down the expression for the impedance of an inductor (phase or notation).
3. Why is a coil a suitable shape for an inductor?

   Bring out a moving - coil loudspeaker
4. How does this loudspeaker work?
5. Over what range of frequencies?
6. What is printed on the loudspeaker ("8 ohms, 0.5W")?
7. Why does it say '8 ohms' without reference to frequency (given that the electrical component is a coil)?
8. Why does it say '0.5W' when you cannot dissipate power in an inductor?
9. How would you relate the mechanical work done by the cone to the electrical characteristics of the loudspeaker?

Return-Path: <shankle@ee.stanford.edu>
Received: from [36.4.0.74] (schankle-mac.Stanford.EDU) by EE.Stanford.EDU with SMTP (5.67b
Date: Mon, 13 Feb 1995 09:16:35 -0800
Full-Name: "Diane J. Shankle"
Message-Id: <199502131716.AA16646@EE.Stanford.EDU>
Mime-Version: 1.0
Content-Type: text/plain; charset="us-ascii"
To: EE-Faculty@ee.Stanford.EDU
From: shankle@ee.stanford.edu (Diane Shankle)
Subject: Quals Questions
Cc: EE-adminlist@ee.Stanford.EDU

Good Morning,

Please turn in your 1995 Quals Questions.

Thanks,
Diane Shankle
Mc C 160

James

1994 EE QUALS - PLUMMER

In the first part of the exam, I asked each student to draw a simple CMOS inverter and to explain its basic operation. I wanted to make sure that each student had a basic understanding of this logic gate and its advantages and disadvantages. Most students correctly drew the inverter, explained its operation, drew a basic transfer function and commented on the reasons for CMOS technology dominance in modern silicon ICs. This part of the exam took only the first 3 minutes or so, and was not weighted very heavily in the score.

The main part of the exam dealt with a bipolar equivalent to the CMOS inverter. I asked each student to sketch a BJT equivalent and to describe how it might operate. Most students did this successfully. However, a direct BJT equivalent will only operate at low supply voltages and I next asked about this problem and what solutions the student might suggest to extend the operating voltage range to say 5 volts. Adding input resistors is the simplest solution, but there are other possibilities. Finally, I asked questions about the relative performance of the BJT circuit vs. CMOS. This led to issues like power consumption, fabrication complexity, speed etc.

In grading the exam, I was primarily looking for how the student reasoned about things he/she had not seen before. Generally I offered as much help as was needed to figure out how the BJT inverter worked and in the follow-up questions comparing CMOS and the BJT circuit. The grade I gave was influenced by how much help I had to give.

From: Vaughan Pratt <pratt@cs.stanford.edu>
Message-Id: <9501270636.AA01889@Coraki.Stanford.EDU>
To: shankle@ee.Stanford.EDU
Subject: My EE exam questions

1. Is the intersection of a type X language and a type Y language a type Z language. Answer for X,Y,Z each regular or context-free (8 cases). Prove or give a counterexample.

Solution:

RRR	yes	two FSA's run in parallel is still an FSA
RRL	yes	regular is context-free
RLR	no	Take R = Sigma*
RLL	yes	The R merely expands the finite control of the L
LRR	no	Take R = Sigma*
LRL	yes	same as RLL
LLR	no	see next line
LLL	no	a^mb^mc^n & a^mb^nc^n = a^nb^nc^n, not context-free.

Expectation: the student should get all 8 yes/no parts, and should have these examples or equivalent.

2. Is the complement of a type X language a type X language, for X (a) regular and (b) context-free?

Solution:

(a) Yes. Complement the set of accepting states of a deterministic FSA.
(b) No. Otherwise the answer to 1(LLL) would be yes by De Morgan's law.

Expectation: (a) this argument (no other is known) (b) this argument or equivalent.

3. State and prove the pumping lemma for context-free languages.

Solution:

If L is an infinite context-free language then there exist strings u,v,w,x,y, with one of v or x nonempty such that uv^nwx^ny is in L for all n >= 0. Proof. Let G be a Chomsky-normal-form grammar for L having k nonterminals. For such a grammar any derivation can at most double the length of a sentential form at each step. Hence any derivation of a string of L of length at least 2^{k+1} must take at least k+1 steps. Hence some symbol, say A, must be rewritten twice in that derivation, by the pigeon-hole principle, via S =>* uAy =>* uvAxy =>* uvwxy. But then S =>* uAy =>* uwy is also a derivation of G, as are S =>* uAy =>* uvAxy =>* uvvAxxy =>* uvvwxxy, S =>* uAy =>* uvAxy =>* uvvAxxy =>* uvvvAxxxy =>* uvvvwxxxy, and so on, showing that all strings uv^nwx^ny are in L. Every step of a Chomsky-normal-form derivation must increase the length, whence in particular uAy =>* uvAxy must increase the length, whence one of v or x must be nonempty. QED

Expectation: This statement or the Hopcroft-Ullman version (there exists an n such that for every z of length n or more, z=uvwxy such that ...).

3)
For relability in hardware, redundancy is used. Why doesn't it work for OS. What's the problem. Solutions?

Software is deterministic so replication doesn't help. Something like N-version programming can help.

From: mendel@Lagunita.Stanford.EDU
To: shankle@ee.stanford.edu (Diane Shankle)
Subject: Re: Quals Questions
Date: Mon, 20 Mar 95 02:45:05 PST

EE Quals - Winter 1995 - Mendel Rosenblum

1)
One of the things that operating systems do is manage the hardware resources of a computer system. Examples of resources include storage space (memory, disks), processing elements (CPU, I/O devices), higher level abstractions (open files, network connections, etc).

There are two related techniques used to control resources: scheduling and allocation.

(a) What's the difference between these techniques?

It is important for the OS not to "lose" track when allocating storage. Two different techniques are used. One is to have the OS explicitly track of storage allocation and deallocation. The other is for the OS not to explicit track but it might need to search around and find requests when needed.

(b) Describe the tradeoffs between these techniques. Give examples when one is better. When would you use each.

ANSWER #1

(a)
We usually used scheduling when talking about preemptable resources and allocation when talking about non-preemptable resources. Scheduling implies "How long" while allocation is "Too whom".

(b)
This is basically asking you to compare explicit resource management such as reference counting with garbage collection. If you have plenty of resources so that you rarely run out, garbage collection can result in a lower overhead than explicitly tracking storage. Explicit is good when tight controls are needed.

2)
The OS defines the interface to resources and services. This can be thought of as an user interface for application programmers. It allows user access and control of resources. Describe issues (tradeoffs) in what should go into interfaces. What do we look for in such a interface. (goals?)

(Example: Subsystem FS)

(b) Are the differences between interfaces for multiprogramming system and personal computers? What? (Optimizations?)

ANSWER #2

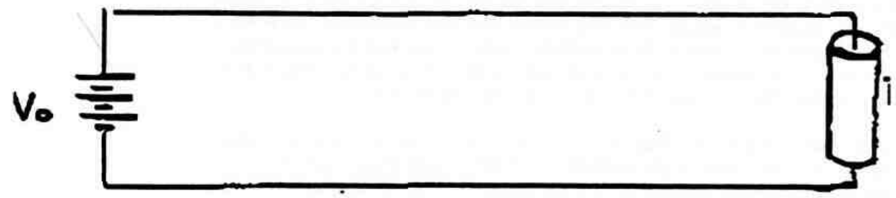
When designing such an interface you need to tradeoff ease of use with providing information for optimizations. More information can make the OSes job easier but the programmers harder.

(b)
Typically, more information is needed in a multiprogramming system to handle balancing the system between the users.

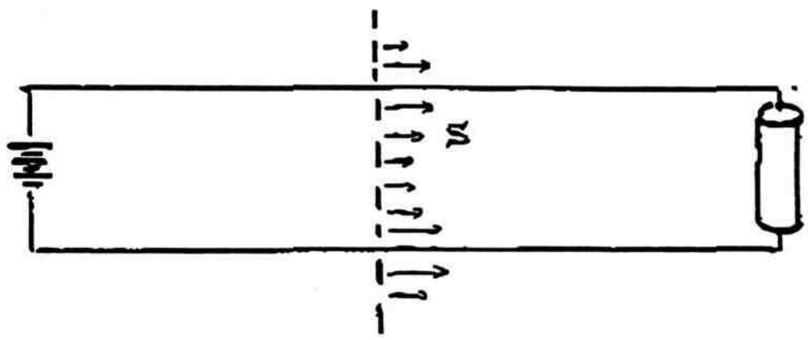
Anthony

Quals Question, A. E. Siegman, January 1995
(Electromagnetic Theory)

First I drew a dc circuit on the board as below and asked the trivial question: what's the DC power delivered by the battery to the resistor?



Then I said, I've heard there's something called the Poynting vector that's related to power: what <u>is</u> the Poynting vector? Is it valid at DC? If I got satisfactory answers to this, maybe after a little probing, I said, OK, can you show me where the E and H fields and the Poynting vector are in the midplane of this DC circuit? I expected to get something like the sketches below. If I did, I could probe this with questions like: Does this really give the power flow? -- or does the DC power really "flow in the wires"? I could also ask" what's the Poynting vector on the surface of the cylindrical resistor?



From: saraswat@cascade.Stanford.EDU
To: shankle@ee.stanford.edu
Cc: saraswat@cascade.Stanford.EDU
Subject: 1995 Quals Question & Answer Devices
Date: Mon, 20 Mar 95 15:08:36 PST

I had an experimental setup with a photodiode connected to an oscilloscope. The photodiode was inside a small box and hence was not obvious. The only source of light in the room was a fluorescent light. It was illuminating the photodiode through a small hole in the box. The oscilloscope showed a 120 Hz signal. I asked the students to analyze the experiment.

I expected the students to first figure out what was generating the signal, i.e. the sensor in the box was a photodiode. Then I expected them to explain why the oscilloscope showed a 120 hz signal. I also had an alternative light source with constant output - a flashlight. They were supposed to figure out that the fluorescent light goes through a discharge in each halves of an electrical cycle and thus converts a 60 Hz electrical input to 120 bursts of light per second. If they did not know how the fluorescent light works, I gave them lots of hints. My sessions were generally fairly interactive with the students.

Krishna Saraswat

Quals Questions:
Len Tyler, January, 1995

Electromagnetics

1. Given a transmitter emitting a single pulse of frequency f_o, and duration T, received by a pair of receiving antennas located at some remote distance, how would you process the signals from the two receiving elements in order to determine the direction from the receiving site to the transmitter? State your assumptions about this problem. Give your answer in the form of the algorithm or the processing method that you propose, and point out the important principles relevant to this problem.

Is the time duration of the pulse important? If so, why?

What factors determine the accuracy with which the direction can be determined?

The difference in the arrival time at the two antennas provides the difference in the path length from the source to the two elements, which from the geometry can be interpreted in terms of the angle of arrival of the signal from the transmitter. This may be measured by noting the time of increase/decrease in the power on the two elements, or by storing the received signals and using cross correlation, or by using the phase difference. When using the phase there is a potential ambiguity in the path difference of an integer number of path lengths, depending on the geometry. In general, the phase measurement is more accurate than the time delay difference, and the ambiguity can be resolved by combining the phase measurement with the arrival time measurement; the actual outcome depends on the geometry, the SNR, and the signal duration. Use of the cross-correlation is essentially equivalent to the combined phase/time-delay technique, provided that the underlying frequency of oscillation is retained. In the extremes, long pulses favor accurate phase measurements, short pulses favor time-delay measurements. Approaches that require the simultaneous presence of signals on the two receiving elements will not work when the length of the pulse is space is comparable to or less than the propagation path difference.

2. It is reported that a static electric field exists in the natural environment, that is, in remote areas well away from cities, factories, highways, and other man-made structures and devices.

What could be the source of such a field?

How would you expect this field to be oriented?

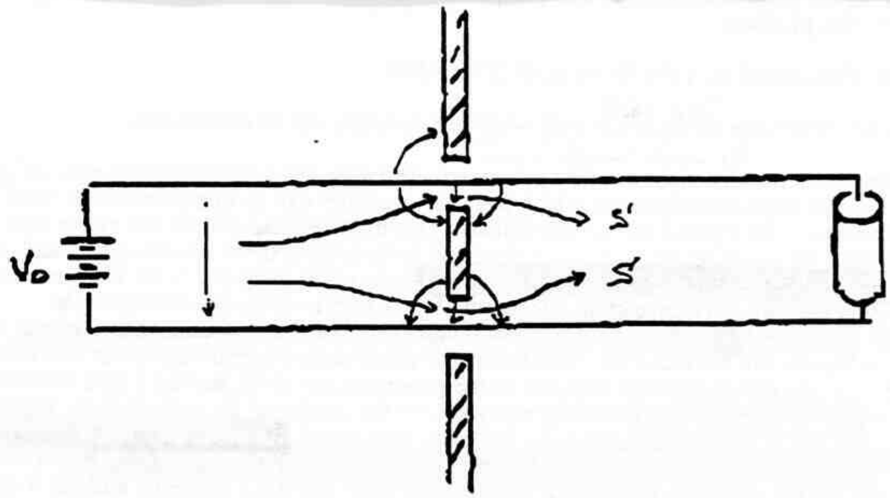
How would you determine if such a field exists — how would you measure it?

What are the important parameters in such a measurement?

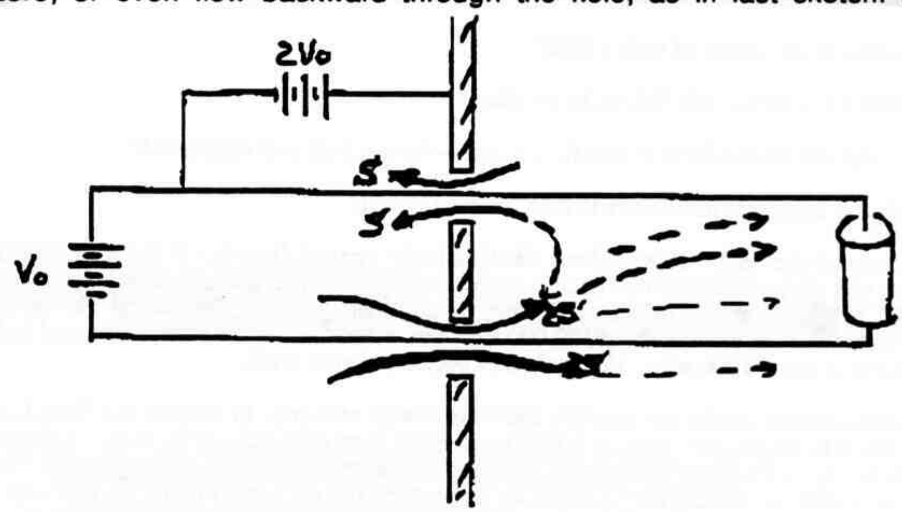
(The source of the field, which is about 100 V/m in the vertical direction, is not well understood. It is part of a global electrical circuit comprising the surface of the earth, the ionosphere, and the atmosphere. This circuit is driven by electric charge exchange in thunderstorms. The net charge on the surface of the earth is about 500,000 Coulombs, and the current between ground and the ionosphere is about 1000 amp. You are not expected to know this!)

Thunderstorms are an obvious possible source of charge exchange to support this field, but others could be suggested. Any such field is expected to be oriented normal to the surface of the ground, owing to the static nature of the field and the finite conductivity of the ground. The field can be measured by placing a large capacitor in the open and then determining the potential difference or the charge that will develop. When measuring the potential difference the impedance of the instrument must be large compared with air! Ben Franklin used a similar technique to determine the much stronger fields that exist in the vicinity of thunderstorms. The presence of an ordinary cloud, however, is readily determined by the change in field strength when it is overhead, as compared with clear skies.

Then I said, OK, let's explore this further. Suppose I put in a metal sheet covering most of the midplane (I drew the sheet on the board), with holes for the wires. It seems to me this thick metal sheet should block much of the Poynting vector—will this really somehow change the DC power flow to the resistor? I expected students to modify the sketch as shown below, deducing that the E fields are changed, becoming stronger in the holes and curved near holes, so that the Poynting vector actually is concentrated and flows through the holes (and quite a few did this).



Finally, with the best students I could play additional games by applying a dc voltage to bias the metal shield up and down; the result of this can be interesting cases where the Poynting vector through either hole may go to zero, or even flow backward through the hole, as in last sketch. (below)



'5 qual questions
nifer Widom

CS

Question 1. Suppose you are given a file of student records, where each record has three fields: ID, course, and grade. You expect to answer many questions of the form: give me all records for ID = x, where x is some constant. Describe the different types of extra mechanisms or structures that could be used so that these types of questions can be answered very efficiently. What are the trade-offs in the different mechanisms/approaches?

Answer 1. (1) Maintain a permanent hash table that maps a record ID to a list of pointers identifying where the records for that ID are located in the file. (2) Use a permanent B-tree indexing structure that, for a given ID, finds the records in the file. (3) Keep the records sorted, either as an optimization to or instead of (1) or (2). If (3) is used instead of (1) or (2), some kind of binary search would be needed. In contrasting (1) and (2), (1) can provide constant time access while (2) requires logarithmic time. However, the performance of (1) can degrade when many new records are added, while the performance of (2) should not.

Question 2: Suppose in a distributed system there is a table R(A,B) at site 1 and a table S(B,C) at site 2. A user at site 1 wishes to get the "join" of tables R and S, i.e., the user wants one record (A,B,C) for every record (A,B) in R and every record (B,C) in S such that the B values match. Assume that the most expensive operation is sending data across the network between sites 1 and 2. Describe two different algorithms for computing the join, and explain in which scenarios th algorithm is preferable.

Answer 2: Algorithm (1) = all of table S is sent from site 2 to site 1; the join operation is performed at site 1. Algorithm (2) = the B values in R are sent from site 1 to site 2; the matching (B,C)s from S are sent from site 2 to site 1; the join is performed at site 1 using the S values received. Algorithm (1) is preferable in the case where most (B,C) values in S are matched in R, since it avoids the extra communication step in which R's B values are transmitted. However, if many S values are not matched in R, and the number of different B values in R is not vastly larger than S, then (2) is preferable since the extra S values are never shipped.

physics

EE Quals '95 , Thomas X. Wang

Prob. : Given a intrinsic semiconductor film, and assume that its resistivity is due to accoustic lattice wave scattering only design a simple experiment to confirm that scattering mecha

Comments: ① $\rho = \frac{1}{\sigma}$, $\sigma = ne\mu_n + pe\mu_h$, $n = p = n_i$

② $\mu_n, \mu_h = \frac{e\tau}{m^*_{n,h}} \propto \tau = \frac{l}{v} \propto T^{-3/2}$

③ $\boxed{n_i = n_i(T) = \sqrt{N_c N_v}\, exp(-E_g/2kT)}$, $N_c N_v = f(T)$

Therefore, the key is to measure $\mu(T)$, not merely σ

④ Four-point method to measure $\sigma(T)$

⑤ Hall effect to measure mobility, $R_H = \frac{V_y}{J_x B_z t_y}$

$$\mu_H = \sigma R_H = \frac{p\mu_p^2 - n\mu_n^2}{p\mu_p + n\mu_n} = \mu_p - \mu_n \propto T^{-3/2}$$

Quals Solution (1995)

(1) 1). $E[y] = E[x] + E[n_1] = 0 + 0 = 0$

(1) 2) $E[y^2] = E[y^2] + E[n_1^2] = 1 + \sigma_1^2 = \sigma_y^2$

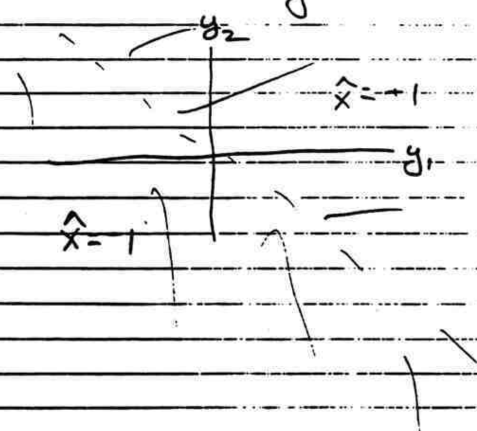
(1) 3). $E[y/x] = x$

(1) 4). $E[y^2/x] = 1 + \sigma_1^2$

(1) 5). $\sigma_{y^2/x} = 1 + \sigma_1^2 - 1 = \sigma_1^2$

(2) 6). $\hat{x} = \begin{cases} 1 & y > 0 \\ -1 & y \le 0 \end{cases}$

(3) 7).



Quals question given by Tom Cover.
Subject area: Elementary probability and statistics

I decided to examine narrowly in probability and statistics based on undergraduate courses like Stat 116 or mezzanine level courses like EE278.

I asked two questions. The first was on the waiting time for recurrence for stochastic processes and the second had to do with two-dimensional Poisson processes.

1. *Question 1: Recurrence times.*

   Question:

   Suppose you open a book to a page at random and pick a position on the page at random and inspect that letter. What is the expected number of symbols you will have to read before you encounter that letter again?

   Answer:

   A typical answer would be: Assume the letters are equally probable and independent. Then the waiting time for success is geometric with expected waiting time $\frac{1}{p}$. Since p is $\frac{1}{26}$, the expected waiting time is 26 letters.

   I would then ask: What if the letters are not independent? Suppose that the letter that is inspected has frequency of occurrence p? What is the expected waiting time to see it again?

   Some examinees saw clearly that this was strictly a combinatorial problem. That if the frequency of occurrence of a given symbol is p, then the gaps between symbols had to be $\frac{1}{p}$, otherwise there would be a contradiction.

   Thus $\frac{1}{p_i}$ is the waiting time to see the recurrence of symbol i and p_i is the probability of seeing symbol i. So the unconditional expected waiting time is $\sum_1^{26} p_i(\frac{1}{p_i}) = 26$ and one gets the same answer as in the independent identically distributed case.

   In short, the examinee is led to discover that the expected waiting time for the recurrence of a randomly chosen symbol is equal to the alphabet size. This exercise approximates the give and take that takes place in thesis research.

2. *Question 2:*

   There were usually three or four minutes left for a question designed to test the knowledge of stochastic processes and elementary reasoning.

   Question:

   Suppose one is given a Poisson process in the plane with parameter λ. Let the random variable R be the distance from the origin to the nearest point. What is the cumulative distribution function for R?

Answer:

Students who did well on this noticed immediately that the random variable R exceeds r if and only if the circle of radius r is empty. This occurs with probability $e^{-\lambda A} = e^{-\lambda \pi r^2}$. This is equal to $1 - F(r)$. Others reduced the problem to solving it on the line and found the density of the minimum of two exponential random variables (again, an exponential random variable).

General Comments:

These two questions had the virtue that no one was shut out. Everybody could get a toe hold on these questions, and the answers could be developed from elementary knowledge. The problem was that the exam didn't create a large gap between the best and the worst performance, nor did it have the sort of depth that would bring out the real stars. On the other hand, the exam is really supposed to be most accurate in ranking those people near the middle. I had the usual difficulty making those distinctions.

I keep reminding myself that the distribution of talents of those taking the exam should look like the upper tail of a Gaussian, since that's the tail we snip off when the students are admitted. Nonetheless, the performance of the students on the exam seemed roughly Gaussian to me.

Ph.D. Qual Question January 1995
Professor Donald C. Cox

signal

We want to transmit a "timing pulse" over a radio link. We will want to detect the radio pulse and use it to start a clock.

First we want to look at the transmitted pulse.

- The transmitter transmits on a carrier frequency of f_0
- The timing pulse we have available is a single rectangular pulse of width T. We may want to modify the shape of the pulse as we proceed in this discussion.

Question 1a: What is the amplitude spectrum or energy spectrum of the transmitted signal if you transmit the rectangular pulse multiplied by $\cos 2\pi f_0 t$? Sketching the spectrum is adequate.

Almost all recognized:

- the pulse spectrum to be T sinc fT
- Cos $2\pi f_0 t$ spectrum to be $\frac{1}{2}[\delta(f - f_0) + \delta(f + f_0)]$
- <u>Multiplication in the time domain to be convolution in the frequency domain</u>
- The amplitude spectrum to be $\frac{T}{2}[\text{sinc}(f - f_0)T + \text{sinc}(f + f_0)T]$

and sketched the spectrum with zeros at $f_0 \pm \frac{1}{T}$ and $- f_0 \pm \frac{1}{T}$

1b: Is this a good spectrum or waveform to transmit?

- Many recognized that the significant amount of energy away from $f_0 \pm \frac{1}{T}$ would be a source of interference, but some didn't. We discussed.

Question 2a: Now look at modifying the transmitted pulse in the time domain to restrict the amplitude spectrum. If we want to restrict the spectrum so that no energy falls outside the band $f_0 \pm \frac{1}{T}$, what would the time domain pulse look like? Perhaps we want to fill the band $f_0 \pm \frac{1}{T}$ uniformly with energy.

Some noted that "filling the band" uniformly would result in a sinc pulse in time. Others truncated the amplitude spectrum, T sinc fT, with a rectangular function in the frequency domain and noted the original rectangular pulse in time would be convolved with a sinc in time. In either case, the resulting time domain pulse is non-causal with "wiggles" or "ripples" out to $\pm\infty$. Most were able to sketch some reasonable version of a time domain pulse.

2b: Is this a realizable waveform?
(no, non-causal, extends to $\pm\infty$)

2c: How might your approximate such a time pulse (since it did have good frequency domain properties)? Most noted you could truncate the pulse and delay it in time to yield a causal pulse. Depth of discussion varied.

2d: What is the effect in frequency domain of the truncation? Most noted energy spills out beyond $f_0 \pm \frac{1}{T}$? We don't want an exact solution, not enough time, but give an approach that could upper bound the energy spilled out, looking only at the truncated time waveform. Discussion followed, often with hints, but only a few noted that integrating the waveform squared outside the truncation boundaries would provide a way to upper bound the energy.

Question 3: If we want to detect the pulse at a remote receiving site and perhaps use it to start a timing clock, what would we need for a receiver? We have an antenna that will receive a band of frequencies around f_0, what is needed after the antenna? Discussion.

Some noted the need for a bandpass filter centered at f_0. Most started with a product demodulator or synchronous detector, i.e., by multiplying the antenna output by cos $2\pi f_0 t$. I then noted you were at a remote site and didn't have a source of f_0. Then what could you do?

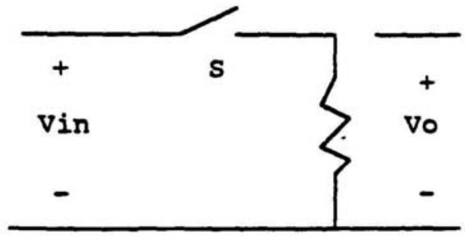
Many students did not know how to proceed from here. Several noted they needed an envelop detector, but didn't know how it could be implemented. A very few noted that a square law-device or a diode detector followed by a capacitor or a low pass filter would work, and they sketched a plausible detector circuit. A few more managed to suggest a diode detector, rectifier or square law device, and low pass filter, after hints.

Very few students went this far.

Question 4: Back to the transmitted pulse. If you were to produce the transmitted pulse digitally, are there any other factors that could result in energy being "spilled" out beyond $f_0 \pm \frac{1}{T}$? that is, any factors in addition to the truncation we discussed earlier? A few mentioned quantization.

Quals Oral questions of G Franklin   *Emeritus*

There were three questions.
1) You are given the circuit drawn below. The switch S is run by a closck and is alternately open and closed.
(a) Is the circuit linear; give a proof of your answer.



ans. The circuit is linear. demonstrate by application of superposition.

(b). Is the circuit time-invarient; give proof of your answer?

ans. NO, demonstrate by application of shift invariance principle.

2). The standard control design methods of rotlocus, Bode's method, Pole placement are all based on linear, time-invarient models. However, ALL applications of control are to non-linear systems . How do we get away with this? Why do we spend so much time of LTI systems when nature is non-linear?
ans. Several points should be made.

i) almost all non-linear systems can be approximated near equilibrium by a linear model.
ii) linear analysis is very general and designs based on linear models depend only on the system and not on the inputs.
iii)Linear design methods are well developed and effective (where they apply).

At this point, the examiner introduces the following:

To fix ideas, suppose the model is given by:

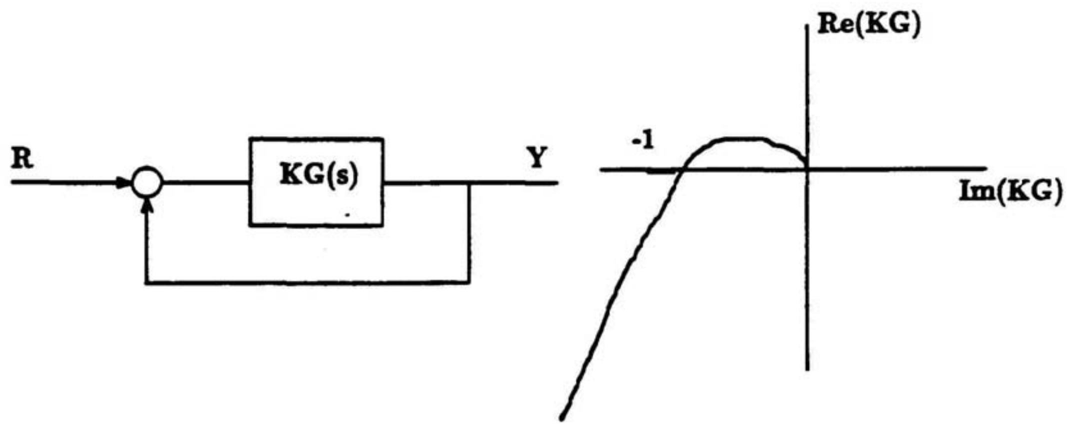
$$\dot{x} = f(x) = Fx + g(x); \quad f(0) = 0; \; x(0) = x_o$$

where f and g are non-linear functions and Fx is the linear approximation to f about the equilibrium. What can we say about the properties of the non-linear equations based on the properties of thelinear approximation?

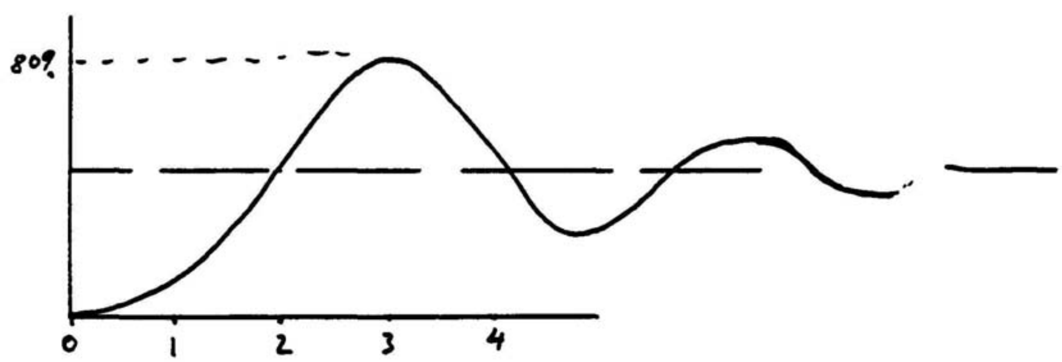
iv) If the linear apprixmation is asymptotically stable, then the non-linear equation wil be stable in some region near equilibrium.
v) Lyapunov stability theory can be used to estimate the extent of the region of stability.

vi) The methond of linear apprixmation has been widely used and found to be effective in control design.

3). Given the standard unity-feedback system sketched below, the Nyquist diagram is found to be as drawn. Please sketch the step response you would expect from the closed-loop system.



ans. The diagram is completed and found not to encircle -1. Asks how many poles of KG(s) are in the right-half-plane. told "none". concludes that system is stable. The Phase margin,PM, is estimated (told "take it to be 20 degrees"). The damping ratio is estimated to be PM/100 thus 0.2. The overshoot is estimated to be large from the damping. (told, "take it to be 80%") The natural frequency at cross over is requested. (Told "take it to be wc=1"). Estimates the rise time to be 1.8/wc = 1.8 sec. From the Nyquist diagram, the system is identified as type I with resulting zero steady-state error to a step. The sketch is made..

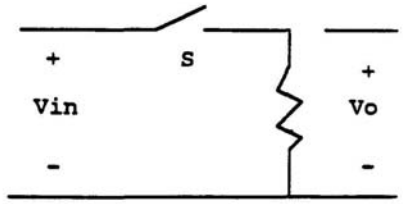


Quals Oral questions of G Franklin

There were three questions.

1) You are given the circuit drawn below. The switch S is run by a closck and is alternately open and closed.

(a) Is the circuit linear; give a proof of your answer.



ans. The circuit is linear. demonstrate by application of superposition.

(b). Is the circuit time-invarient; give proof of your answer?

ans. NO, demonstrate by application of shift invariance principle.

2). The standard control design methods of rotlocus, Bode's method, Pole placement are all based on linear, time-invarient models. However, ALL applications of control are to non-linear systems . How do we get away with this? Why do we spend so much time of LTI systems when nature is non-linear?
ans. Several points should be made.

i) almost all non-linear systems can be approximated near equilibrium by a linear model.
ii) linear analysis is very general and designs based on linear models depend only on the system and not on the inputs.
iii)Linear design methods are well developed and effective (where they apply).

At this point, the examiner introduces the following:

To fix ideas, suppose the model is given by:

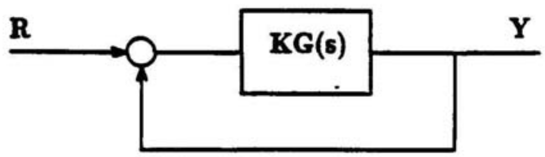
$$\dot{x} = f(x) = Fx + g(x); \quad f(0) = 0; \quad x(0) = x_o$$

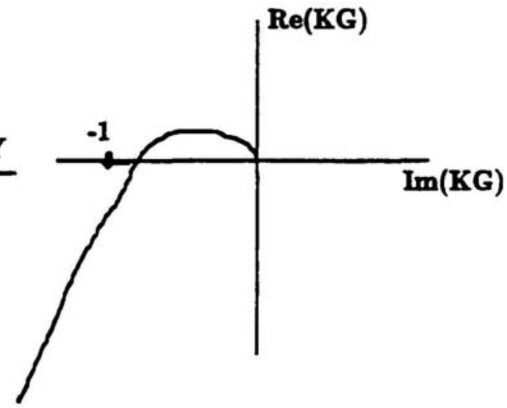
where f and g are non-linear functions and Fx is the linear approximation to f about the equilibrium. What can we say about the properties of the non-linear equations based on the properties of thelinear approximation?

iv) If the linear apprixmation is asymptotically stable, then the non-linear equation wil be stable in some region near equilibrium.
v) Lyapunov stability theory can be used to estimate the extent of the region of stability.

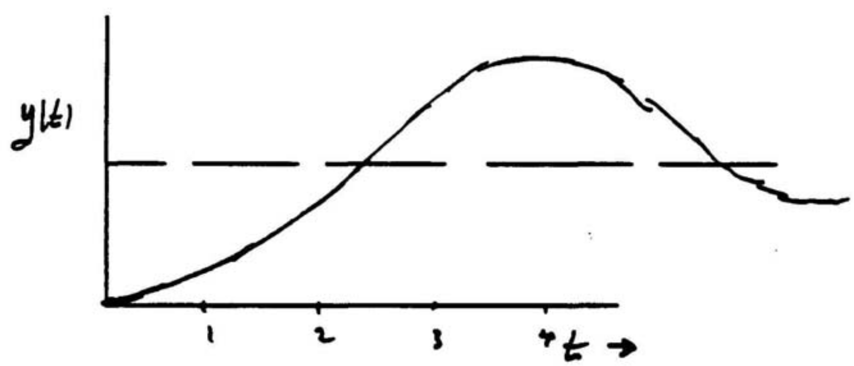
vi) The methond of linear apprixmation has been widely used and found to be effective in control design.

3). Given the standard unity-feedback system sketched below, the Nyquist diagram is found to be as drawn. Please sketch the step response you would expect from the closed-loop system.



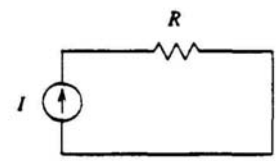


ans. The diagram is completed and found not to encircle -1. Asks how many poles of KG(s) are in the right-half-plane. told "none". concludes that system is stable. The Phase margin,PM, is estimated (told "take it to be 20 degrees"). The damping ratio is estimated to be PM/100 thus 0.2. The overshoot is estimated to be large from the damping. (told, "take it to be 80%") The natural frequency at cross over is requested. (Told "take it to be wc=1"). Estimates the rise time to be 1.8/wc = 1.8 sec. From the Nyquist diagram, the system is identified as type I with resulting zero steady-state error to a step. The sketch is made..



1995 Electrical Engineering Qualifying Examination Questions
John Gill Signal

Consider the following electrical circuit.



1. What is the voltage drop across the resistor?

   ANSWER: $V = IR$

2. Suppose that the resistor is a random variable $\tilde{R}$ with uniformly distributed in the range $R \pm \Delta R$. What is the expected value of the voltage drop?

   ANSWER: $E[V] = E[I\tilde{R}] = IE[\tilde{R}] = IR$

3. Suppose that the current source is also a random variable $\tilde{I}$. What is the expected value of the voltage drop.

   EXPECTED QUESTIONS: Are $\tilde{I}$ and $\tilde{R}$ independent? What is the joint probability distribution of $\tilde{I}$ and $\tilde{R}$.

   ANSWER: If $\tilde{I}$ and $\tilde{R}$ are independent, then $E[V] = E[\tilde{I}\tilde{R}] = E[\tilde{I}]E[\tilde{R}] = IR$, where $I = E[\tilde{I}]$.

4. What is a weaker condition than independence that guarantees that $E[\tilde{I}\tilde{R}] = IR$?

   ANSWER: Uncorrelated.

5. Suppose that two random resistors $\tilde{R}_1$ and $\tilde{R}_2$ are connected in series. What is the average resistance?

   ANSWER: $E[\tilde{R}_1 + \tilde{R}_2] = E[\tilde{R}_1 + \tilde{R}_2] = 2R$

6. What if the resistors values are not statistically independent?

   ANSWER: The expected value of a sum is always the sum of the expected values.

7. Suppose that two random resistors $\tilde{R}_1$ and $\tilde{R}_2$ are connected in parallel. What is the average resistance?

   EXPECTED QUESTION: What is the joint probability distribution of $\tilde{R}_1$ and $\tilde{R}_2$? Suppose the resistors are independent.

ANSWER: For any two values of $\tilde{R}_1$ and $\tilde{R}_2$, the parallel resistance is

$$\frac{1}{1/R_1 + 1/R_2} = \frac{R_1 R_2}{R_1 + R_2}.$$

Therefore the expected value of the resistance is

$$E\left[\frac{R_1 R_2}{R_1 + R_2}\right] = \frac{1}{(2\Delta R)^2}\int_{R-\Delta R}^{R+\Delta R}\int_{R-\Delta R}^{R+\Delta R} \frac{r_1 r_2}{r_1 + r_2}\, dr_1 dr_2$$

The details of the integration are messy and not very interesting.

8. What about the average conductance?

ANSWER: The average conductance is the sum of the average conductance for each resistor (whether or not the resistors are independent). Since $G = 1/R$,

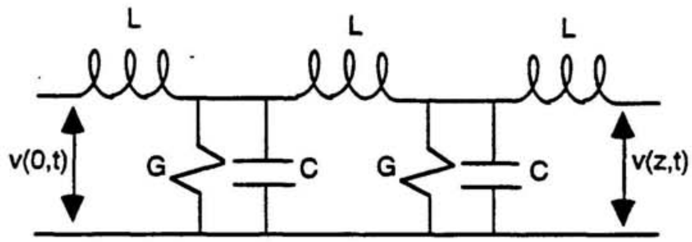
$$E[G] = E\left[\frac{1}{R}\right] = \frac{1}{2\Delta R}\int_{R-\Delta R}^{R+\Delta R} \frac{1}{r}\, dr = \frac{1}{2\Delta R}(\ln(R + \Delta R) - \ln(R - \Delta R))$$

Joseph

Quals Question
J.W. Goodman
Januray 1995

This question is designed to test your knowledge of linear systems, and to see if of you can handle the confusion of space and time variables at the same time.

Consider a lossy, infinite-length transmission line which can be modeled with limped approximations as below:



v(0,t) is the input voltage and v(z,t) is the output voltage, measured at distance z down the line. L, C and G are the inductance, capacitance and conductance per unit length.

The behavior of this line is known to obey the differential equation

$$\frac{\partial^2}{\partial z^2} v(z,t) - LG \frac{\partial}{\partial t} v(z,t) - LC \frac{\partial^2}{\partial t^2} v(z,t) = 0$$

Consider this transmission line as a <u>system</u>, with input v(0,t) and output v(z,t).

(a) Viewing the mapping of v(0,t) into v(z,t) as a system, is this system linear? How do you know?

answer: Yes, the system is linear. The lumped elements iare all linear, but more importantly, the voltage satisfies a linear partial differential equation.

(b) Is the system time-invariant? How do you know?

answer: Yes the system is time invarint. A shift of the input clearly results in a similar shift of the output. The coefficients of the partial differential equation are independent of time.

(c) Since the system is linear and time invariant, it must have a transfer function. Can you find the transfer function of this system, including its dependence on z?

answer: There are many possible ways to find the transfer function. Perhaps the simplest is to apply an input of the form

$$v(0,t) = V_0\, e^{-j\omega t}.$$

Due to linearity and time-invariance, the response (solution) must be of the form

$$v(z,t) = V(z,\omega)e^{-j\omega t}.$$

Substitution of this form in the differential equation yields a new differential equation for $V(z,\omega)$:

$$\frac{d^2V(z,\omega)}{dz^2} + \left(LC\omega^2 + jLG\omega\right)V(z,\omega) = 0$$

This equation has a general solution of the form

$$V(z,\omega) = A(\omega)e^{-kz}$$

Substitution of this solution in the above ordinary differential equation plus cancellation of common factors yields the following relation between k and ω :

$$k^2 + \left(LC\omega^2 + jLG\omega\right) = 0$$

Solving for k in terms of ω, we obtain:

$$k = \pm\omega\sqrt{LC}\sqrt{1 + j\frac{G}{\omega C}}.$$

A boundary condition at $z = \infty$ implies that k must have a positive real part, meaning that the plus sign should be chosen. A boundary condition at $z = 0$ implies that $A(\omega) = V_0$. Then the transfer function must be

$$H(\omega) = \exp\left[j\omega\sqrt{LC}\sqrt{1 + j\frac{G}{\omega C}}\, z\right]$$

(d) At frequencies for which $G << C\omega$, can you find an approximate form for the transfer function and give it a physical interpretation?

answer: If $G << C\omega$, then the first two terms of the binomial approximation to the square root can be used:

$$\sqrt{1 + j\frac{G}{\omega C}} \approx 1 + j\frac{G}{2\omega C}$$

to yield an approximate transfer function:

$$H(\omega) \approx \exp\left[j\omega\sqrt{LC}\, z\right]\exp\left[-\frac{G}{2}\sqrt{\frac{L}{C}}\, z\right]$$

The first term, by the shift theorem, corresponds to a time delay of $\tau = \sqrt{LC}z$, while the second is a frequency-independent attenuation.

1995 Quals question of R.M. Gray System

Robert

Suppose that $\{y_n;\ n = 0,1,\ldots,N-1\}$ is a data set of real numbers, where N is a power of 2.

1. Describe how to evaluate the Fourier coefficients a_k in the Fourier series

$$y_n = \sum_{k=0}^{N-1} a_k e^{j2\pi \frac{k}{N} n};\ n = 0,1,\ldots,N-1.$$

Solution and Comment:

$$a_k = \frac{1}{N}\sum_{n=0}^{N-1} y_n e^{j2\pi \frac{k}{N} n};\ k = 0,1,\ldots,N-1.$$

This was intended to just got started and was worth at most only 1 point. Just quoting the formula was fine, but it was fixed or derived if not done correctly.

2. Define $x_n = A(-1)^n; n = 0,1,\ldots,N-1$, where A is a positive real number. Find the Fourier coefficients a_k for $y_n = x_n$ all n.

Solution and Comment: The solution looked for here was to realize that $(-1)^n = e^{j\pi n} = e^{j2\pi \frac{N}{2} n}$, i.e.. this is just one of the complex exponential basis functions used in the Fourier series. By orthogonality, this will imply that $a_k = 0$ for all k except $k = N/2$, in which case plugging into the formula yields $a_{N/2} = A$.

This problem can also be done by turning the crank to evaluate the sum using a geometric series, where the primary potential pitfall was not realizing the usual formula for evaluating the series is not valid if the denominator is 0.

3. Now assume A above is unknown. You observe the Fourier coefficients $\{a_k\}$ of the corrupted signal $y_n = x_n + \beta_n$. Find an estimator $\hat{A}$ for A satisfying

   (a) $\hat{A}$ is a linear function of the $\{a_k\}$

   (b) If $\beta_n = 0$ for all n, then $\hat{A} = A$.

   (c) If $|\beta_n| \le \epsilon$ all n, then $|A - \hat{A}| \le \epsilon$.

Solution and Comment: The looked for solution was to realize that by linearity the Fourier coefficients of the corrupted signal will be $a_k = B_k$, the Fourier coefficients of the β sequence if $k \neq N/2$, and $a_{N/2} = A + B_{N/2}$. Thus in the absense of noise an estimator satisfying (a) and (b) is simply $a_{N/2}$ (it is trivially linear and it was just shown that this coefficient for x_n is A.) The first two conditions can also be satisfied by just adding up all

Fourier coefficients a_k. but this will not work for (c). To verify (c) you just need to use the linearity of the Fourier transform (and hence of the Fourier series coefficients) to note that

$$|A - \hat{A}| = |A - N/2| = |B_{N/2}|$$

$$= |\frac{1}{N}\sum_n \beta_n(-1)^n| \leq \frac{1}{N}\sum_n |\beta_n| \leq \epsilon.$$

4. Suppose that β_n are uncorrelated random variables with mean 0 and variance σ^2. Is your estimator optimal in the sense of minimizing $E(|A - \hat{A}|^2)$ over all $\hat{A}$ satisfying (a)–(b)?

Solution and Comment:

For the estimator $\hat{A} = a_{N/2}$ the mean squared error is

$$E[|A - \hat{A}|^2] = E[(\frac{1}{N}\sum_k \beta_n(-1)^n)^2] = \frac{1}{N}\sum_k E[\beta_n^2] = \frac{\sigma^2}{N}$$

(This is a standard computation in proving the weak law of large numbers in Stat 116 or similar courses.)

If you use an arbitrary linear estimate, say $\tilde{A} = \sum_k b_k a_k$ instead of $a_{N/2}$, then you need $b_{N/2} = 1$ to satisfy (b) and you get

$$E[|A - \tilde{A}|^2] = \sum_{k=0}^{N-1} b_k^2 E[|B_k|^2] = \frac{\sigma^2}{N}\sum_{k=0}^{N-1} b_k^2$$

which is greater than the average squared error achievable with $\hat{A}$ since the sum is bound below by 1 (the value for the $k = N/2$ term alone).

Note the last part was intended only for the very few who sailed through the first three parts.

To: shankle@ee.Stanford.EDU
Cc: darlene@mojave.Stanford.EDU
Subject: Quals Question.
Date: Sun, 19 Mar 95 13:20:46 PST   Computer Architecture
From: Mark Horowitz <horowitz@chroma.Stanford.EDU>

Here was my quals question:

The question was really to see how students handled dealing with an element that they had not seen before -- a relay. To help them out, I started out with more familar material, CMOS switch logic.

1. Using CMOS switches build a XOR gate

There are many ways to approach this problem, and I didn't really care which was chosen. The easiest is to build the gate from two switches that form a 2:1 mux. The top switch connects when the input A is true and the bottom switch connects when the input A is false. The top switch connects to B_b and the bottom switch connects to B. One could have built the gate out of a 4:1 mux too.

2. Using CMOS switches build an AND gate

Here the best solution is to use the same 2:1 mux solution used above. The top switch connects to B and the bottom switch connects to Gnd. Most students choose to build an AND gate using 4 switches -- two series devices connected to Vdd, and two parallel devices connected to Gnd.

3. Actually I was not really interested in using CMOS switches. I really want to build logic gates out of relays. A relay is an electro-mechanical device, where a current creates a magnetic field which pulls a cylinder into a coil and mechanically changes the switches. The input goes to the coil (one end is connected to Gnd), and this relay has one normally connected switch, and one switch which is normally not connected (so there are 5 terminals to this device). In terms of abstract switches, how would you represent this element?

This relay is a GREAT device. It basically consists of two ideal switches, on connects when the input is 1 (the normally not connected) and the other connects when the input is 0 (the normally connected switch). This means that the relay is like a package of an nMOS and a pMOS transistor. But unlike transistors, there is no problem with threshold drops.

4. Using this relay as a basic element please make an XOR gate. (I allow them to use inverted signals at first, but the final solution can have only the true value of signals)

Since the relay contain both type of switches, connecting the switch outputs together forms a 2:1 mux. Using another relay it is easy to make an inverter to form B_b from B.

5. Now build an AND gate.

Again use the 2:1 mux and connect B to the normally not connected switch, and connect Gnd to the normally connected switch. (The latter connection is not really needed, see the following questions)

6. In logic built out of CMOS switches the output is not allowed to be left floating. Why?

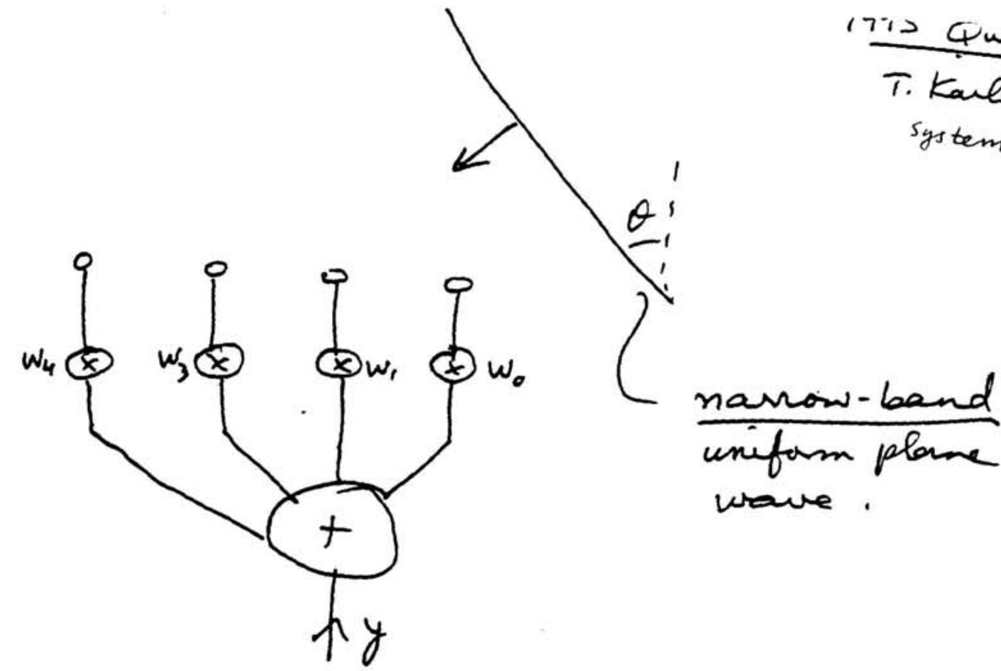
If an output is left floating, it with retain the previous value, becuase the inputs of CMOS switches do not take input current. To prevent building a latch, you need to make sure that the output is always driven.

7. In logic built out of relays, are floating outputs ok? Why or why not?

Since relays are activated by current, a 1 must be a path that can supply current. If the output is left floating, there will not be a path for current. Thus, a floating output is the same as a zero. For relays there is not need to drive a zero value. It is ok just to leave the output floating.

1.

1995 Quals
T. Kailath
System



a) In the noiseless case (no antenna noise), show how to choose the weights to get the 'best' signal y?

b) How would this system respond to interfering signals ("noise") from other unknown directions.

Ans: a) With the narrowband assumption time-delays get converted to a phase-shift at the carrier frequency: $e^{jn\frac{\omega_0 \Delta \cos\theta}{c}}$, $n = 0, 1, 2, 3$.
The weights should be chosen to bring the outputs of each antenna back into phase.

T. Kailath

2. $x(\cdot)$ is a stationary random process with $E\,x(t) \equiv 0$, $E\,x(t+\tau)x^*(\tau) = R(\tau)$,

$$S(f) = \int_{-\infty}^{\infty} R(t)\, e^{-i2\pi ft}\, dt.$$

Let $$X(f) = \int_{-\infty}^{\infty} x(t)\, e^{-i2\pi ft}\, dt.$$

i) Are $X(f_1)$ and $X(f_2)$ correlated? What do you think?

ii) Justify your answer.

<u>Soln.</u> $$E\left[X(f_1)\, X^*(f_2)\right] = S_x(f_1)\,\delta(f_1-f_2)$$

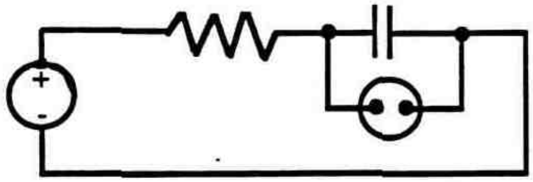
after a little algebra.

G. KOVACS' QUALS QUESTION JAN 1995

circuits

This question involved oscillators built using gas discharge lamps. The objective of the examination was only partly to see if the student could correctly answer the questions posed... equally important was the student's approach.

The basic circuit employed was as follows:



The voltage applied to the circuit was provided by a DC-to-DC converter running off a low-voltage, adjustable DC laboratory supply. The student was told of this and it was pointed out that the DC-to-DC converter had nothing to do with the phenomena to be discussed. The voltage applied to the circuit was displayed using a digital multimeter so that the student realized that it was > 80 V.

Several of the circuits as shown above were assembled in a stack. The neon lamps were flashing (each at a steady rate) and the student was asked to explain the operation of the circuit. This explanation was facilitated by the available information, including the measured applied voltage, clues provided during the exam, and the student's observations (looking at the physical circuit was helpful!). Knowing the exact component values was not necessary.

The mechanism is that the capacitor charges up to the discharge voltage of the neon lamp, at which point it stays lit as the capacitor discharges down to a substantially lower voltage (where it can no longer maintain a discharge). The capacitor then charges up to the discharge voltage and the cycle repeats.

The student was then instructed to look at another similar circuit with an LED in series with the neon lamp and explain why the LED was flashing (simply because the current was gated by the neon lamp).

Finally, the student was asked to look at a circuit wherein an LED (the fact that it was some kind of LED was either already clear to the student or was pointed out) was flashing in a similar circuit. The question was whether or not one could construct such an oscillator from an **ordinary** pn junction diode (such as an LED), a capacitor and a resistor. The point here was to see if the student understood how such oscillators might work and whether he or she believed what they were seeing or what they knew to be correct.

Again, the student's approach to the problem was most important.

Stanford University
Department of Electrical Engineering

1995 Ph.D. Qualifying Exam Question of Tom Lee circuits

The students were shown the following:

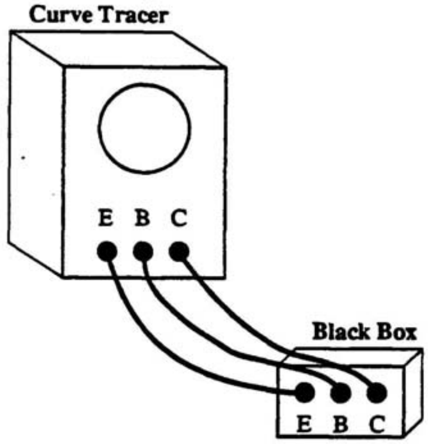


Figure 1 - Experimental Setup

The black box (actually a brown bag) contained a nonlinear active device (a *testistor*® or *examotron*™) that is known not to be an ordinary bipolar or MOS transistor. (In fact, it was a weak, leaky vacuum tube triode, but this information would hardly have helped the student.)

The curve tracer plotted I_C vs. V_{CE}, with V_{BE} as the stepped parameter. The students were asked two questions:

1) Given these measured characteristics, what is the maximum small-signal voltage gain (to 10-20%) that can be obtained from a common-emitter amplifier built with such a device?

2) Suppose the testistor is biased to the condition corresponding to 1). If the external load has a resistance of 40 kilohms, to what value does the gain now decrease (again, to 10 or 20%)?

Outline of Solution:

By using a testistor, the students were forced to demonstrate their command of fundamentals. Memorized formulas, such as "output resistance = Early voltage/I_C," were largely useless (in testistors, the I_C vs. V_{CE} curves do *not* extrapolate to a single intercept on the V_{CE} axis, so the Early voltage concept does not apply).

The key idea was to propose an incremental model (all students chose something similar to a bipolar or MOS model, but this was not the only valid choice), then test it by looking at the measured characteristics. After demonstrating the reasonableness of the model, it could be used to derive an expression for the gain:

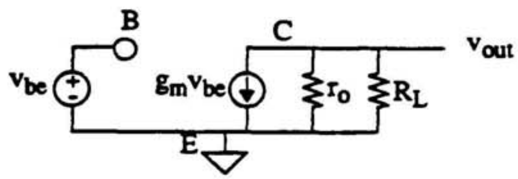


Figure 2 - One Possible Incremental Model of Testistor Amplifier

Since the first question asked for the *maximum* gain, the external resistance, R_L, should be set to infinity (some students resisted this choice on practical grounds, but were then asked about current sources to get them to discover that large resistors and high voltages are not necessary to make large resistances), leading to a gain magnitude of $g_m r_o$. So, the rest of this part of the problem is mainly an exercise in applying the fundamental definitions of transconductance and output resistance:

$$g_m \equiv \frac{\partial i_C}{\partial v_{BE}}; r_o \equiv \frac{\partial v_{CE}}{\partial i_C}$$

The gain is therefore:

$$g_m r_o = \left(\frac{\partial i_C}{\partial v_{BE}}\right)\left(\frac{\partial v_{CE}}{\partial i_C}\right) = \frac{\partial v_{CE}}{\partial v_{BE}}$$

We may approximate the derivative(s) by finite deltas. Now, v_{BE} increments by a constant 0.2 volts between successive curves in this experiment. Additionally, with an infinite load resistance, the load line is horizontal, so the problem reduces to looking for the maximum horizontal distance between successive v_{BE} curves. With this particular testistor, the maximum ΔV_{CE} was about 6 volts for a ΔV_{BE} of 0.2 volts, making the magnitude of the maximum gain equal to 30. The required constructions are shown below:

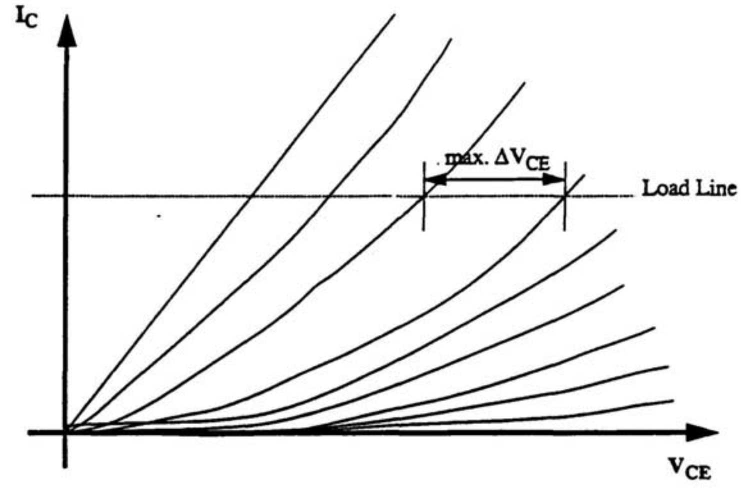


Figure 3 - Measurement of Maximum Testistor Voltage Gain

Part 2 of the question asks what happens if the external resistor is not infinite, but instead is actually 40 kilohms. If one constructs a load line passing through the bias point of part 1) with a slope of 1/(40 kilohms), it is possible to read off the new gain (it turns out to be about half the maximum value), again by looking at what ΔV_{CE} results for a given ΔV_{BE} of 0.2 volts, now traversing the new load line between successive v_{BE} curves. This particular load resistance was chosen to provide a simple-to-draw load line (one division by one division, for the particular scale factors used on the curve tracer):

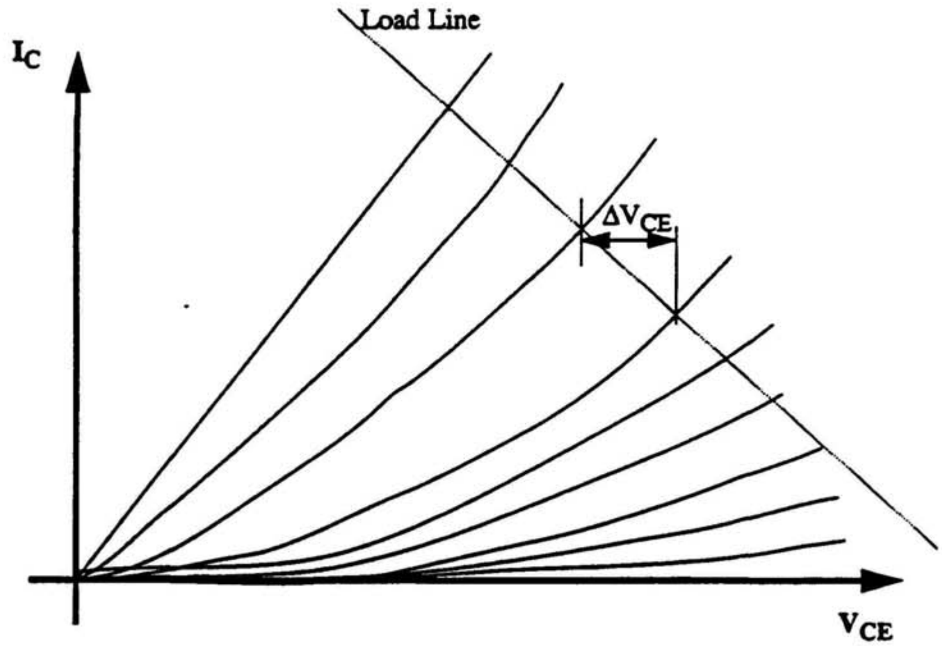


Figure 4 - Measurement of Voltage Gain with R_L = 40 kilohms

Alternatively, one could find the value of r_o (it turns out to be 40 kilohms in the neighborhood of the optimum bias point), to deduce that the voltage gain should decrease to half its previous value.

Comments: Only the output characteristics of the testistor were shown, so the base current and base-emitter impedance were unknown. Since a voltage drive was used in this experiment, though, it didn't matter. If the student wanted to include an input impedance (such as r_π) in the incremental model, it was all right to do so, as long the dependent current generator was chosen to depend on v_{be} rather than base current. Students who insisted on using base current as the independent drive variable immediately got into big trouble and received lower scores than those who proposed models that were more sensibly linked to the actual experiment.

Other students got as far as figuring out that the gain was the product of transconductance and output resistance, but then attempted to find the product of the maximum of each, rather than the maximum of the product.

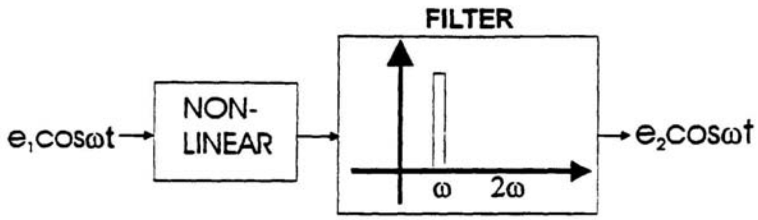
A perfectly valid alternative choice (which no student proposed) would have been to employ a testistor model that contained a voltage-controlled *voltage* source, with an equivalent series resistance. This particular approach can lead to the answer more directly than use of a transconductor-based model.

Finally, some students were able to derive the fundamental equations, but failed to recognize which variables were to be held constant while taking the derivatives, and thus were unable to read the information off of the curve tracer.

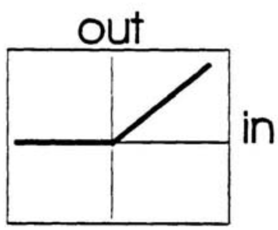
Grading proceeded along the following lines:

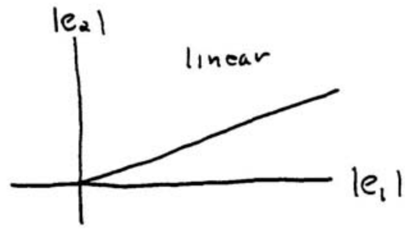
10: Student solved both problems with no hints after the problem statement
6-9: Both problems solved, but student needed varying degrees of prodding
0-5: At most one problem solved, and student needed varying degrees of prodding

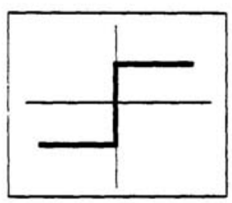
A cosine signal is applied to a non-linear device and then filtered with a narrow band-pass filter. What is the frequency spectrum emerging from the non-linear device? · A line spectrum consisting of multiples of ω.

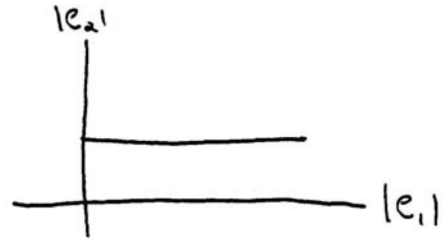


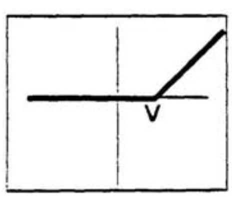
Using the following non-linear input-output characteristics, plot the magnitude of e_2 vs e_1

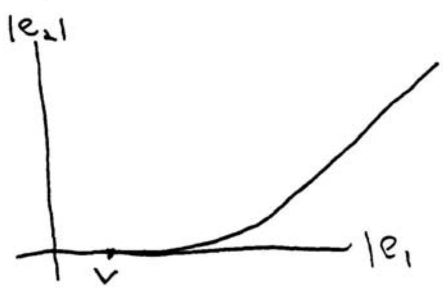








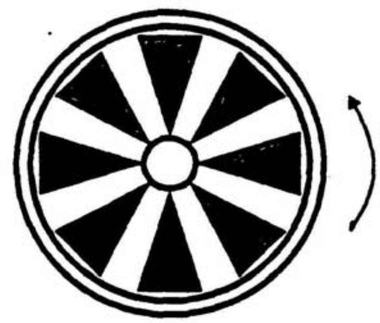




IN MOVIES A ROTATING WAGON WHEEL OFTEN APPEARS TO ROTATE BACKWARDS.

WHAT CAUSES THIS? Stroboscopic effect

WHAT LINEAR SYSTEM PHENOMENON IS INVOLVED? aliasing



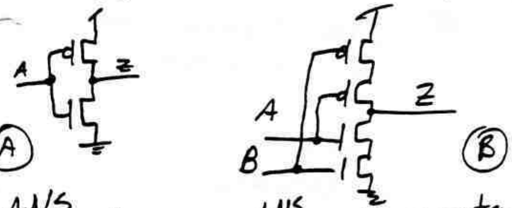
WHAT FRAME RATE IS REQUIRED TO AVOID THIS PHENOMENON?

$\geq 16R$ to reproduce intensity vs. time

If harmonics of the temporal waveform are significant, the frame rate must be greater.

1-95 Quals E J McCluskey

1) **Warmup** what function is realized by circuit A? circuit B? Computer Architect



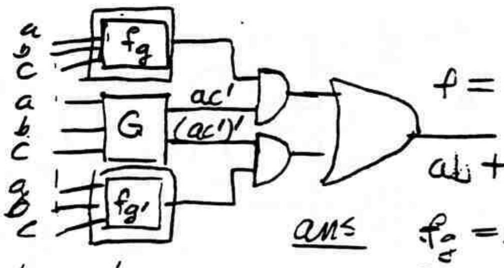
ANS Inverter

ANS Tri-state Inverter

2) Draw diagram for a Multiplexer

ANS many circuits

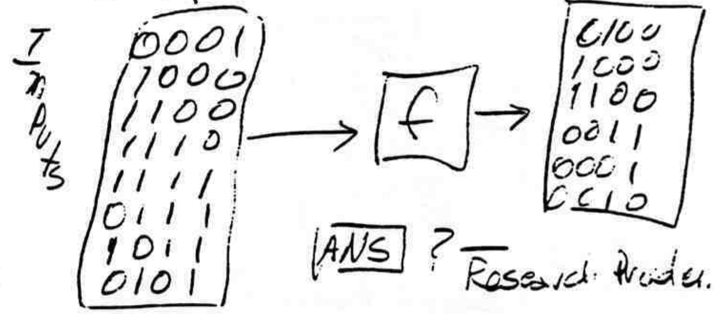
3) For circuit given, find functions fg and fg' to make output $f = ab + a'c$



ans $f_g = b$ or 0

$f_{g'} = a'c + ab$

4) Please design an efficient circuit that receives the 8 4-bit patterns shown as inputs (other 8 patterns can't occur) and has the 6 patterns shown as outputs - you can choose any correspondence between inputs & outputs.

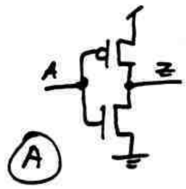


ANS ? Research Problem.

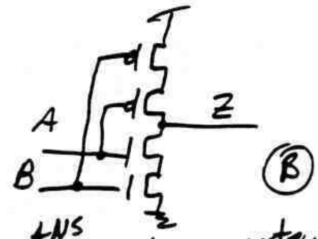
1-95 Quals

E J McCluskey

① **Warmup** what function is realized by circuit A? circuit B?



ANS Inverter

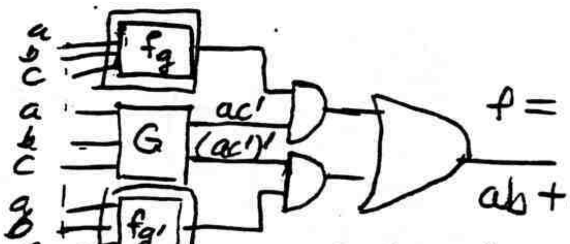


ANS Tri-state Inverter

② Draw diagram for a Multiplexer

ANS many circuits

③ For circuit given, find functions f_g and $f_{g'}$ to make output $f = ab + a'c$

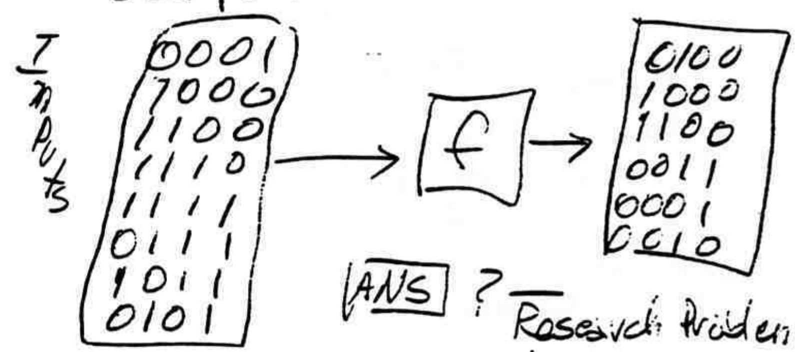


$f =$ $ab + a'c$

ans $f_g = b$ or 0

$f_{g'} = a'c + ab$

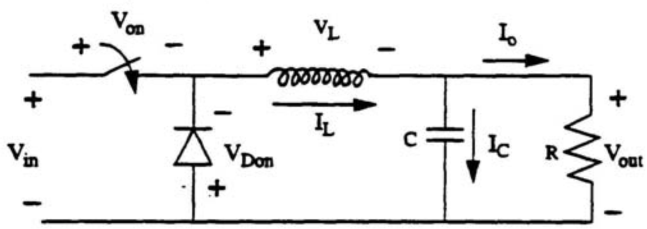
④ Please design an efficient circuit that receives the 8 4-bit patterns shown as inputs (other 8 patterns can't occur) and has the 6 patterns shown as outputs - you can choose any correspondence between inputs & outputs.



ANS ? Research Problem?

who?

2. Switching Regulators



(a) Analyze the above circuit assuming a steady-state situation exists. For example, when the switch is closed, write down the change of inductor current over time.

$$V_{on} = \frac{dI_L}{dt} = V_{in} - V_{on} - V_{out}$$

(b) When the switch is open, the change of inductor current becomes...

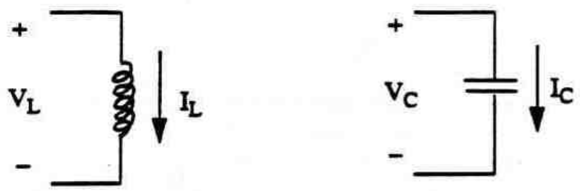
$$V_{off} = \frac{dI_L}{dt} = -V_{on} - V_{out}$$

(c) Using T_{on} to represent the switch *on* time and T_{off} the switch *off* time, T_{total} the period ($T_{total} = T_{on} + T_{off}$), can you derive the relationship between V_{out} and V_{in}?

For steady-state

$$\Delta I_{on} = \Delta I_{off} \Rightarrow (V_{in} - V_{on} - V_{out})T_{on} = (-V_{on} - V_{out})T_{off}$$

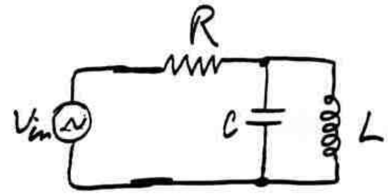
1. Inductors and Capacitors



(a) Write down the equations that describe the relationships between terminal voltages and currents of an inductor and a capacitor.

$$V_L = L\frac{dI_L}{dt} \qquad I_C = C\frac{dV_C}{dt}$$

(b) Design a high-Q filter centered at 1GHz for a radio receiver front-end circuit using an appropriate power source and passive elements.

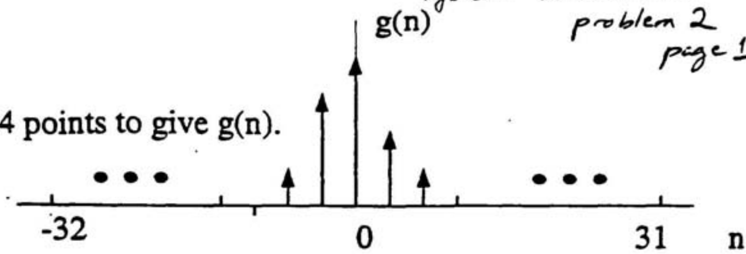


Or any structure that'll give you a high-Q filter.

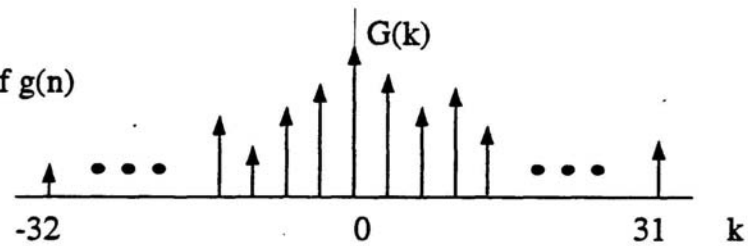
Depending on the technology used, L & C numbers may vary.

System Dwight Nishimura problem 2 page 1

(t) is sampled to 64 points to give g(n).



G(k) is the DFT of g(n)



Problem Statement.
see page 2

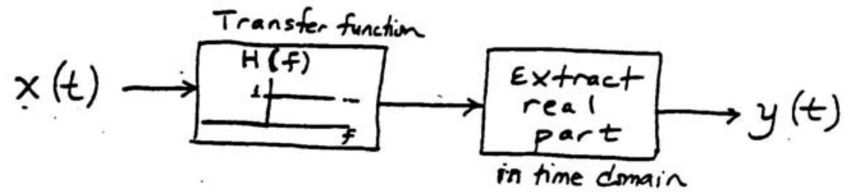
Answers: to Problem 2

frequency resolution $= \frac{1}{\text{duration}} = \frac{1}{64}$ Hz

Method 1: 32-pt seqn is a windowed version of g(n)
So 32-pt DFT = 64-pt DFT convolved (circularly) with a sinc, then downsampled.

Method 2: Can be viewed as conv with ⇈ followed by downsampling in frequency domain.
So time signal is slightly windowed and then experiences time aliasing

Nishimura
problem 1



1. **Is this system linear?**
2. **Is this system time-invariant?**
3. **If $x(t)$ is real-valued, what is $y(t)$?**

<u>Answers</u>

1) No. extracting real part is nonlinear (consider $i\,x(t)$)
2) Yes
3) $\frac{1}{2}x(t)$ time-domain or freq-domain approach ok

To: shankle@ee.Stanford.EDU
Subject: Quals question
:: Thu, 09 Feb 95 10:48:36 PST
.n: kunle@ogun.Stanford.EDU

Q. If I wanted to compare the performance of two computer systems on a set of floating point intensive benchmarks using MFLOPS, how would I go about it?

A. Measure normalized MFLOPS of each benchmark. Begin by counting the number of normalized floating point operations in the source program. This number, which is the same for both computers, is divided by execution time of the benchmark to produce MFLOPS. Use harmonic mean to get an average MFLOPS rating across the set of benchmarks for each computer. This measure will track execution time which is the real measure of performance. Compare the machines using the average MFLOPS rating.

Q. Compare a branch prediction buffer (BPB) and a branch target buffer (BTB).

A. Talk about the cost versus performance of the two schemes.
BPB: low cost. Can reduce cost by eliminating the tag. Only useful for conditional branches.

BTB: higher cost because it must store tag and target address. BTB can be used for both conditional branches and unconditional branches. The BTB has lower branch delay on a hit than the BPB.

Given the same area a BPB would have more entries and better prediction accuracy and than the BTB.

Kunle leave

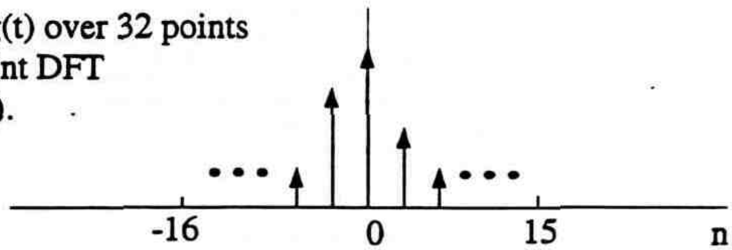
system Nishimura ... ... —

If the sampling period is 1 second, what is the resulting frequency resolutio
(in Hz)

Consider the following 2 methods that "reduce" the frequency resolution by ..

Method 1

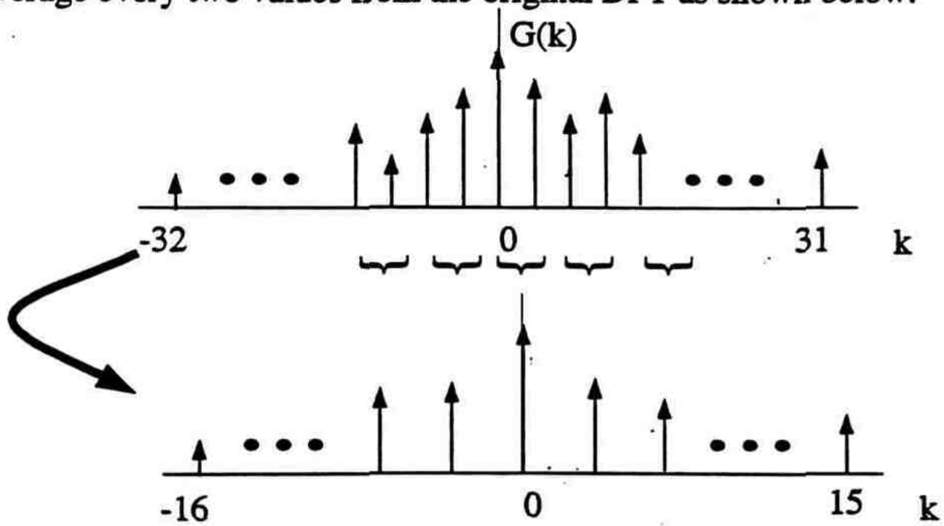
Consider sampling g(t) over 32 points
and taking its 32-point DFT
(same sampling rate).



How does its 32-point DFT compare with the original 64-point DFT?

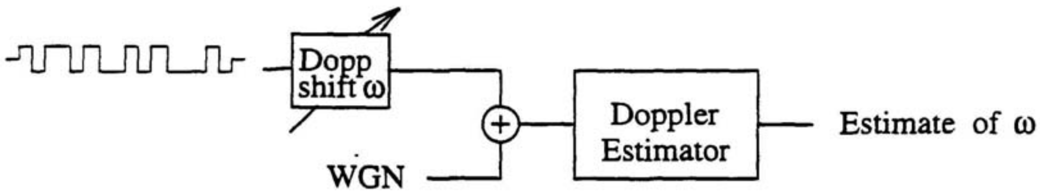
Method 2

Average every two values from the original DFT as shown below.



What operations are involved here
and what effects do they have on the resulting time signal?

Doppler Experiment



- Q 3a: What is the structure of the optimum Doppler estimator

  3b: What factors determines estimator performance

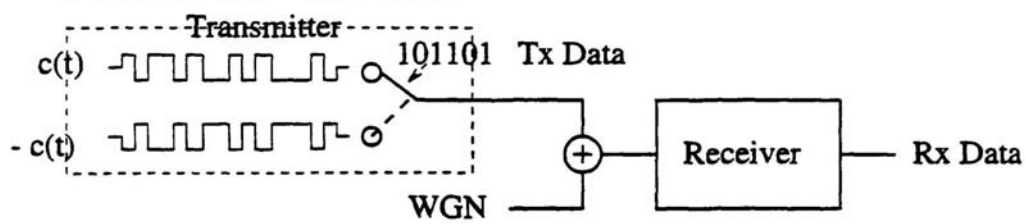
  A 1a: Doppler bank (bank of matched filters shifted in frequency)

  1b: Noise spectral density, signal energy and time duration

- Q 4 How would you jointly estimate τ and ω could these estimates be coupled

  A 4 Search in delay and Doppler, Yes they could be coupled as in linear FM puls

Communication Experiment



- Q 5a What is the structure of the receiver ?

  5b On what does the BER depend on? Is signal bandwidth a factor ?

  A: 5a: Matched filter and check against zero threshold

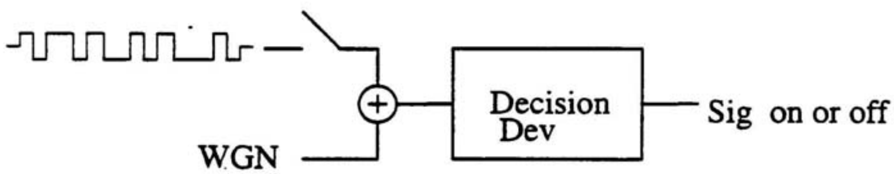
  5b: SIgnal energy and spectral noise density. Bandwidth is not a factor

Prof. A Paulraj

Quals Question

Let c(t), $O < t < T$ be a random binary coded pulse

Detection experiment



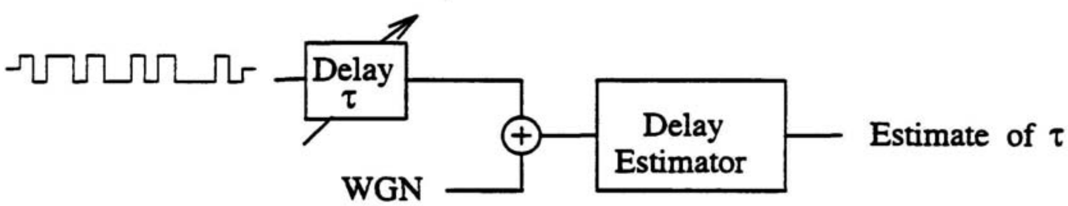
Q 1a: What is the structure of the optimum decision device

1b: What factors determine detector performance

A 1a: Matched filter or replica correlator and test against threshold

1b: Spectral noise density and signal eneregy

Ranging experiment

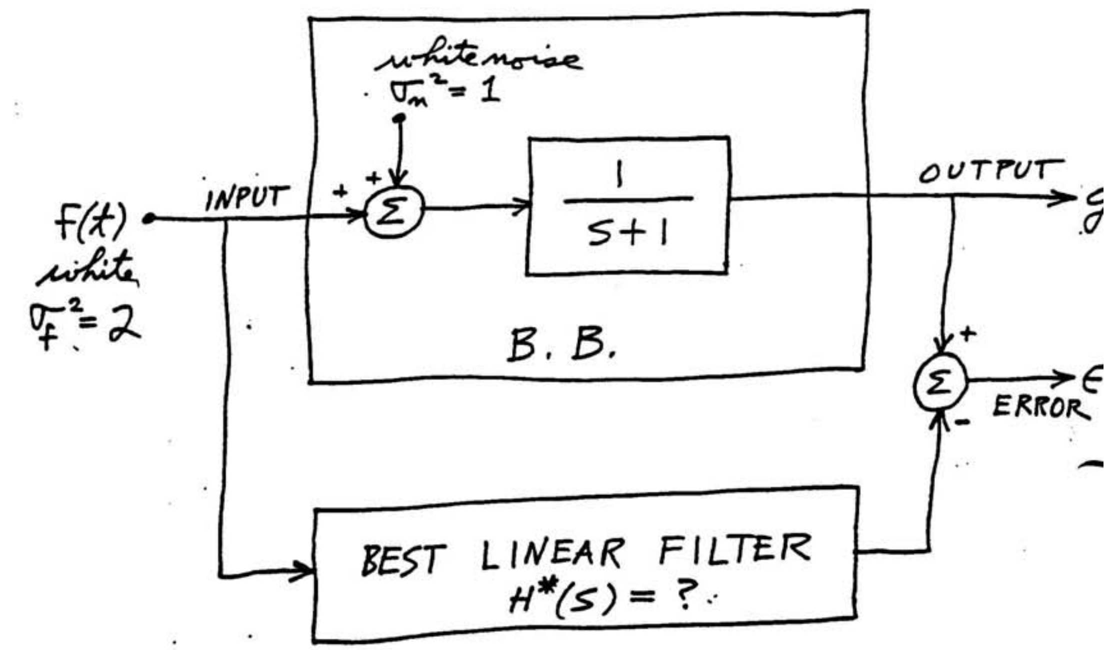


Q 1a: What is the structure of the optimum delay estimator

1b: What factors determine estimator performance

A 1a: Matched filter or moving window correlator and peak detect

1b: Spectral noise density, signal eneregy and bandwidth



(A) WHAT IS THE BEST MODELING FILTER THAT MINIMIZES THE MEAN SQUARE OF ERROR $\epsilon(t)$?

($H^*(s) = ?$)

(B) WHAT IS THE MINIMUM MEAN SQUARE ERROR?