Annual Report of Faculty Activities
(January 2004 – December 2004)

N. Sanjay Rebello

APPENDIX A: SUMMARY OF TEACHING ACTIVITIES

Below, I have presented my own personal reflection of my teaching activities as well as sample copies of my syllabus, course materials, exams and evaluations for each class that I taught during this period. The classes discussed here are:

Spring 2004

Physical Measurement and Instrumentation – PMI (PHYS636)

Fall 2004

Teaching University (PHYS620)

You may access complete documentation for the courses above on K-State Online.
Please go to: http://online.ksu.edu
Login as:
User name: physfaculty@phys.ksu.edu
Password: CW119
Click on the above courses.

Spring 2004

Physical Measurement and Instrumentation – PMI (PHYS636)

This was my third time teaching PMI at K-State. I had previously taught electronics, both analog and digital as separate courses at Clarion. The first time at K-State in Spring 2002, I had followed the lab manual written by Dr. Brett DePaola quite closely. Based on feedback from students the last time, as well as my own ideas, I decided to try a new approach in Spring 2003, which was fundamentally different in some ways. The new curriculum was quite successful in many respects, although there were some flaws in the experimental write-ups and the conceptual development in some of the areas could have been done differently. This time, I modified each of the activities, based on feedback from students last year. For instance, to be sure that the students were on the right track I began to introduce 'stopping points' in the activities. At these stopping points students were expected to talk with me and/or the TA about their approach and what they had discovered. The main purpose of these 'stopping points' was to ensure that students did not waste too much time following unproductive strategies or approaches for too long.

The new curriculum covered the same content as the previous one, although it differed significantly in the pedagogy. There were two significant differences. 1) The students were seldom told the circuit that they needed to build. Rather they were expected to go through a process of guided discovery to design the circuit, then simulate it, then build it, and compare the real measurements with the simulations. 2) We followed the modeling cycle pedagogy that included two phases: In the model development phase, students explored the electrical characteristics of a device by performing I-V or other measurements. Based on these I-V measurements and past knowledge they built a model of how the device works. The typical representation for this model was an equivalent circuit consisting of previously studied electrical elements (e.g. equivalent circuit of a diode based on switches, resistors and batteries). In the model deployment phase, students applied the equivalent circuit model to predict the behavior of the device when it was embedded in a circuit. They compared their predictions first with simulations and then with real measurements.

Some of the other features of the pedagogy used included collaborative learning, self-reflection, and Socratic dialog. Students were guided by a script on an activity sheet that asked them leading questions. My role and that of the teaching assistant was to walk around the class and interact with the students as they worked through the questions on the activity sheets. In keeping with the idea of Socratic dialog, seldom did we answer questions which students asked directly. Often we responded to students' questions by asking them other leading questions. Sometimes, when a problem was widely prevalent in class, I interrupted the class to go over this issue in a lecture-based format. This intervention became less likely as the course continued mainly because different students were at different stages of completion of the activities and it made more sense to address students' concerns as they arose in small groups

At the very beginning of the course, because the pedagogy used in the course might be novel to most students, the approach was made explicit to the students from the beginning and its intentions were made clear. They were told that this class would most likely be a departure from previous classes that they may have had. They were required to record all of their work in a permanent lab notebook. It was emphasized to the students that even wrong approaches could be productive learning experiences and that everything that they did – right or wrong – should be recorded in the notebook. In addition to the students, the pedagogy was also explained to the TA who was generally very cooperative toward these efforts.

There was one mid-term exam and a final exam. The mid-semester exam was a take-home exam and an oral final exam. The mid term and homework included paper-and-pencil calculation and design problems as well as simulations to verify the paper-and-pencil design. Since I had changed the pedagogy from before I asked some of the same questions that I asked the previous year to see if students would still be able to solve these questions after using the modified pedagogy. I found that students were equally proficient at solving the exam questions. Moreover, they often used new strategies to solve problems and started from first principles in their calculations rather than following a pre-defined recipe. Students also seem to have developed superior modeling skills as was evidenced by the types of questions that they were able to solve on the final exam. One of these questions required students to look at the I-V curves of a device and work backwards to construct an equivalent circuit model for the device. All of the students who were asked this question were successfully able to solve it. The device in question was MOSFET, which we had not gotten a chance to cover in the course because of the lack of time. However, in spite of not having covered that particular device, students were able to develop an equivalent circuit model of it based on the hypothetical experimental evidence presented to them. I do not believe students in the course that I taught the previous year would have developed this skill.

My overall impressions from the new approach were positive. I also solicited feedback from students through an online mid-semester survey (using the K-State Survey System) as well as additional questions on the TEVAL at the end of the semester. Interactive engagement approaches usually result in coverage of less content. In this case, I covered about 70% of the material I had covered in the previous time I taught the course without the modified pedagogy. Through my observation of students' work and feedback from students, I believe I have identified the materials that need to be revised so that coverage can be increased while still maintaining the same pedagogical approach. Some areas where time was spent unproductively are the modeling of complicated devices such as bipolar transistors or flip-flops. In hindsight more scaffolding and some amount of direct instruction could be provided to the students in these topics so that less time is spent following unproductive leads as the students construct their models for these devices.

Other comments from the students reflected the need for a little more direct instruction to tie up loose ends. So, the next time I teach this course, I plan to spend at least one hour each week going over the main ideas that students would have learned through their activities. However, the lectures will not be a substitute for the discovery-based approach; rather they will mainly synthesize what students have already learned through this approach.

Based on my experiences in this course, I presented a talk at the 2004 Summer Meeting of the American Association of Physics Teachers. One of the former students in this course, Kara Gray is a co-author for this talk. Kara also completing an M.S. in Physics with me on a different topic. Her research is unrelated to the course; however her knowledge of physics education research coupled with her role as a student in the course, gave her a unique perspective to provide me with formative feedback as the course progressed.

Results from student evaluations as well as handout slides from the poster are attached. I would like to thank the following individuals for their useful comments and support throughout the course:

Dr. Brett DePaola was helpful in providing me with the laboratory manual that was initial framework for the content of this course. Although, I modified the pedagogy, I was still following the content that Dr. DePaola had covered during the previous times that he taught the course.

Mr. Peter Nelson was especially useful in helping me set up the lab. He helped procure and put up the inexpensive white boards that I used in the class. He also lent me an old projection system and helped me purchase and transport the laptops that I used in the class from State Surplus in Topeka. Mr. Nelson along with Mr. Mark Newman helped reconfigure the furniture in the class.

Fall 2004

Teaching University Physics (PHYS620)

This was my first time teaching this class. I had previously sat in on the class taught by Dr. Zollman, so I decided to follow a similar approach. Unlike most other physics classes, this course meets in a discussion format each day. Readings were assigned prior to each class and students were asked to come prepared to discuss these readings in the class.

Toward the beginning of the semester, I used to have students summarize the readings to the rest of the group. Later, it appeared that this exercise was not very productive in getting students to reflect carefully on the article, so I changed focus and had students talk about specific questions. As far as possible the questions of a practical nature i.e. discussing how information in the readings could be applied specifically to a physics teaching situation.

The class had a mix of students. There were three undergraduates, at least one of whom planned to teach physics at the high school level in the future. The others were graduate students, most of who were in their second year of their graduate work and were also simultaneously teaching the Engineering Physics Studio. Their teaching experiences gave them a context within which to discuss some of the readings in the class.

In terms of content there were a few differences from previous years. We spend a bit more time discussing theoretical underpinnings than we did previously. The field of physics education research is soon beginning to be informed by cognitive psychology. Some of these influences were reflected in our readings. However, we always tried to relate it back to the concrete experience of teaching, and it was my experience that most students preferred this applied bent of the class.

There were a few things that I would do differently. For one, the discussion questions would be more focused and task oriented rather than pure discussion. The use of contrasting cases is an important tool that I tried to employ in this class, but I could perhaps use more often. At times in the discussion there were several unresolved issues at the end of class. It appears from student feedback that students would have preferred to leave the class with a more definite sense of where I stood on some of these issues. I personally feel it is important for students to be able to engage in an informed debate or at least be aware of the arguments on either side of the debate. Therefore, I will spend some time at the end of each class next time to summarize these ‘take-home’ points. Finally, there was the issue of grading. Unlike most physics classes, the assignments in this class involve papers and project that students have to write. Most students did not possess adequate writing skills, and I felt I did not adequately address this issue in my feedback to the students. I realize that this issue has probably been dealt with in other disciplines where writing assignments are the norm, and I will certainly learn how these issues are tackled there.

Since this course is offered once every two years, and the field of physics education research is rapidly advancing, it is likely that each time the course is taught the emphasis may have to shift slightly. For instance, the field appears to be moving more toward looking at epistemological and motivational factors that influence student learning. I believe it is important that the methods of teaching physics, which is what this course is about, should be informed by these research efforts. However, the course is not one that is taken *only* be graduate students interested in physics education research, rather by a more general audience. Therefore, a balance needs to be struck between making the course theory-based vs. practically orientated. These are the challenges that will have to be addressed each time the course is taught. I do hope that I get future opportunities to teach this course and address these challenges.

PHYS636
5 CREDITS

PHYSICAL MEASUREMENT & INSTRUMENTATION

***Instructor:* N. Sanjay Rebello**

SPRING 2004
MTWU 2: 30 – 4:20

SYLLABUS

ROOM & TIME

Lab: Room 312, Cardwell Hall   Monday, Tuesday, Wednesday, Thursday: 2:30 – 4:20 PM

INSTRUCTOR CONTACT INFORMATION

Rm. 503 Cardwell Hall (Note: There is no elevator access above the 4th floor in Cardwell Hall. If you need to use an elevator, please call me and I can meet you in the lobby on the 4th floor of Cardwell.)

Phone: [Office] 532 1539 [Home] 537 7543   Email: srebello@phys.ksu.edu (several times daily)

OFFICE HOURS

Fridays: 9:00 – 11:00 AM. Feel free to drop by or call me anytime.

COURSE GOALS

Upon completion of this course you will be able to:

- Explain the basic physical principles underlying electronic devices and circuits that use these devices.
- Analyze and design analog and digital circuits (e.g. filters, amplifiers, multiplexers etc.).
- Simulate analog and digital circuits using industry-standard simulation tools.
- Build and test these circuits using standard electronic equipment (oscilloscopes, multimeters etc.).

COURSE PEDAGOGY

This course will be based on the premise (supported by educational research) that we learn best when we are actively engaged in the learning process. In this spirit, I will minimize formal lecturing. Seldom will you be told how a device, circuit or instrument works. Rather you will discover what you learn by yourself through performing hands on experiments, computer simulations, discussing with your classmates, and above all, thinking. This process that you will engage in to actively construct your knowledge (rather than be handed down) is often called discovery-based learning.

We will provide you with handouts that will guide your discovery-based learning process. The handouts will contain information that helps you perform the activities as well as questions that you should strive to answer. Please respond to all of the questions in the lab notebook provided to you (see "Laboratory Procedures" below). Often the questions may ask you to make predictions. You will NOT be penalized for an incorrect prediction, as long as you have a logical (albeit incorrect) explanation to support it. Following this task, you will often be asked to verify your prediction through an experimental observation or a computer simulation and explain your observations. Finally, you may also be asked to apply what you have learned to the analysis or design of a different circuit. This sequence of tasks: Predict, Explore, Explain, and Apply will form the pedagogical framework in this course.

RECOMMENDED TEXTBOOKS

There is **NO REQUIRED TEXTBOOK** for this course. However, there are four ***recommended*** textbooks. Collectively these texts will address all of the topics that we discuss in this course. The "Course Schedule" indicates the chapters in each text pertaining to each topic

I do ***NOT*** expect you to purchase any of these textbooks. Therefore, I will provide you with handouts (see "Course Handouts" below) containing explanations and questions that you will answer in class. The handouts will be as self-contained as possible so that you do not need to refer to the textbooks.

At least one copy of each textbook will be available in the lab. You can check out these textbooks from the lab for a day or so, and photocopy selected portions if you so wish.

I have listed the textbooks below (not in any particular order), along with my personal comments about each.

Principles of Electronic Instrumentation, 3rd Edition, by Diefenderfer & Holton, Brooks & Cole Publishing.	Covers both analog and digital, but covers digital in not as much depth as we would in this course. It has some chapters dedicated to instrumentation applications that are interesting, but we will not have time to cover.
Electronic Circuit Analysis and Design, 2nd Edition, by Neamen, McGraw Hill Publishing.	Covers analog almost exclusively. The last couple of chapters do address digital circuits but from the perspective of the internal hardware of digital devices and not how to use the digital devices as building blocks in circuits.
Fundamentals of Digital Logic, by Brown & Vranesic, McGraw Hill Publishing.	Covers only digital electronics and NO analog. It introduces a powerful simulation language that is used in several examples.
The Art of Electronics, 2nd Edition, by Horowitz & Hill, Cambridge University Press	This was the textbook last year (but students did not like it). It covers both analog and digital, again focusing mainly on analog. Also, it is written more as a reference book for those who may have had prior exposure to the course material.

COURSE HANDOUTS

Since there are **NO REQUIRED textbooks** for this course, I will provide you with detailed handouts that will combine material from various texts. I will make every attempt to make these handouts as self-contained as possible, so that you do not need to refer to any of the textbooks. However, the handouts will not merely contain information as in a text. Rather there will be two kinds of handouts that you will use.

- *Lab Handouts*: These handouts will serve as will also serve as guides to the discovery-based learning process that you will engage in class. They will contain information to guide your learning, and more importantly questions that you will have to answer in the lab notebook.
- *Summary Handouts*: These will be provided at the end of the week, *after* you have learned the material in class. These handouts will synthesize the information that you have discovered in class, and perhaps some additional relevant information.

WEB SITE

All of the class handouts, homework, as well as homework and exam solutions will available via *K-State Online* http://online.ksu.edu

I would also encourage you to use *K-State Online* to post any queries you have regarding the course on the Message Board so that other students can benefit from it. You may also use *K-State Online* to send me email or to check your grade.

If you were pre-enrolled in this class, *and* if you already have a *K-State Online* account (because you used it in another course previously) use your current username and password to logon, then should see PHYS636 listed as one of your options.

If you have never used *K-State Online* before, but were pre-enrolled for this class then you will need to create a K-State Online account by clicking the **Create an Account** button on the left side of the first login screen that you see.

LABORATORY PROCEDURES

The laboratory is the most important component of the course and is worth 45% of the course grade. You are expected to do the following in connection with the laboratory:

- You will be provided with a hardbound lab notebook in which you will record all of your data, analysis etc. It is important to realize that the lab notebook is a record of ALL of the events that occur in a lab, including circuit diagrams, predictions and conclusions reached with your partner. It is particularly important to record your mistakes. Please DO NOT erase or strike out these mistakes, just simply write a note in the margin later when you have figured out what you did wrong and why. Mistakes or erroneous assumptions are an important part of the learning process. A lab notebook that contains errors and mistakes can be a useful reference in the future that can alert you to what went wrong the first time.
- Before you begin using the notebook, please number all pages. Please leave the first four pages blank where you can create a table of contents indicating the page number, lab experiment, and date. Please be sure to begin the record for each date on a new page. Write the date on the top left corner of each page, and record that information, along with the lab experiment and page number in the table of contents.
- You may be asked to simulate some of the circuits that you will build in the lab prior to doing the lab. Please record your data from the simulations in the notebook. Data printed out from the simulations must be attached to the notebook appropriately. Unfortunately, we do not have access to a printer in the lab, so you would need to copy the data on a floppy and print it elsewhere.
- Complete all of the lab exercises indicated on the Worksheet. If you are unable to complete all the tasks on the handout for that week you can use the lab after hours to complete the tasks. If you need to access the lab outside of class hours. To accomplish that you will need to gain access to the laboratory after hours. If you need to do so, please contact me in advance and I can let you in.
- Please hand in your lab notebook for grading to the instructor by 5:00PM on Friday of each week there is lab. This will give you time to complete any experiments that you were not able to get done before end of lab on Thursday.
- The lab notebook will NOT be graded on neatness of your work, so please do NOT spend time trying to be unduly neat (please be legible, however!). Most of your graphs and circuits will be drawn freehand using the grid on the notebook. The lab notebook WILL be graded based on completeness of the information you provide including explanations and diagrams. The main question I will ask myself as I grade the lab notebook and which you should ask as you prepare it is: *To what extent can someone (other than the author) recreate the lab experience based on what is described in the lab notebook (as well as the handout)*?

HOMEWORK

Homework will be assigned about once every three weeks. A total of four homework assignments will be worth 20% of the course grade. You homework may involve questions that can involve paper and pencil tasks such as calculations, qualitative explanations, analysis and design of circuits. You may also be asked to simulate circuits as well as build and test them in the laboratory.

You are encouraged to work collaboratively on the homework, but merely copying someone's homework will be detrimental to your performance on the exams and final, where you are required to work alone.

EXAMS & FINAL

There will one mid-term exam during the semester and a cumulative final. The mid-term and final are take-home. Like the homework, questions on the exams and final can involve paper and pencil tasks, as well as simulations. They may also require you to build and test circuits in the laboratory.

Unlike the homework, collaborative work on the exams and final is prohibited. You are however permitted to access resources such as texts, websites or any other non-human resources to answer the questions.

ASSESSMENT

Your performance in this course will be assessed by weighing various components of evaluation as follows:

Type of Assignment	Points per Assignment	Total Points
Laboratory	15 Weeks X 30 points	450
Homework	4 Homework X 50 points	200
Mid Term Exam	1 Mid Term Exam x 150 points	150
Final Exam	1 Final Exam x 200 points	200
	TOTAL POINTS IN COURSE	**1000**

COURSE GRADE

Your course grade will be calculated based on the total points that you score in the course (out of a Maximum of 1000). The point range for each grade is as follows:

Points Scored in Course	Course Grade
900 or Above	A
800 – 899	B
650 – 799	C
649 or Below	D

STUDENTS WITH DISABILITIES

If you have any condition such as a physical or learning disability which will make it difficult for you to carry out the work outlined here, or which will require academic accommodations, please notify the lecturer and contact the *Student Disability Services* (Holton 202) during the first two weeks of the course.

ACADEMIC DISHONESTY WARNING

Plagiarism and cheating are serious offences and may be punished by failure on the exam, paper or project; failure in the course; and/or expulsion from the University. For more information refer to the "Academic Dishonesty" policy in the *K-State Undergraduate Catalog* and the *Undergraduate Honor System Policy* on the Provost's web page at http://www.ksu.edu/honor/

Please refer to the ***Course Schedule*** for information on the topics covered, relevant chapters in the recommended texts, as well as the dates of the Homework and Exams.

PHYS636 ***PHYSICAL MEASUREMENT & INSTRUMENTATION*** ***SPRING 2004***

5 CREDITS ***Instructor:* N. Sanjay Rebello** ***MTWU 2:30 - 4:20***

TENTATIVE COURSE SCHEDULE

Subject to change with prior notice. Changes will be posted on K-State Online and announced in class

WHEN	**TOPIC**	**Homework & Exam (Due Date)**	**CHAPTERS IN RECOMMENDED TEXTS** **Not all sections in each chapter may be relevant.** **More information will be provided for each topic when we discuss it.**			
			Diefenderfer & Holton	**Neamen**	**Brown & Vranesic**	**Horowitz & Hill**
Week 01 1/22	Getting Started	--	--	--	--	--
Week 02 1/26 –1/29	RC Circuits	HW 1 **(1/29)**	Ch 1& 2	--	--	Ch. 1
Week 03 2/02 –2/05	Diode Circuits	--	Ch 5	Ch 1,2	--	Ch. 1
Week 04 2/09 – 2/12	BJT Circuits	--	Ch 6, 7	Ch 3, 4	--	Ch. 2
Week 05 2/16 – 2/19	BJT Circuits -- Continued	HW 2 **(2/19)**	Ch 6, 7	Ch 3, 4	--	Ch. 2
Week 06 2/23 – 2/27	FET Circuits	--	Ch. 6, 7	Ch 5, 6	--	Ch. 3
Week 07 3/01 – 3/04	FET Circuits -- Continued	--	Ch. 6, 7	Ch 5, 6	--	Ch. 3
Week 08 3/08 – 3/11	OPAMP Circuits	--	Ch. 9	Ch. 9	--	Ch. 4
Week 09 3/15– 3/18	OPAMP Circuits -- Continued	**Mid Term** **(3/18)**	Ch. 9	Ch. 9	--	Ch. 4
3/22– 3/25	**SPRING BREAK**					
Week 10 3/29 – 4/01	Digital Gates & Logic Functions	--	Ch. 10	--	Ch. 2, 4	Ch. 8
Week 11 4/05– 4/08	Arithmetic Circuits	--		--	Ch. 5	--
Week 12 4/12 – 4/15	Combinational Circuits	HW 3 **(4/15)**	Ch 11	--	Ch. 6	Ch. 8
Week 13 4/19 – 4/22	Flip-Flops	--	Ch 10	--	Ch. 7	Ch. 8
Week 14 4/26 – 4/29	Sequential Circuits	--	Ch 11	--	Ch. 8, 9	Ch. 8
Week 15 5/03 – 5/06	Sequential Ckts. -- Continued	HW 4 **(5/06)**	Ch 11.	--	Ch. 8, 9	Ch. 8
Week 16 5/10 – 5/13	Analog – Digital Conversion	--	Ch. 11	--	--	Ch. 9

Final Exam (take home) is due at the time designated for the final on the University's Final Exam schedule.

Bipolar Junction Transistors

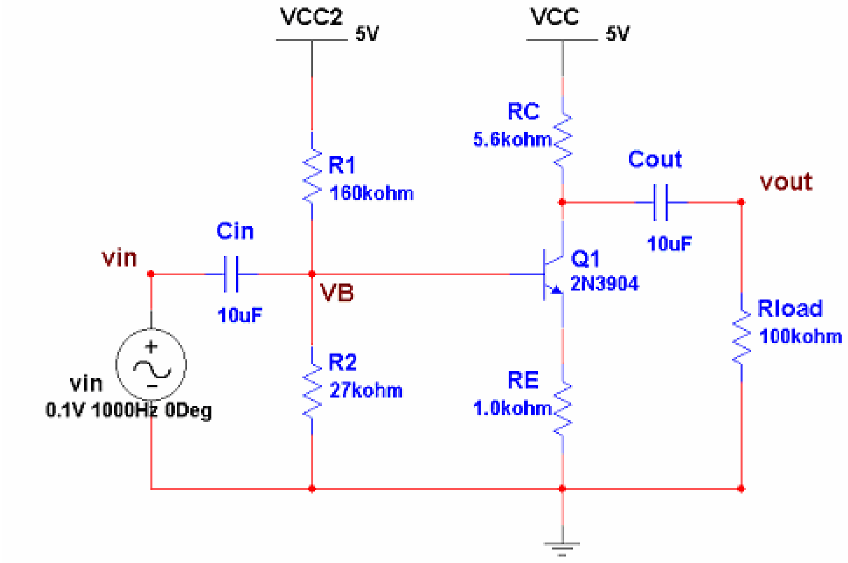
Lab 03 -- Part 8

Designing Transistor Amplifiers

In the last activity you figured out an expression for the voltage gain of a transistor amplifier circuit shown.

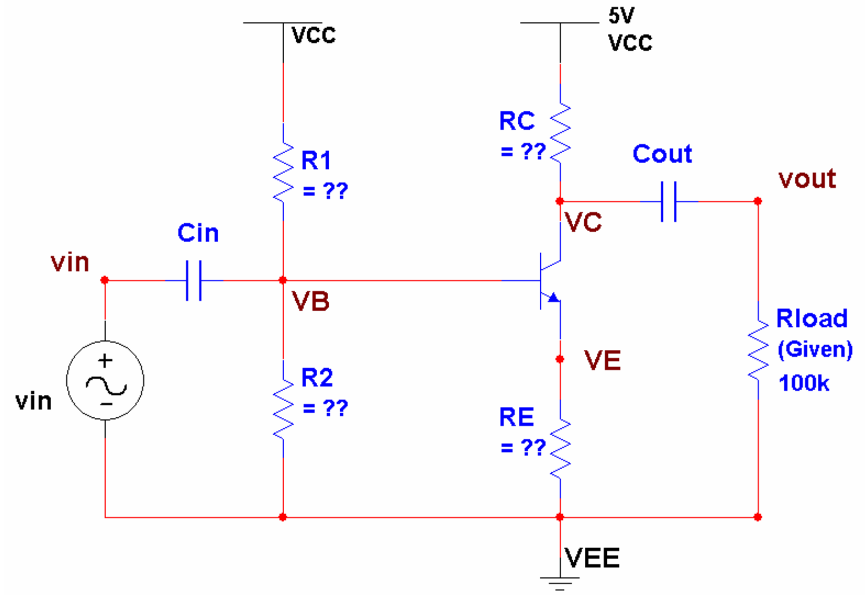
$$A_v = \frac{|v_{out}|}{|v_{in}|} \approx -\frac{R_c \,\|\, R_{Load}}{R_E}$$

You may have noticed that the expression for Gain did not contain β or g_m or any other transistor parameter: This fact makes this circuit advantageous to use as an amplifier, because there transistor parameters are typically unreliable and therefore it is not wise to base your design such that the amplifier gain depends upon them.



In this activity you will devise a procedure that will allow you to work backward to figure out the values of various resistances in the circuit above that would give you a desired AC voltage gain, A_v (= $|v_{out}|/|v_{in}|$).

Q1. Suppose you were asked to design an amplifier that would provide a particular load, R_{Load} with a certain voltage gain, A_v (say 10), can you simply choose any arbitrary combination of R_E and R_C to give you the desired voltage as per the equation above (with other resistor values chosen randomly), or are there other considerations to worry about? [Hint: Go back to **Lab03 Part 6** and think about the "range of validity" in which you calculated the AC voltage gain i.e. is there a certain range of DC values of V_B (or V_{IN}) around which you should provide your AC perturbation to get your desired voltage gain?]



The act of choosing the choosing the values of various resistances (R_1, R_2, R_C, and R_E) such that the DC voltages for V_B and V_C are in a desirable range in which the circuit acts as an amplifier, is called ***biasing***. Appropriate biasing is in fact the crux of designing an amplifier circuit. The circuit topology (connections between various resistors etc.) is usually pre-determined i.e. it the one shown – what is left to the designer's ingenuity is selecting the appropriate values of R_1, R_2, R_C, and R_E that would meet at least two conditions:

1) Provide the desired AC voltage gain, A_v (= v_{out}/v_{in}). [For example, say $|A_v|$ = 15dB] *
2) Provide the appropriate DC voltage at the output (V_C), that would allow you the voltage signal at the output, v_{out} to swing in the positive and negative directions, is as large as possible without hitting the allowed extremes: V_{CC} (which is the +5V in this case) and V_{EE} (which is ground in this case.)

Since 1) above is a concept that we have discussed previously, let us focus on 2) above.

Q2. What should the DC bias voltage at the output (V_C) be in terms of V_{CC} (+5V) and V_{EE} (ground) so that the output voltage swings in both the positive and negative directions around V_C is as large as possible?

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* Gain is typically specified in decibels (dB). Later, in this activity when you use this value in your design calculations you would need to convert it to number: $A_{dB} = 20\log(|v_{out}|/|v_{in}|)$

Your answer to this question tells you unambiguously what the DC value of V_C should be (to allow for maxim swings of the output voltage signal without getting clipped off). So, let us move on and see what we can say about the DC bias voltage at another terminal of the transistor: V_E.

Now V_C and V_E are two potentials that lie along the path of the main current that flows through the transistor. So, let us try and use this information, and what you know about V_C above to see if we can find out more about the value of V_E.

Q3. Finding emitter bias voltage, V_E: Use the questions (i) through (iv) below to guide you through this process.

(i.) How are the currents through R_C and R_E related to each other? [Hint: Refer to **Q3** in **Lab03 – Part 5**]
(ii.) How is the current through R_C related to V_C? [Hint: Refer to Ohm's Law]
(iii.) How is the current through R_E related to V_E? [Hint: Again, refer to Ohm's Law]
(iv.) How are the resistances R_C and R_E related to each other? [Hint: Think about one of the conditions that we are trying to meet when we build this circuit.]
(v.) By answering the questions (i) through (iv) above, can you find V_E, unambiguously? Explain.

Now, let us move on to find the remaining DC bias voltage at the third terminal of the transistor: V_B.

Q3. Finding base bias voltage, V_B: When the transistor is in the "ON" state, i.e. current flows through it what is the diode voltage V_{BE}? [Hint: What is the diode's turn-on voltage?] Based on this answer, and the answer to the previous question, can you find V_B, unambiguously? Explain.

STOP and Check with Instructor

At this point you have figured out what the various DC bias voltages V_C, V_B and V_E of the transistor need to be for it to meet both of your requirements 1) and 2) specified earlier. The next step is figuring out the values of R_1, R_2, R_C and R_E that would enable you to achieve the DC bias voltages that you need. As you work through this process, you may or may not be able to arrive at unique answers for each of the resistances – don't worry just go ahead and make as good a guess as possible.

Q5. Can you find an appropriate combination of values of R_1 and R_2 that would yield a value of V_B that you calculated above? Explain [Hint: You may have already done something very similar in a recent previous activity.]

Q6. Can you find an appropriate combination of values of R_C and R_E that would yield a value of the desired AC voltage gain. Keep in mind that the output voltage is supplied to a 100kΩ load resistor.

Use the values of R_1, R_2, R_C, and R_E that you calculated above and simulate the circuit. Test how well your simulated circuit meets the specifications that you set out to meet:

(i.) Perform a DC Operating Point analysis to check the values of the node voltages V_B, V_C, and V_E.
(ii.) Perform a transient analysis to find the AC Voltage gain and see if it meets the requirement: $|A_v| = 15\text{dB}$.

Q7. How well does your simulated circuit meet the specifications above. Explain any discrepancies.

Q8. Attempt to 'fix' any discrepancies by tweaking the values of R_1, R_2, R_C, and R_E that you have used. Justify why you may be adjusting these values either up or down compared to the values that you have now.

Q9. Build the real circuit and…

(i.) Measure the DC node voltages V_B, V_C, and V_E and compare them with the ones in the final simulation.
(ii.) Apply an AC signal and measure the amplitude v_{out} and v_{in}, calculate the AC Voltage Gain and compare it with the one in the final simulation above.

STOP and Check with Instructor

Additional Considerations

Q10. In the above design are the values of R_1, R_2, R_C, and R_E that you have used uniquely defined? i.e. Are there other combinations of these values that would give you the same DC Operating point as well as AC voltage results? Explain why or why not.

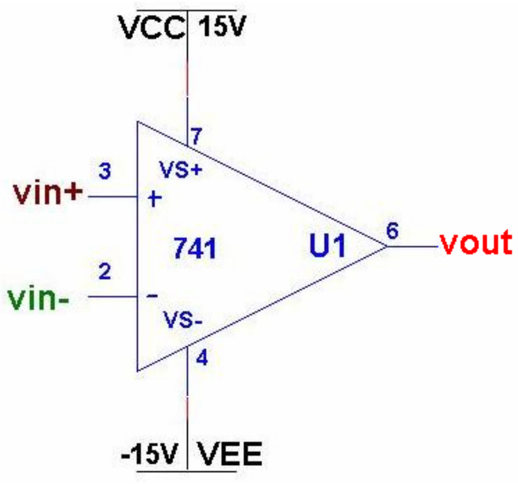
In the next activity you will learn about some other considerations that circuit designers typically have to worry about as they design the amplifier circuits. The considerations may narrow the number of options that you have for the various resistances and involve some 'trade offs' where you have to balance one specification with another.

Summary 04

OPAMPS & OPAMP Circuits

OPAMPS – General Characteristics

OPAMPS (Operational Amplifiers) are high gain differential amplifiers i.e. they amplify the difference between the signals received at the two inputs.



The 741 OPAMP is one of the most commonly used OPAMPS.
The inputs are:

v_{in+} the non-inverting input (Pin 3) , and
v_{in-} are the inverting input (Pin 2).

The output voltage of an OPAMP is: $\boxed{v_{out} = A_v (v_{in+} - v_{in-})}$

where A_v is the voltage gain.

The 741 OPAMP needs a +15V and a -15V power supply.

Some of the most important characteristics of an OPAMP are the following:

- Extremely high voltage gain A_v: $\boxed{A_v \to \infty}$
- Extremely high input impedance: $\boxed{Z_{in+} = Z_{in-} \to \infty}$

The consequences of these characteristics of the OPAMPS are the following:

- Because $A_v \to \infty$: $\Rightarrow A_v = \dfrac{v_{out}}{(v_{in+} - v_{in-})} \to \infty$

  Now, v_{out} is finite, then the only way this can happen is if $(v_{in+} - v_{in-}) \to 0$ $\Rightarrow \boxed{v_{in+} \approx v_{in-}}$

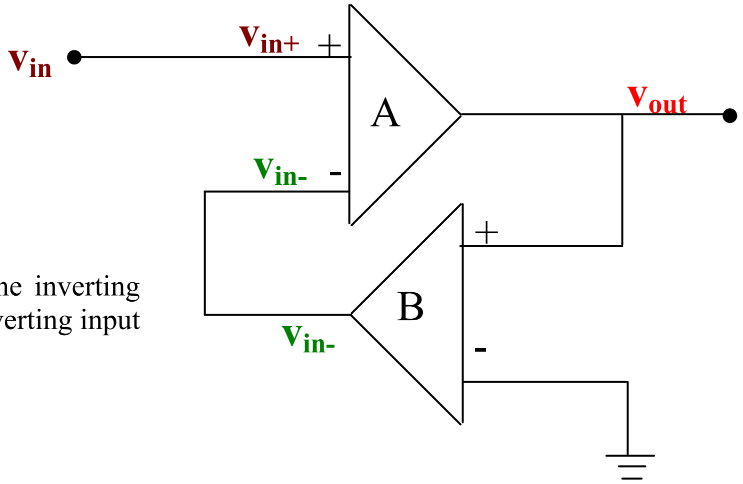
  So, if $v_{in-} = 0$, then $v_{in+} \approx 0$ It acts as a *virtual* ground.

- Because Z_{in+}, $Z_{in-} \to \infty$ $\Rightarrow Z_{in} = \dfrac{v_{in}}{i_{in}} \to \infty$

  Now, v_{in} is finite, then the only way this can happen is if $\boxed{i_{in} \to 0}$

OPAMPS -- Voltage Feedback

Because the voltage gain (A_V) of an OPAMP is so high, even a very small difference in the input voltages (v_{in+} and v_{in-}) can cause the output to fluctuate between V_{S+} (+15V) and V_{S-} (-15V). Therefore, to stabilize the output, an OPAMP is often used with some type of feedback i.e. a portion of the output signal is fed back to the inverting input (Pin 2) and subtracted from the input signal v_{in} which is supplied to the non-inverting input. (Pin 3)



Then: $$\boxed{v_{out} = \frac{A_{VA}}{1 + A_{VA}A_{VB}} v_{in}}$$

Where:

A_{VA} = The open loop gain of Amplifier 'A'
A_{VB} = The open loop gain of Amplifier 'B'

The term 'open-loop' gain refers to the gain without feedback.

Note: It is important that the feedback is provided to the inverting input of 'A'. If the feedback were provided to the non-inverting input then, the above expression would have become:

$$v_{out} = \frac{A_{VA}}{1 - A_{VA}A_{VB}} v_{in}$$

which can lead to an unstable situation when $A_{VB} = 1/A_{VA}$.

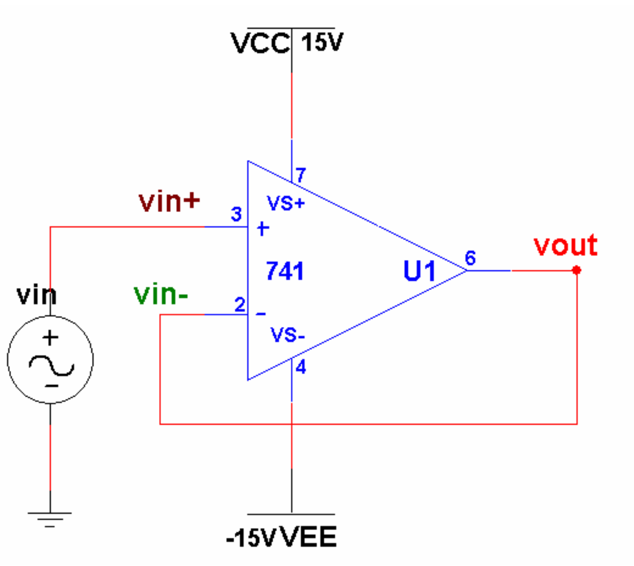
OPAMPS – Circuits with Voltage Feedback

The following features of an OPAMP have important implications for the behavior of an OPAMP in a circuit.

$A_v \to \infty$

$Z_{in+}, Z_{in-} \to \infty$, and

$v_{in+} \approx v_{in-}$



Unity Gain Voltage Follower

$v_{in+} = v_{in}$

Since $v_{in-} \approx v_{in+}$ $\Rightarrow$ $v_{in-} = v_{in}$

But, $v_{out} = v_{in-}$ $\Rightarrow$ $\boxed{v_{out} = v_{in}}$

The advantage of using this circuit is that it ensures that $Z_{in} = \infty$

Another way of analyzing this circuit is to recognize that it is similar to the generic feedback circuit shown on page 1, only here $A_{VB} = 1$. Substituting in the expression for v_{out} you get:

$$v_{out} = \frac{A_{VA}}{1 + A_{VA}A_{VB}} v_{in} \qquad \Rightarrow v_{out} = \frac{A_{VA}}{1 + A_{VA}} v_{in}$$

Also, $A_{VA} \to \infty$ So, dividing uniformly by A_{VA} and using $1/A_{VA} \to 0$,

We get: $v_{out} = \dfrac{1}{1/A_{VA} + 1} v_{in}$ $\Rightarrow v_{out} = v_{in}$ Which is same as the expression derived above.

Non-Inverting Amplifier

$v_{in+} = v_{in}$

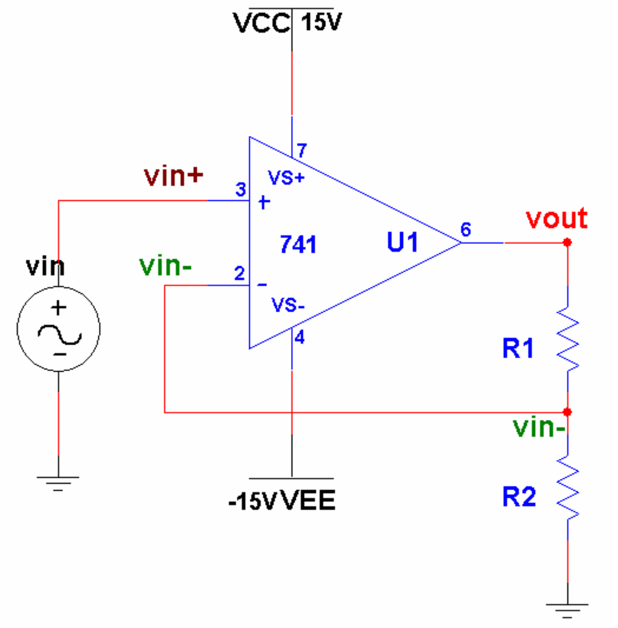
Since $v_{in-} \approx v_{in+}$ $\Rightarrow$ $v_{in-} = v_{in}$

But, using voltage division: $v_{in-} = v_{out} R_2 / [R_1 + R_2]$

So: $v_{out} = v_{in} [R_2 + R_1] / R_2$

$\Rightarrow$ $\boxed{v_{out} = v_{in} [1 + R_1/R_2]}$

The advantage of using this circuit is that it ensures that $Z_{in} = \infty$.



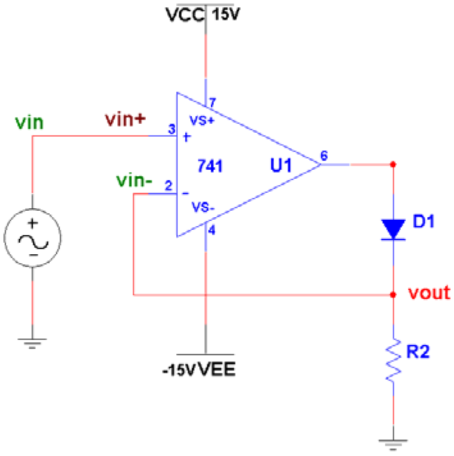
Another way of analyzing this circuit is to recognize that it is similar to the generic feedback circuit shown on page 1, only here $A_{VB} = R_2 / [R_1 + R_2]$ by voltage division.

Substituting in the expression for v_{out}, and using $A_{VA} \to \infty$ you get:

$$v_{out} = \frac{A_{VA}}{1 + A_{VA}A_{VB}} v_{in} \qquad \Rightarrow v_{out} = \frac{1}{1/A_{VA} + A_{VB}} v_{in} \qquad \Rightarrow v_{out} = \frac{1}{0 + R_2/[R_1 + R_2]} v_{in}$$

Simplifying: $v_{out} = v_{in} [1 + R_1/R_2]$ Which is same as the expression derived above.

Half-Wave Rectifier

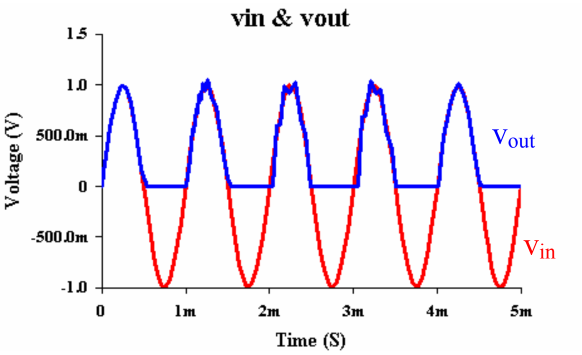


When v_{in} is positive,

- $\Rightarrow$ Output voltage of diode (Pin 6) is positive
- $\Rightarrow$ Diode is forward biased
- $\Rightarrow$ Diode acts as a short.
- $\Rightarrow$ Circuit acts as a Unity Gain Follower
- $\Rightarrow v_{out} = v_{in}$

When v_{in} is negative,

- $\Rightarrow$ Output voltage of diode (Pin 6) is negative
- $\Rightarrow$ Diode is reverse biased
- $\Rightarrow$ Diode acts as an open switch.
- $\Rightarrow v_{out}$ is only connected to ground via R_2
- $\Rightarrow v_{out} = 0$



This rectifier is called the *Active Rectifier* because it uses an active element i.e. an OPAMP.

It is superior to a passive rectifier because v_{out} is not less than v_{in} by the 0.6V diode drop.

Diode Clamp

$v_{out} = v_{in-} \approx v_{in+} = v_{in}$

However, when $v_{out} > V_{pos} + V_{Diode}$

The diode D_{pos} conducts

v_{out} is clamped at $V_{pos} + V_{Diode}$

$\Rightarrow v_{out} = V_{pos} + V_{Diode}$

$\Rightarrow v_{out} = V_{pos} + 0.6$

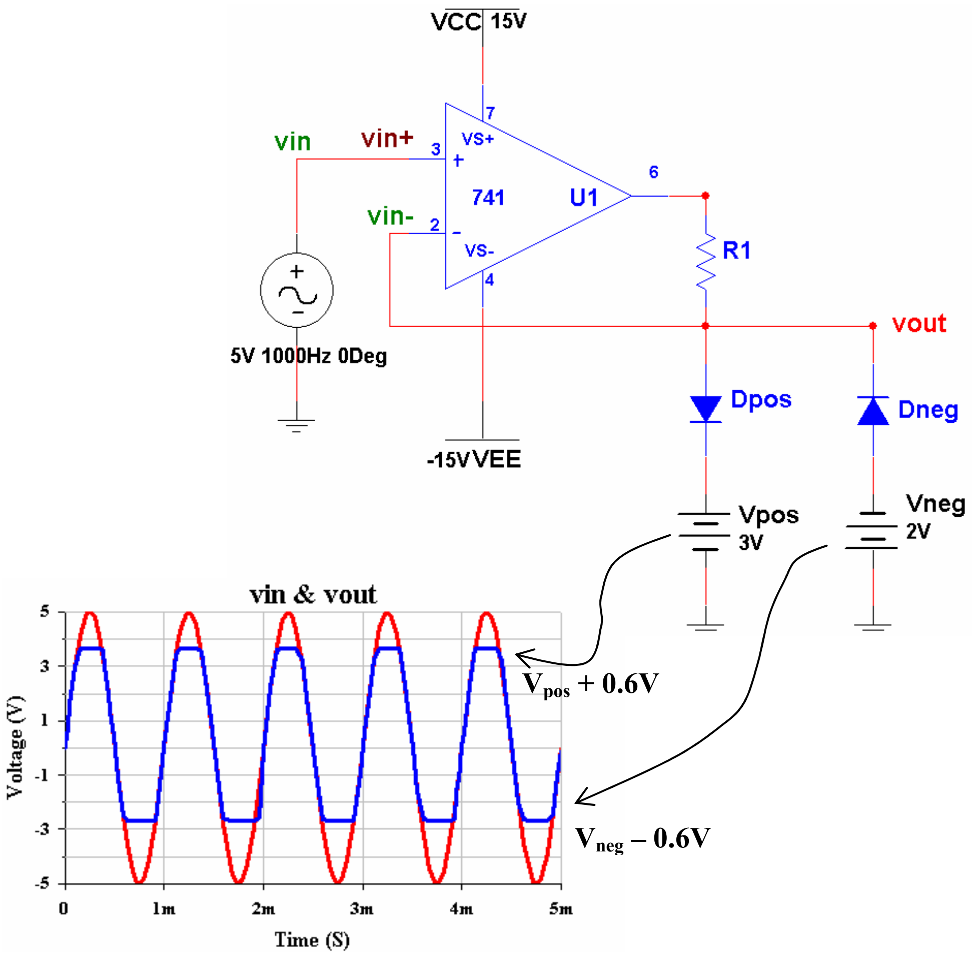
However, when $v_{out} < V_{neg} - V_{Diode}$

The diode D_{neg} conducts

v_{out} is clamped at $V_{neg} - V_{Diode}$

$\Rightarrow v_{out} = V_{neg} - V_{Diode}$

$\Rightarrow v_{out} = V_{neg} - 0.6$



The main advantage of this *Active Diode Clamp* is the very large input impedance.

OPAMPS – Circuits with Current Feedback

Sometimes feedback is provided in form of a current (rather than voltage, as was the previous case). Here a path is provided for the current to flow between the input and the output. The input resistance Z_{in} is no longer ∞. Then the above analysis is modified. Here you rely mainly on the facts that: $\boxed{v_{in+} \approx v_{in-}}$ and $\boxed{i_{in} \rightarrow 0}$

Inverting Amplifier

$v_{in+} = 0$

Since $v_{in-} \approx v_{in+}$ $\Rightarrow$ $v_{in-} = 0$

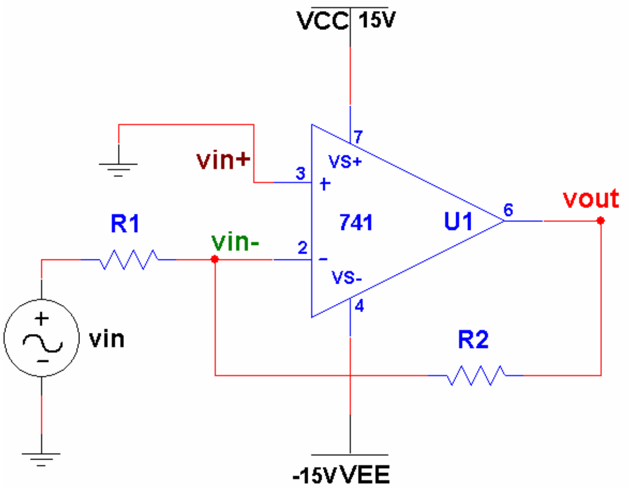
Because $Z_{in-} \rightarrow \infty$ $\Rightarrow$ $i_{in-} = 0$

Using Kirchoff's Current Law at v_{in-}:

$i_{R1} = i_{R2}$ $\Rightarrow$ $(v_{in} - 0)/R_1 = (0 - v_{out})/R_2$

$$\Rightarrow \quad \boxed{v_{out} = v_{in}\,[-R_2/R_1]}$$

The input impedance is: $Z_{in} = R_1$.



Summing Amplifiers

Because the inverting amplifier is based on the principle of Kirchoff's Current Law, it is possible to add several different voltage inputs (with appropriate weighting coefficients), by choosing different ratios of resistances.

To create a voltage output:

$$\boxed{v_{out} = -[Av_{inA} + Bv_{inB} + Cv_{inC} \ldots]}$$

Then:

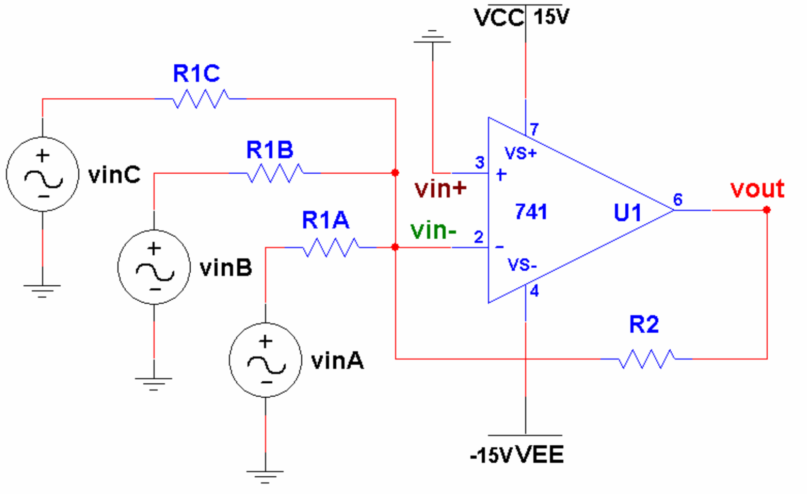
$A = R_2/R_{1A}$

$B = R_2/R_{1B}$

$C = R_2/R_{1C}$

… and so on.

Note: There is a negative sign in the front indicating that it is an inverter.



Combining the Inverting & Non-Inverting Amplifiers

$v_{in+} = v_{inB}$

Since $v_{in-} \approx v_{in+}$ $\Rightarrow$ $v_{in-} = v_{inB}$

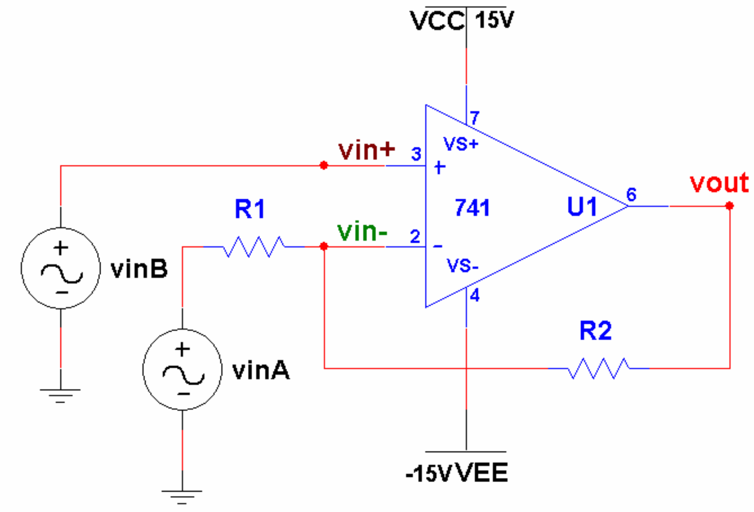
Because $Z_{in-} \rightarrow \infty$ $\Rightarrow$ $i_{in-} = 0$

Using Kirchoff's Current Law at v_{in-}:

$i_{R1} = i_{R2}$

$\Rightarrow (v_{inA} - v_{inB})/R_1 = (v_{inB} - v_{out})/R_2$

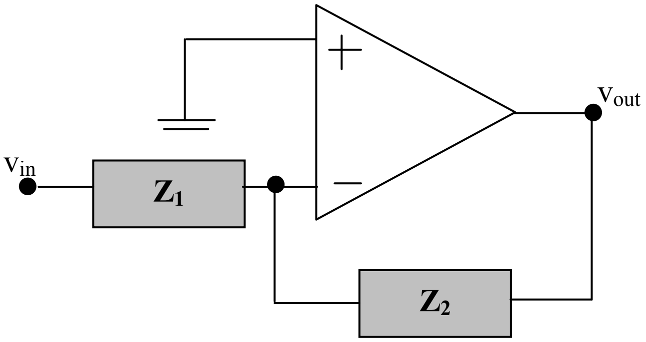
$$\Rightarrow \quad \boxed{v_{out} = \underbrace{v_{inA}\,[-R_2/R_1]}_{\text{Inverting } v_{inA}} + \underbrace{v_{inB}\,[1 + R_2/R_1]}_{\text{Non-Inverting } v_{inB}}}$$



Integrator & Differentiator

General expression for any type of current feedback:

$$\boxed{v_{out} = v_{in}\,(-Z_2/Z_1)}$$



Integrator

Here: $Z_2 = X_{C2} \parallel R_2$

$\Rightarrow Z_2 = X_{C2}R_2 / [X_{C2} + R_2]$

$\Rightarrow Z_2 = R_2 / [1 + j\omega R_2C_2]$

and $Z_1 = R_1$

So: $v_{out} = v_{in}\,[-Z_2/Z_1]$

$\Rightarrow v_{out} = -v_{in}\, R_2 / R_1[1 + j\omega R_2C_2]$

When $\omega R_2C_2 >> 1$

Then: $v_{out} \approx -v_{in}\, R_2 / R_1[j\omega R_2C_2]$

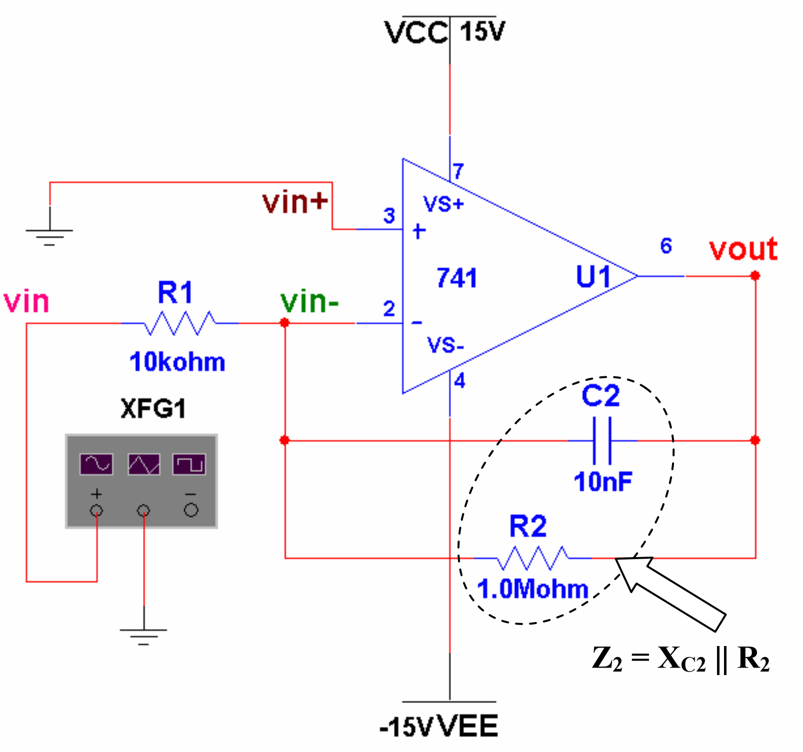
$\Rightarrow$ $v_{out} \approx -v_{in} / j\omega R_1C_2$

So, the circuit acts as an integrator.

When $\omega R_2C_2 << 1$

Then: $v_{out} \approx -v_{in}\, R_2 / R_1$

So, the circuit acts as a simple inverting amplifier.



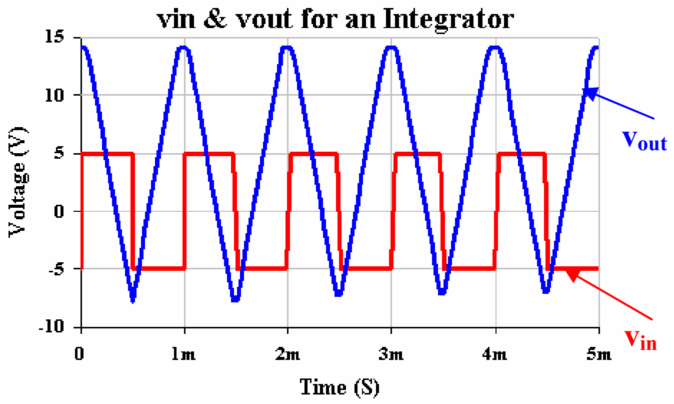
In the example shown:

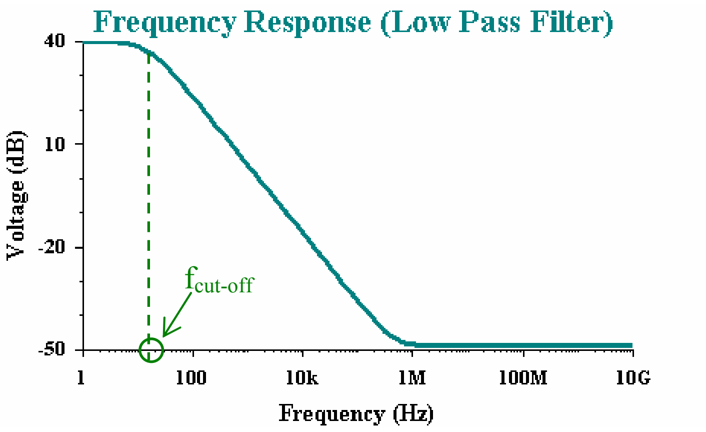
$f = 1\text{kHz} \Rightarrow \omega = 6.3\text{x}10^3$ /s

$R_2 = 1\text{M}\Omega = 10^6\Omega$, $C_2 = 10\text{nF} = 10^{-8}\text{F}$

$\Rightarrow$ $\omega R_2C_2 = (6.3\text{x}10^3\text{ /s})(10^6\Omega)(10^{-8}\text{F}) = 63 >> 1$

So the circuit acts as an integrator.


vin & vout for an Integrator


Frequency Response (Low Pass Filter)

The advantage of this *Active Integrator* (over the passive one) is that v_{out} is not necessarily $<< v_{in}$

The circuit also acts as an *Active Low Pass Filter* with a cut-off frequency $\boldsymbol{\omega_{cut\text{-}off} = 1/R_2C_2}$

Differentiator

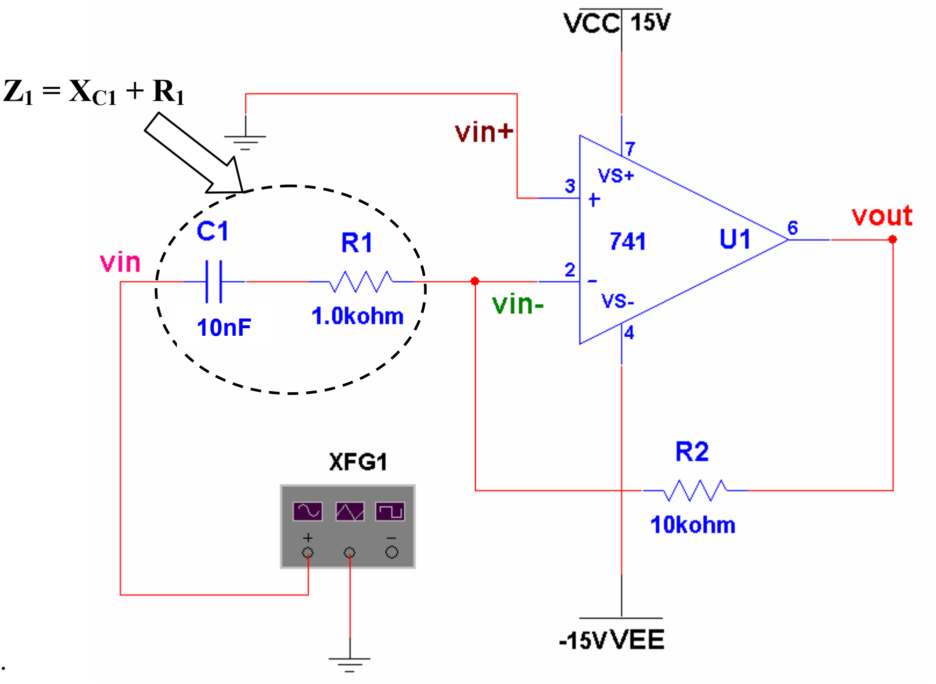
Here: $Z_1 = X_{C1} + R_1$
$\Rightarrow Z_1 = R_1 + 1/j\omega C_1$

and $Z_2 = R_2$

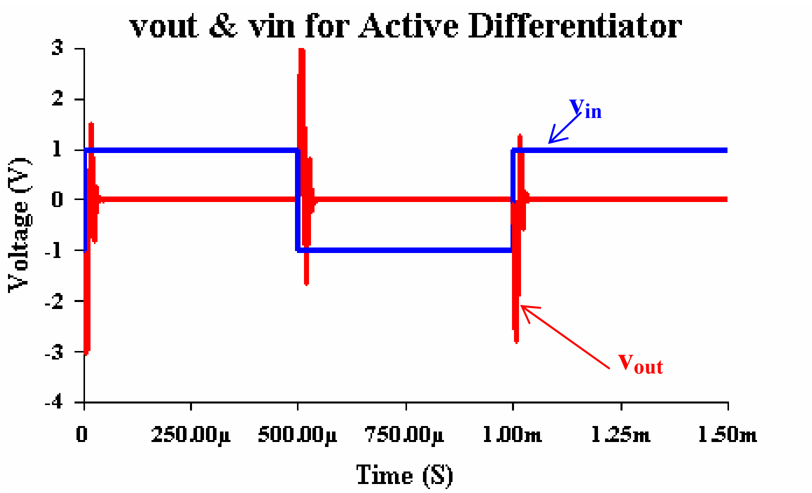
So: $v_{out} = v_{in}\,[-Z_2/Z_1]$
$\Rightarrow v_{out} = -v_{in}\,R_2 / [R_1+(1/\,j\omega C_1)]$
$\Rightarrow v_{out} = -v_{in}\,(j\omega R_2C_1) / [1 + j\omega R_1C_1]$

When $\omega R_1C_1 >> 1$, Then:
$v_{out} \approx -v_{in}\,(j\omega R_2C_1) / [j\omega R_1C_1]$
$v_{out} \approx -v_{in}\,R_2/R_1$
So, the circuit acts as an inverting amplifier.

When $\omega R_1C_1 << 1$, Then:
$v_{out} \approx -v_{in}\,(j\omega R_2C_1) / [1]$
$v_{out} \approx -(j\omega R_2C_1)\,v_{in}$
So, the circuit acts as a differentiator.



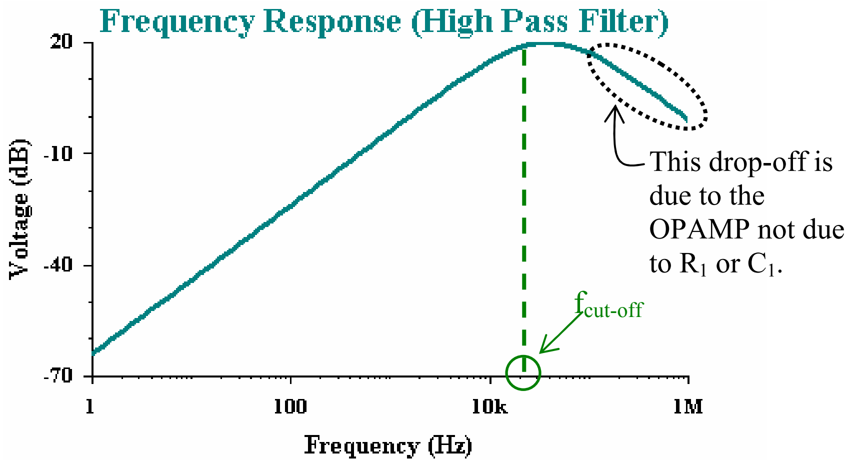
In the example shown:
$f = 1\text{kHz} \;\Rightarrow \omega = 6.3\text{x}10^3$ /s
$R_1 = 1\text{k}\Omega = 10^3\Omega$,
$C_1 = 10\text{nF} = 10^{-8}\text{F}$
$\Rightarrow \omega R_1C_1$
$= (6.3\text{x}10^3\ /\text{s})(10^3\Omega)(10^{-8}\text{F})$
$= 6.3\text{x}10^{-5} << 1$
So the circuit acts as a differentiator.



The circuit also acts as an *Active High Pass* filter with a cut-off frequency of:
$\omega_{cut\text{-}off} = 1/R_1C_1$

In this example:
$\omega_{Cut\text{-}off} = 1/(10^3\Omega)(10^{-8}\text{F})$
$= 10^{+5}$ /s.

$f_{Cut\text{-}off} = \omega_{Cut\text{-}off}\,/2\pi$
$= 16\text{kHz}.$


Frequency Response (High Pass Filter)

This drop-off is due to the OPAMP not due to R_1 or C_1.

MID-TERM EXAM

DUE 5:00PM FRIDAY, MARCH 19

!!FIRM DEADLINE!!

Please Observe the Following Code for this Exam

- You **MAY**:
  - Refer to information in any book, notes, CD-ROM or media.
  - Refer to any material accessible over the internet.
  - Consult with your instructor for this course.
- You **MAY NOT** consult with any person other than your instructor for this course.

NOTE: Please upload all *simulation* files onto K-State Online. The file name for each file must indicate your last name, exam and question number as per the following example: "**Rebello _PMImidterm_Q1b**." You may turn in your written solutions via file upload or handwritten solutions as you did for Homework 01.

Maximum Points on Mid-Term Exam = 40 Points per Question x 4 Questions = 160 Points.

Q1:

Part (a)

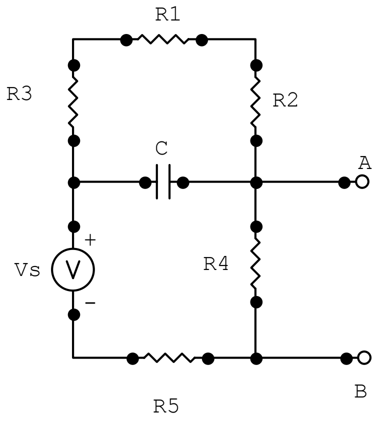
Find the Thevenin equivalent circuit for the following network between terminals A and B

(i) At very low frequencies.

(ii) At very high frequencies.

(iii) Repeat (i) and (ii) if the capacitor is replaced with an inductor.

(iv) Verify your predictions with a simulation.



Part (b)

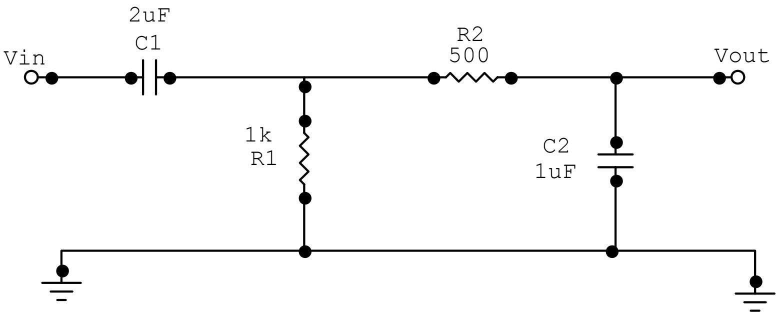
For the circuit shown…

(i) What is kind of filter is it?

(ii) Determine its cut of frequencies.

(iii) Sketch the Bode plot of its frequency response.

(iv) Verify your predictions with a simulation.



Q2:

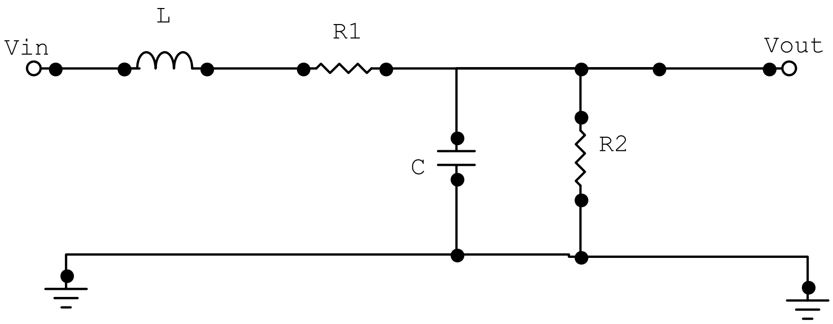
Part (a)

(i) Design a circuit that has the same frequency response as the circuit shown in **Q1 Part (b)**, but uses inductors instead of capacitors.

(ii) Verify your design with a simulation.

Part (b)

Calculate the magnitude and phase of the gain (v_{out}/v_{in}) as a function of frequency and the values of R_1, R_2, C and L



Q3:

Part (a)

Design a full wave rectifier circuit that can deliver 1mA to a 10kΩ load from using a 60Hz, 110V line supply with a 0.1% ripple factor. Find out….

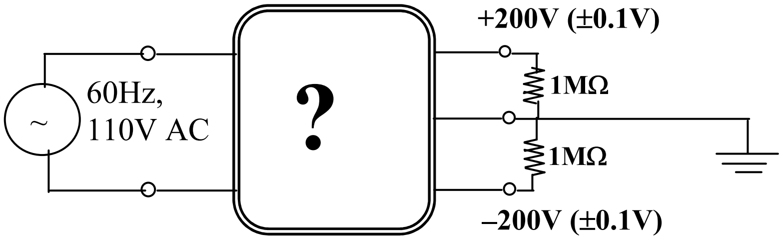
(i) The turns ratio of the transformer that you would need?

(ii) The value of the capacitor(s) used?

(iii) Simulate the circuit (You can use a voltage controlled voltage source as your transformer, because the other transformers may not let you change their turns-ratio). Verify your design to check whether you are indeed getting the right voltage and ripple factor that you calculated. Explain the discrepancies, if any between your design and the simulation.

Part (b)

The figure shows a "black box" for a split power supply that runs off a 60 Hz, 110VAC line, and has two output terminals, at +200V and the other at –200V, each with a ripple factor ≈±0.1V when supplying a 1MΩ load.



(i.) What are the internal components of the "black box"? Draw a schematic

(ii.) Determine the values of each component that would meet the specifications. (Hint: You may need more than one transformer, capacitor, and diode)

(iii.) Simulate the circuit based on the values you determined in (ii) and verify whether it meets the specifications.

(iv.) Explain any discrepancies between the simulation and your predictions.

Q4:

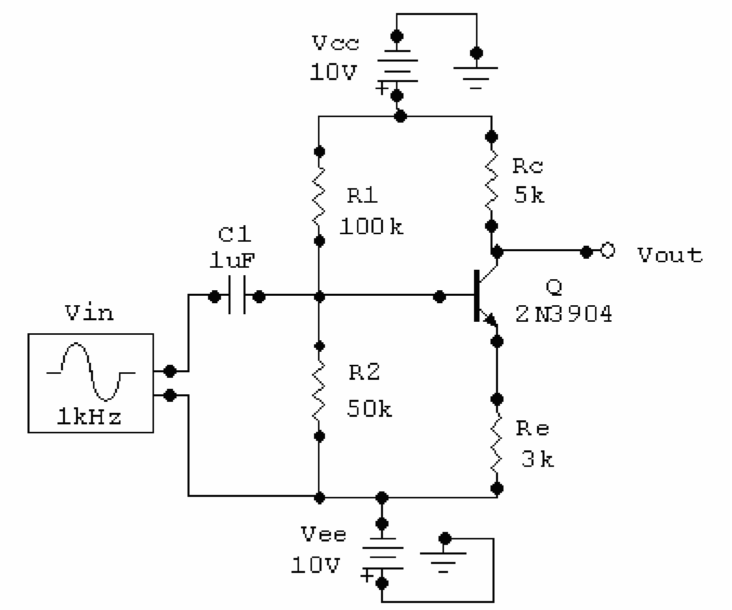
Part (a)

For the circuit shown…

(i) Find the DC operating point voltages and current for the transistor.

(ii) Sketch the output waveform for the following circuit if v_{in} has an amplitude of 1mV.

(iii) Verify your prediction using a simulation.



(iv) What is the role of C_1 in the circuit? What will happen if you remove it? Verify your prediction using the simulations.

Part (b)

Design a transistor amplifier that meets the following specifications:

(1) operates at a quiescent current less than 250μA,

(2) uses a single +15V power supply (and of course, ground)

(3) has at least a 30dB voltage gain when loaded with a 20kΩ load coupled through a 1μF capacitor,

(4) allows for the maximum possible voltage swing, within the limits of the power supply.

For the circuit that you have designed…

(i) What is the DC operating point of the transistor?

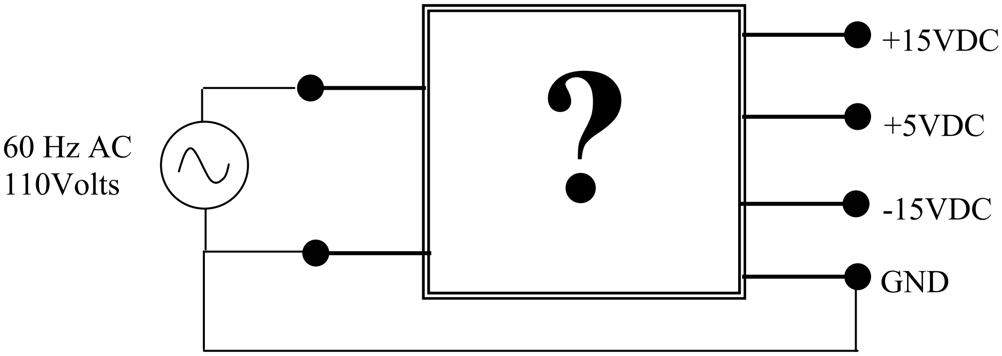
(ii) What is the output waveform for a sinusoidal input of ±5mV?

(iii) Simulate the circuit and verify whether it meets the specifications above.

FINAL EXAM

Question 1:

The black box shown is the power supply in our lab. Design the internal electrical circuitry of the power supply shown such that it produces the DC output voltages shown.

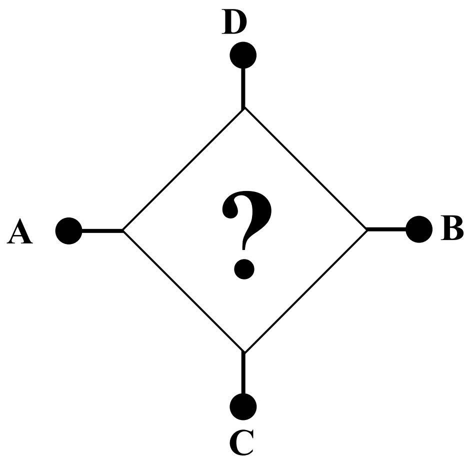


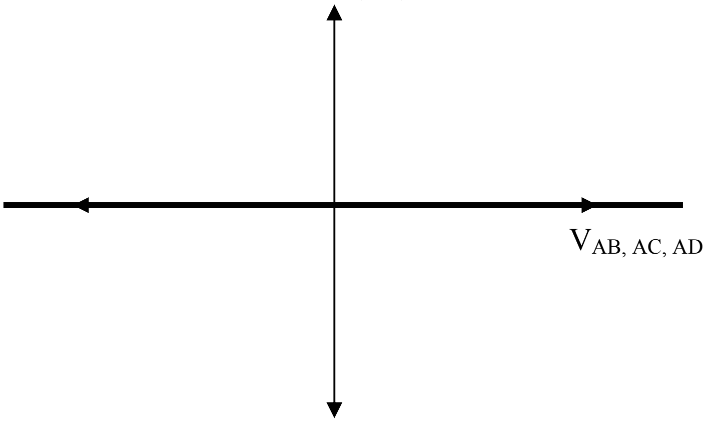
Question 2:

A four-terminal device is shown to have following set of I-V curves:

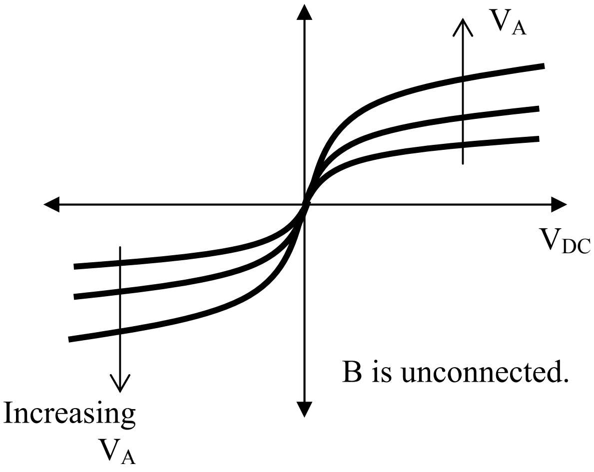
Based on the information shown what can you tell about the device?

Can you construct its equivalent circuit?

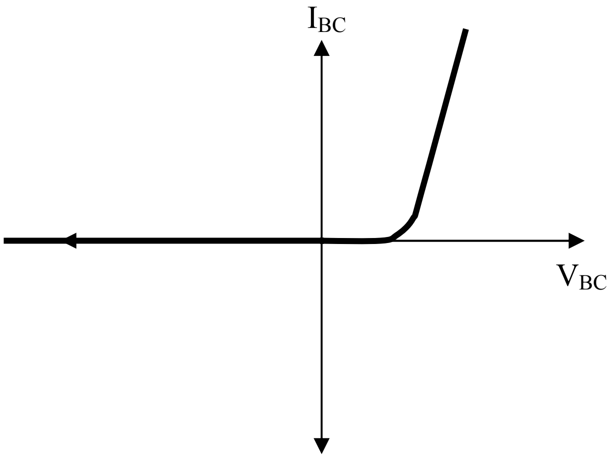




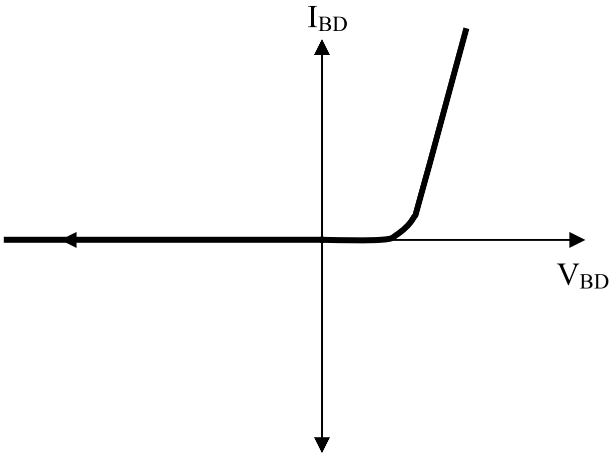
No change with voltage at the other terminal.



B is unconnected.



No change with voltage at A or D.



No change with voltage at A or C.

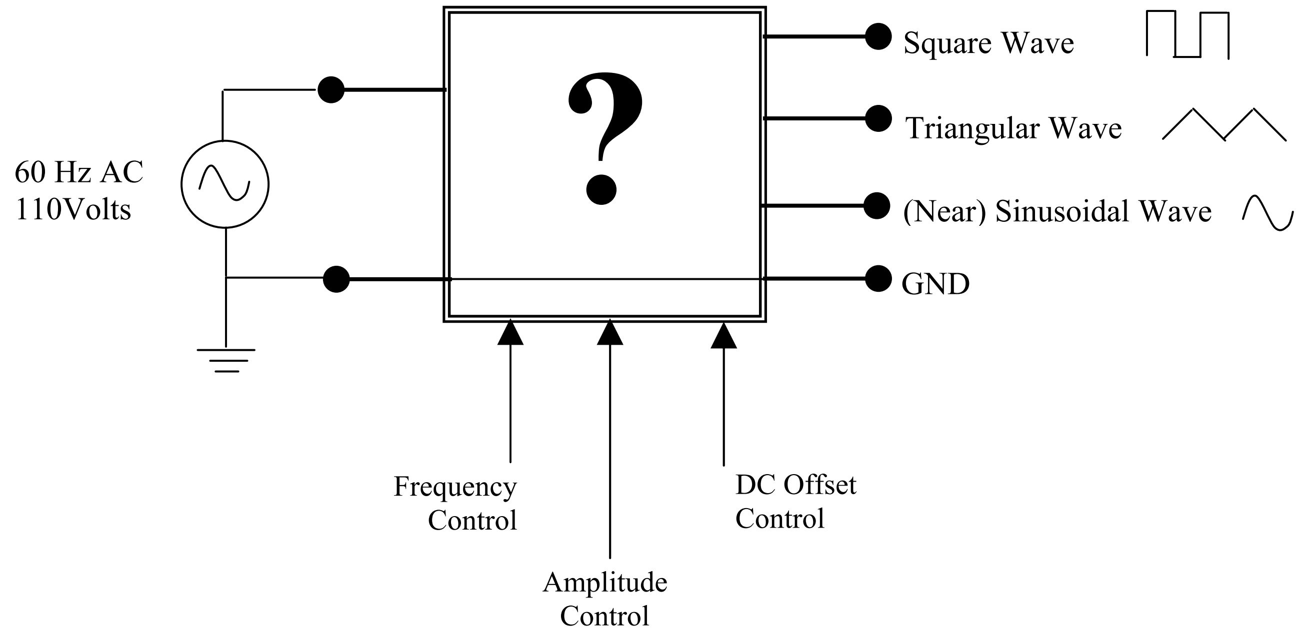
Question 3:

Design a function generator similar to one that you used in the lab in that it uses a 60Hz, 110V AC line power to produce a square wave, triangular wave or a (approximately) sinusoidal wave that allows for a…

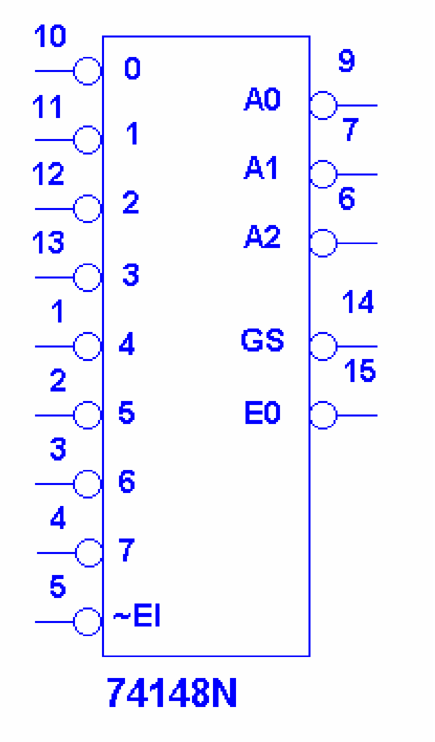
(a) Variable frequency.

(b) Variable amplitude (0 to 15V).

(c) Variable DC Offset (0 to 5V).



Question 4:



The figure shows a **74148N** chip which is an 8-input priority encoder. The chip has 8 inputs (0 through 7). Depending upon which of these inputs is active, the corresponding 3-bit binary number is displayed a the output ($A_2A_1A_0$). If more than one of the inputs is active, then the binary output corresponds to the highest input, hence the name priority encoder.

Additionally the chip has the following…

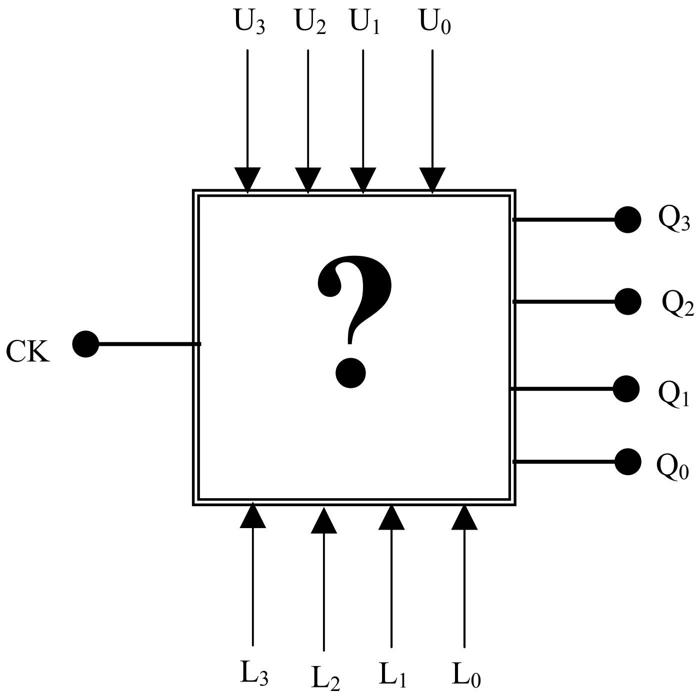
- Enable Input ~EI: The chip works only when this is active.
- Enable output EO: This is active *only* when the chip is enabled AND *all* the inputs are inactive.
- Output GS: This is active *only* when the chip is enabled and *at least one* of the inputs is active.

a) Describe the internal circuitry of the chip i.e. explain how one of the outputs (say corresponding to A_1) is calculated from the inputs and the enable input.

b) Suppose you had 16 input lines, can you think of a way in which to use this chip (perhaps more than one of these) to create a 16 to 4 priority encoder?

Question 5:

Design a counter that counts sequentially from a 4-bit binary number $L_3L_2L_1L_0$ up to a different 4-bit binary number $U_3U_2U_1U_0$. Assume you have a clock input available for use.



Physics 620
Teaching University Physics
Fall 2004
Revised October 5, 2004

Instructor: N. Sanjay Rebello Email: srebello@phys.ksu.edu
Office: CW 503 Voice: 532-1539 Fax: 532-6806
Class Meeting Time: Tuesday, Thursday 8:00-9:15am. Room: CW 023
Office Hours: Monday, Wednesday 3-5pm or just drop by.
The Class Web Page is maintained at K-State On-line: http://online.ksu.edu/
Physics Education Research Group Home Page: http://web.phys.ksu.edu/
Instructor's Home Page: http://www.phys.ksu.edu/~srebello/

Goals

In this course you will study and discuss recent developments in our understanding of how students learn physics. Emphasis will be placed on models of learning and teaching techniques which can be applied to the teaching of physics to university students. After completion of this course, you will have a have a better grasp of the issues and techniques pertaining to the teaching and learning of undergraduate physics.

Topics

The class discussion will concentrate on a few of the topics which are part of the efforts of researchers in physics education. Five topics are listed below. I anticipate that we will have time for four of them.

1: Future directions in undergraduate physics teaching and learning
The new millennium prompted several authors to consider the state of physics teaching and learning and make recommendations for the future. We will look at some of these discussions.

2: Models of physics teaching learning, and the development of reasoning
We will discuss models and strategies which research suggests are most appropriate for conceptual change among college students. This discussion will include several related models and some discussion of the learning theories which support them.

3: Conceptual learning and how it is assessed
Many physics teachers will state that the major goal of their efforts is to have students understand the basic concepts and not just plug-and-chug with equations. In the topic area of dynamics significant effort has been made to measure how well students are learning the concepts. Our discussion will focus on the some concept inventories as a measuring tool, some of the data from them, and the question of what they actually measure.

4: Student attitude, expectations and beliefs toward physics
This topic will address the types of students who major in physics and why many students who are capable of doing the work do not choose to take advanced courses in physics.

5: Applying research to physics teaching and learning
The class will investigate learning/teaching styles which attempt to respond to situations discussed above. The treatment here will include the application of research and the use of technology in the teaching of abstract ideas. We will also look to the future of physics teaching and learning in colleges and universities.

General Procedures

This course will operate in a discussion format. In some cases the class will discuss topics as a whole; in others, we will break into small groups to discuss topics and then each group will report back to the rest of the class. For this format to work everyone must come to class prepared. Assignments need to be completed *before* class begins.

Texts

There is no formal textbook for this course. However, there are some books that we will refer to quite often during the course. A list of these books will be placed on the course website, and will be updated when necessary. If you are aware of any books that could be useful in this class, please let me know.

Readings

We will use a series of reading from reports, workshops and journals. These readings will be made available on the class Web site. In addition to the readings that will be used as the basis for discussion, several other documents will be used as reference material.

Reviews

Independent reading will be an important part of this course. Each week (starting Week 2) you must submit a short review of material which falls into one of the following areas:

- a paper on physics and science education. Over the course of the semester, please make sure that you review at least one article from each of the following journals: The Physics Teacher, American Journal of Physics, European Journal of Physics, Physics Education, Journal of Research in Science Teaching, International Journal of Science Education. Web links to these journals are provided on the course website.
- a chapter in a book which discusses physics and/or university education,
- a teaching tool such as software, a videodisc or CD-ROM, or
- a World Wide Web site related to physics education.

By the end of the semester you must have completed at least two reviews from each of the last three areas above as well as one review from each of the journals listed in the first bullet.

Recommended journals are listed on the course Web pages

These reviews will be due by at **5:00 p.m. on Friday** of each week of the semester except the first week. A short review is defined to be equivalent to one page that is single spaced with normal margins and 12 point or smaller font (~2,000 characters). Reviews should be submitted in electronic format. They should be uploaded onto the Web site using the “File dropbox” link under “Tools” on the left navigation bar on the course website.

Class Assignments

Daily assignments will be announced in class. In addition the class will have three major assignments and a final project.

Major Assignments.

Comparison of your education in science and math with the discussion in the Black, Euler, Goodstein, Jossem and Redish papers (individual) **Due Friday, September 17 at 5:00 p.m.**

Think about your college level education in the context of the discussion in the introductory papers. Discuss how your science and mathematics courses do or do not meet the recommendations in these discussions. What are the most important changes that would make your undergraduate education be compatible with the issues raised in these papers? Would these changes be good for physics teaching and learning? Why or why not?

Analysis of a teaching technique or tool in terms of development of reasoning (collaborative) **Due Friday, October 22 at 5:00 p.m.**

Select a teaching tool such as a textbook, lab manual, videodisc, or CD-ROM. Use the ideas that are presented in the *Workshop on Physics Teaching and the Development of Reasoning* and related papers to analyze the effectiveness of this tool for teaching introductory physics at the undergraduate level.

Conceptual learning at different levels (collaborative) **Due Wednesday, November 24 at 5:00 p.m.**

Choose a topic in physics that is taught in conceptual-based (e.g. P. World), algebra-based (e.g. General Physics) calculus-based (e.g. Engineering Physics) courses, as well as an advanced undergraduate course. By analyzing the textbook presentation at each level compare and contrast how the presentations help students develop a *conceptual* understanding of the topic. The choice of topic should be discussed with the instructor before you begin.

Final Project **Due Monday, December 13 at 5:00 p.m.**

The final project is your opportunity to demonstrate what you have learned and the quality of your understanding. Thus, it should include information from all aspects of the course as well as the literature in physics education. For a final project you have two choices:

- *Creation of teaching materials (collaborative)* Develop some teaching materials that can be used in a physics class at the introductory level. The materials should use active learning techniques to have students investigate some aspects of the physics of an application of electricity, magnetism or 20th Century physics. The lesson that you create should require about 4-6 hours of student activity. You should provide a complete description of what the students will do as well as references to any other instructional materials that they will need. In addition to the instructional materials, you should write a paper which connects your instructional design to the various topics that we have discussed throughout the semester.
- *Completion of a small research project (collaborative)* Design and complete a small research project related to learning and teaching of physics at the undergraduate level. The project needs to address issue which are discussed during class and must follow proper research techniques. Most projects are likely to involve interactions with students or analyses of classroom interactions. Thus, you will need to start early. Proposals for research projects must be discussed with the instructor no later than **October 22**.

Guidelines for Collaborations

- If an assignment is labeled collaborative, you may collaborate with one other student to complete the assignment. If you choose to collaborate, you and your partner will submit one assignment that represents both of your work. This assignment should represent about twice as much work as one you would have done by yourself.
- For a collaborative project both students will receive identical grades. You may not collaborate on two different projects with the same student.
- The materials that you submit for each project should represent a significant effort. You are not limited to paper and ink but may use any available resource including World Wide Web, audio - and videotape, digital audio and video, etc. You are encouraged to submit assignments electronically.

Web Discussions

We are a small class so using network technology seems unnecessary. However, we need to learn how to use the techniques that are likely to be significant teaching tools of the future. Thus, a threaded discussion will be established on the class home page. We will establish discussions of specific topics and use them outside of class. These discussions will also serve as the class forum when the instructor is out-of town.

Grades

Course grades will depend on all aspects of the class with the distribution listed below:

Projects during semester	30%	Weekly reviews	15%
Final project	30%	Class participation	25%

Other Related Activities

You are encouraged to attend the Physics Education Seminars. The seminar is somewhat informal. A schedule will appear on the Web as it becomes available. At least one of the Physics Colloquia will focus on material related to this class. All class members are required to attend these events.

Disabilities

If you have any condition such as a physical or learning disability, which will make it difficult for you to carry out the work as I have outlined it or which will require academic accommodations, please notify me and contact the Disabled Students Office (Holton 202), in the first two weeks of the course

Plagiarism

Plagiarism and cheating are serious offenses and may be punished by failure on the exam, paper or project; failure in the course; and/or expulsion from the University. For more information refer to the "Academic Dishonesty" policy in K-State Undergraduate Catalog and the Undergraduate Honor System Policy at http://www.ksu.edu/honor/

Assignment 04 -- Due 5:00pm on Wednesday, September 1.

Read each of the following articles: *Cognitive Research -- What's in it for Physics Teachers? (Mestre, 1989), Implications of Cognitive Studies for Teaching Physics (Redish, 1994)*

- Write down the most important points in each article?
- What, if any are the common themes emerging from these articles?
- What, if any are the differences between the points made by these various articles?
- What chronological trends, if any do you notice in the way in which cognitive research has played a role in physics education?

This assignment is due on the by **5:00pm on Wednesday, September 1**.

Please write your responses using Microsoft Word and upload them using the "File Dropbox" link under "Tools" on the left panel of the class website. Please name your file using the following format: "Lastname_mm-dd" where 'mm' and 'dd' are numbers indicating the month and date that the assignment is due. For this assignment 'mm' is 09and 'dd' is 01.

Cognitive Research? What's in it for Physics Teachers (Mestre, *The Physics Teacher*, 1989)

Several findings in cognitive research have not been actively disseminated to the physics teaching community.

Most teachers know that they need to emphasize conceptual understanding and problem solving rather than memorization, but not clear how cognitive research can play a role here.

Dissemination is not sufficient – rather close cooperation between cognitive researcher and teacher/practitioner is needed.

Cognitive Research explains:

- Initial (Novice) state of student.
- Final (Expert) state of student.
- Transition from Novice to Expert and how it occurs.

Initial (Novice) States:

- Students are not clean slates – they often have naïve theories about how the world works, based on everyday experiences.
- We all unconsciously construct these theories or models of how the world works.
- These theories often interact with knowledge presented in class and interfere with their development of expert knowledge.
- Examples of students misconceptions are presented
    - Atwood's machine – Block hanging lower is heavier.
    - Circular motion – Body follows circular path when released.
    - Airborne ball – Three forces: gravity, drag force, impact force. (possible reason: language)
    - Electric circuits -- Two resistances in series act differently in influencing a light bulb.
    - Other areas – e.g. Optics.

Implications for Instruction

Teaching by telling does not work because a student's preconceptions interfere with the "message" that the teacher wants to convey. Often students hear what they think the teacher is saying and not what s/he is really saying.

Methods to Overcome Misconceptions

Students to should engage in active learning to actively challenge their misconceptions through their experiences: They make a prediction based on their misconception and find out that their prediction does not match reality. That makes them much more amenable to change their prediction. Typically a small number of misconceptions occur in a majority of students.

Several Methods to Address Misconceptions

- Use of demonstrations as Conceptual Bridges is one example – A conceptual bridge provides a scenario that amplifies a particular physical principle that students can apply to other contexts e.g. discharging a large capacitor, or springy table to show springiness in a regular table.
- Use of computer programs and visualizations that are not possible in the real world.
- Computer-based labs – “software plus transducer”. E.g. Graphs of motion plotted in real time.

Identifying Misconceptions

- Listen to students verbalize their understanding.
- Look for patterns in errors made by students.
- Reflect on your own thinking.

Expert/Novice Research

If we look at experts and compare them with novices we can perhaps think about what novices need to do to become experts.

Research Questions

- How to experts and novices organize and retain domain-related knowledge?

  Experts…

  Organize knowledge into a domain-relate hierarchical pyramid – Most fundamental concepts on the top and more specific ones at the bottom, which can only be accessed via more fundamental concepts at the top.
    - Cluster knowledge into coherent bits or pieces or chunks.
    - Each chunk has more features associated with it.
    - Relate chunks of knowledge to one another
    - Retrieve related chunks of knowledge.

  Two studies have clearly shown that helping students organize knowledge (as experts above) helps them perform better both on recall as well as on problem-solving tasks.

- How to experts and novices apply this knowledge to solve problems?

  Experts…
    - 1st: Consider the deep structure of the problem – Fundamental principles.
    - 2nd Perform a qualitative analysis of the problem.
    - 3rd : Develop a strategy to solve the problem
    - 4th: Execute the procedures in the strategy.

  Novices
    - Focus on the surface features of the problem.
    - Immediately jump into solving the problem.

  Studies demonstrated that…

  - novices categorize problems based on surface features rather than the physical principles involved in the solution.
  - Novices can become more expert-like if they are guided to think like experts about problem solving. This involves:
    - Describing problem in detail before solution.
    - Determining relevant information.
    - Deciding the appropriate procedures to use.

Example: HAT – Hierarchical Analysis Tool (For research not for teaching).
Student makes decisions about the problem by dynamically generated computer menus that start with general and become increasingly specific as one progresses.
Finally, the student is provided with a set of equations that help solve problem.

The study:

Experimental group used HAT
Control groups: 1) Used textbook method 2) EST (Equation Sorting Tool) – computerized, searchable database for sorting equations.

Comparison on three tasks
1) Problem categorization 2) Explanations 3) Problem solving

Results:

- HAT group exceeded others in categorization task.
- HAT groups applied higher order concepts more significantly than other.
- All three groups improved significantly on the problem solving task, but no statistically significant difference.
- Other results showing improvement of EST group.

Implications of Study for Teaching:

- Structured problem solving (e.g. using HAT) helps develop expertise.
- Should not rely solely on paper-and-pencil problem solving to measure expertise. For instance, categorization and explanation tasks are also important and students who show identical problem solving expertise may vary on these tasks.
- Organization is key -- Students tend to focus on surface features even when deep structure is identical.
- Ability to recognize range of applicability of concepts is also key. So teachers must explore how a concept can be applied in a variety of contexts.

<u>Conclusions</u>

- Increased collaboration between teachers and cognitive researchers is necessary
- Major obstacles remain:
  - Textbooks emphasize quantitative rather than qualitative learning.
  - No effective assessment instruments.

Implications of Cognitive Studies for Teaching Physics (Redish, *AJP*, Vol. 62, No. 9, 1994)

Society has a need for scientifically literate people and not just a few scientists.

Our introductory physics courses do not account for the vast number of students – most leave them with no clear conceptions of the field. This is because not much attention has been paid to how students learn physics.

Research exists on how students learn physics, their difficulties in doing so and how to help them.

However, few researchers have tried to construct a "general theoretical framework" of how students learn physics.

We need to think about how students learn physics as we would a scientific problem – propose theories that are based on and verifiable by scientific evidence.

This essay reviews some of the things that Redish has learned about cognitive science and how it applies to teaching and learning physics.

Models of student learning and *not* akin to computer programs – they are not clear cut. There are some guiding principles but not hard and fast rules.

He proposes four fundamental principles of learning physics:

Construction principle:

Fundamental Hypothesis: People organize their experiences and observations into mental models. Mental models contain chunks of information called schema. Mental models have the following properties:

1) Contain images, rules and procedures.
2) May contain contradictory elements.
3) May be incomplete.
4) People may not necessarily know how to use or "run" these mental models.
5) Do not have firm boundaries between elements – can be confused or overlap.
6) Are used to minimize mental energy.

Construction Principle: People must create the mental models for themselves. Teachers can only provide students the appropriate experiences to help them create the mental models, but cannot provide them with the mental model.

Corollary 1.1: Goal of physics teaching vis-à-vis mental models is to help students:

- ☐ Reason about the physical world based on their observations.
- ☐ Organize their reasoning into mental models.
- ☐ Learn how to apply the model.

Thus, it is not sufficient to assess mastery of content. Rather, we should test for whether students can do what we have outlined in the above corollary.

Corollary 1.2: Students must acquire the higher-order thinking skills of evaluating whether the results they have obtained is reasonable i.e. are the mental models that they have reasonable.

Again, this means we must assess students' mental models, not merely their ability to use some problem solving strategies.

Corollary 1.3: Students have prior experiences with the physical world and organize these experiences into mental models.

Corollary 1.4: Students build new mental models by active engagement and experiences, rather than by watching or listening.

For a few students, reading a book or listening to a lecture can be actively engaging, because they engage in a mental dialog with the speaker or the book. Other students may need other ways to be actively engaged.

Corollary 1.5: Most students do not have a mental model for effectively learning physics.

Most students do not have the right "mental ecology" i.e. they do not have a mental model that tells them what mental model to apply in a given situation.

When we became teachers we paid more attention to our own mental ecology, which helped us become better learners.

Assimilation Principle:

We mostly learn by matching, extending, or building on something that we already know

The mental model that we have also dictate they way in which we modify them i.e. how to deal with new information.

Corollary 2.1: We learn by building on something that we already know:

Effective teaching helps students build on their existing information by facilitating the assimilation of new information and experiences (e.g. use of physics words in everyday contexts – students have unclear meanings of what they mean, however we can try and build on these meanings rather than expecting students to discard them completely and adopt new ones.)

Corollary 2.2: We learn mostly by building analogies with what we already know.

Corollary 2.3: We need problems and examples that we can return to again and again – We can then build on these examples and enrich them. These examples should be appropriately interwoven into the storyline for a course.

Accomodation Principle:

It is very difficult to change an established mental model substantially i.e. replacement of new ideas by giving up old ideas is more difficult than assimilating new ideas into an existing mental framework or mental model.

Often new material gets added on, but it is not well integrated into the framework and therefore is not very effective.
Often students may transform what they hear to match their existing mental model.

However, it is possible to transform a mental model through predict-observe-explain tasks, where students confront reality and realize that their existing mental models cannot predict reality correctly.

Corollary 3.1: To change a mental model, a proposed replacement must be

1) Understandable.
2) Plausible.
3) Address cognitive conflict i.e. explain something that the previous model did not.
4) Be useful – same as 3) but in wider situations.

Individuality Principle:

Different students have different mental models for physical phenomena and different models for learning i.e. different mental ecologies.

To learn how students think we must examine them through individual, think aloud interviews.

Corollary 4.1: People have different learning styles:

- ☐ Authoritarian vs. Independent.
- ☐ Abstract (or prefer deductive reasoning) vs. Concrete (or prefer inductive reasoning)
- ☐ Algebraic vs. Geometric.

Use of multiple representations helps students go from one type of representation (or modality) to another

Corollary 4.2: Different students respond differently to the same teaching method – There is no best way to teach a subject.

Corollary 4.3: We should not base our teaching on our own personal experiences as students.

Corollary 4.4: Listen to your students!

Contrasts between the papers (*Class discussion)*

- Redish’s views are more encompassing than Mestre’s. Redish talks about a framework, while Mestre talks about individual misconceptions.
- Mestre’s work is an “application” of Redish’s ideas to problem solving and expert/novice comparisons. Redish’s work is more theoretical than Mestre’s.
- Mestre’s target audience is practicing teachers in high school and introductory college courses, while Redish aims more at researchers and college professors.