

Appendix E.1. The Physical Computing & Robotics Integrated Robotics Curriculum

What is the Physical Computing & Robotics Integrated Curriculum?

This document contains classroom assignments and projects for students enrolled in my **Physical Computing & Robotics (PC&R)** classes at George School in Newtown, PA, USA. This new, *integrated curriculum* interlaces the learning of programming, design, electronics, and robotics throughout the first 20-22 weeks of the course. This integrated curriculum jumps back and forth through both volumes of the *Physical Computing & Robotics* textbooks, allowing students to experience the more hands-on, engineering components of the course (*e.g.*, electronics, robotics, and design) as early as possible.

In our older, more traditional curriculum, students had to fully cover *all* of the basics of C-language programming covered in Volume One before they were permitted to explore Volume Two topics of electronics, sensors, data acquisition, actuators, and robotics. The new, integrated curriculum is much less sequential in nature, allowing students to get a taste of both coding and engineering robotics early in the school year.

Introduced in 2018, this new, integrated curriculum has many benefits over the previous traditional (chronological) curriculum, including:

- The topics are covered more quickly, keeping things fresh.
- Hands-on activities involving real-world objects are introduced much earlier in the year.
- Students do not burnout on months of endless programming. (Some students prefer physical and mechanical tasks to more cerebral coding tasks.)
- Programming concepts are reinforced as topics are re-covered throughout the year.
- Students who are partial to programming are happy, as are students who prefer hands-on, mechanical tasks.

Most assignments involve reading some portion of a chapter in textbook and solving some of the **Challenge Problems**, which are found at the end of each chapter. Timelines and due dates can be found on the Canvas LMS system. The due dates are somewhat flexible because ours is a student-driven course, allowing students to follow a pace that suits their needs and interests. While there is no maximum speed with which you can cover the material, there is a minimum speed that must be adhered to. Students having difficulty keeping the minimum pace must come to Consultations, the Friday Supplemental Lecture, or complete their classwork for homework.

Students should endeavor to complete one chapter per week. Some of the more complex material will require more time, and some of the less complex material will require less time. Adhering to this timeline will permit students to spend all ten weeks of **Term 3** on their **independent final projects!**

Table of Contents

- Appendix E.1. The Physical Computing & Robotics Integrated Robotics Curriculum 1
 - What is the Physical Computing & Robotics Integrated Curriculum?..... 1
 - E.1.1. First Monday Introductions..... 4
 - E.1.2. Day 2 Beginnings 6
 - E.1.3. Laser Cutting Introduction – Making a Nameplate for Your Shelf Space..... 6
 - E.1.4. SketchUp Introduction 7
 - E.1.5. 3D Printing Introduction – Making a Decal/Nameplate for Your Toolbox..... 7
 - E.1.6. Progress Quiz: Lab Tour Quiz – Vocabulary #1..... 7
 - E.1.7. Chapter 1 – Introduction to Physical Computing..... 8
 - E.1.8. Chapter 2 – Serial Output and Intro to Functions..... 8
 - E.1.9. Chapter 3 – Data Types, Variables, and Constants 9
 - E.1.10. Chapter 4 – Arithmetic and Rounding..... 10
 - E.1.11. Progress Quiz: Chapters 1-4..... 10
 - E.1.12. Soldering Introduction 11
 - E.1.13. Pushbutton Circuit Board Fabrication and Testing 11
 - E.1.14. Hall Effect (Magnetic Field Sensor) Circuit Board Fabrication and Testing..... 11
 - E.1.15. Chapter 5 – Functions and Arguments..... 12
 - E.1.16. PRT3 Motherboard Build and Fabrication and Testing..... 12
 - E.1.17. Chapter 13 – Vol 2 Chapter 13 - An Intro to Electronics and Getting to Know the PRT3 Motherboard..... 13
 - E.1.18. Chapter 14 – Getting Started with Circuits 14
 - E.1.19. Progress Quiz: Chapter 14..... 14
 - E.1.20. Chapter 15 – Creating Sound and Light with a Breadboard and PRT3 as the Voltage Source..... 15
 - E.1.21. Chapter 7 – Advanced Mathematics..... 16
 - E.1.22. Chapter 6 – Serial Keyboard Input and Modular Programming..... 16
 - E.1.23. Progress Quiz: Chapters 5-6..... 17
 - E.1.24. Chapter 8 – Random Numbers..... 17
 - E.1.25. Chapter 16 – Creating Sound & Light with digitalWrite() 18
 - E.1.26. Chapter 10 – While- and Do-While Loops..... 19
 - E.1.27. Chapter 11 – For-Loops..... 20
 - E.1.28. Chapter 16 – Re-do with For-Loops 21
 - E.1.29. Chapter 17 – Creating Sound & Light with Pulse Width Modulation using analogWrite and digitalWrite..... 22
 - E.1.30. Chapter 18 – Introduction to Servomotor Programming..... 23
 - E.1.31. Chapter 19 – Making Your Robot Move with Servomotors..... 24
 - E.1.32. Chapter 9 – If-Then Logic Statements..... 25
 - E.1.33. Progress Quiz: Chapters 8 & 9..... 25
 - E.1.34. Chapter 10 – Re-do with If-Then Statements 26
 - E.1.35. Chapter 11 – Re-do with If-Then Statements 26
 - E.1.36. Progress Quiz: Chapters 10 & 11..... 26
 - E.1.37. Chapter 20 – Infrared Range-Finding (Analog) Sensors 27

E.1.38. Chapter 21 – Environmental Sensing with Voltage Dividers and Other Analog Sensors	28
E.1.39. Chapter 22 – Ultrasonic Rangers, Buttons, Whiskers, and Other Digital Sensors.....	29
E.1.40. Design and 3D Print an LED Light Diffusion Dome	30
E.1.41. Design and build a license plate for your OneBot with the Laser Cutter	30
E.1.42. Design and build a license plate for your OneBot with a 3D Printer.....	30
E.1.43. Design and Fabricate Your Own Circuit Board using ExpressPCB Software	31
E.1.44. Final Independent Project!.....	31
E.1.45. PC&R Chapters with SKIPPED material (this material is not assigned to anyone)	32

E.1.1. First Monday Introductions

- Welcome and introductions
- Students must decide what kind of textbook they want. Enter their choices in the spreadsheet and order books today! Here are the hard-copy options:

	Volume One	Volume Two
Black & White, Spiral Bound	\$22.68	\$25.64
Color, Perfect Bound	\$32.90	\$38.32

- Spiral is good to conserve desk space.
 - If you buy only **one** color book, make it Volume Two because it is more necessary to see colors for the electronics connections.
 - If you are unable to afford the book or if you must have an e-copy of the text, talk to Chris.
- Otherwise, there is nothing else they need to purchase for the class. (Some supplies will be given to you tomorrow, and will be charged to your account.)
 - Students may wish to buy a small notebook that can be stored in the bottom of the toolbox. (Have an example on hand to display.) Notebooks are often used by programmers to work out their algorithms on paper before coding them into the computer!
- Assign computers, robots, and toolboxes to each student.
 - Record the device numbers for each student
 - Which students will bring their own computer, and which will use a school machine?
- Log into computers. This may take a while. Remember your laptop number!
- Create e-mail distribution list
- Point out location of syllabus on Canvas.
 - Discuss syllabus and safety concerns.
- Have fun with some Robot Demos, such as:
 - YouTube playlist from last year's Open House (see Pages on Canvas)
 - LCD screen output
 - Student-made LED screen (thanks, Ellie Clermont!)
 - Line Following 3D-Printed Robot
 - Hacked Robosapien
 - IR Card Swipe
 - Fingerprint Reader
 - RGB LEDs with Bluetooth activation
 - MP3 Player
 - Kynex robot
 - ESRA (facially expressive robot from Patton Robotics)
 - Tank
 - 3D Printer
 - Etc.
- **Homework:**
 - ❖ Read the course syllabus on Canvas >> Files >> Syllabus & Course Info
 - ❖ During the next class period, you will learn how to use the laser cutter. If you plan to use your own computer to make designs, download and install the following tonight:
 - **eMachineShop for CAD Design for 3D Printer and Laser Cutter**
 - Download this handy software for advanced laser cutter designs and gears for 3D printing: <https://www.emachineshop.com/free-download/>
 - **RDWorks Software for Laser Cutting Interface and Design**
 - Download latest version of LaserWORKS (RDWorks) here: <https://www.bosslaser.com/laser-software/>
 - ❖ If you plan to use your own computer, download and install the following within the next few weeks:

- **SketchUp Software** for CAD design for Architecture and 3D Printing
 - Download SketchUp (<https://www.sketchup.com/download/make>). Select “Educational Use”.
 - Alternatively, go to <https://www.sketchup.com/download/all> and select “Make 2017” for your particular OS.
 - SketchUp Make is free
 - Download and install the SketchUp STL plugin. (ITS may not yet have installed this on all machines.) You can get this in the Files section on Canvas like so: Files >> 3D Printing & CAD Files >> SketchUp Files >> SketchUp Plug-ins >> sketchup-stl-2.1.7.rbz
- **Repetier 3D Printer Software** to convert your CAD designs to printer code
 - Download and install the Repetier-Host from <https://www.repetier.com/>.
 - This is a free download, but I recommend supporting this excellent piece of software with a small donation. It is worth it!
- **Express PCB (printed circuit board) CAD Software**
 - The software is free, but only works on a PC machine.
 - Download and install ExpressPCB from <https://www.expresspcb.com/free-cad-software/>.
 - You do **not** need to install ExpressSCH, but you can if you wish.
- **MakerBot 3D Printer Software**
 - We don’t really use the MakerBot anymore, but you can download and install the MakerBot Makerware from <http://www.makerbot.com/desktop>.
 - Select MakerBot Replicator 2 (not 2X)
- ❖ (Optional) For those interested in building a resume, you may want to create your own “academic/professional” YouTube or other video-posting channel. You can post videos of your robotic projects here, so parents, friends, college admission people, and future employers may hit on this page.
- ❖ (Optional) Create a Twitter account and follow @GSRobotics.

E.1.2. Day 2 Beginnings

- Any questions about the syllabus?
- Log into computers. This may take a while. Remember your laptop number!
- Create folders for the following projects:
 - **Teensy Sketches** (for robot apps)
 - **Laser Cutter** (for laser cutting)
 - **SketchUp Designs** (for 3D printing)
 - **ExpressPCB** (for circuit board designs)
- Pass out toolboxes, which belong to George School. They should contain:
 - Robot parts including chassis, motors, wheels, standoffs, spacers, hardware, and Velcro strip
 - Large and small hex wrenches
 - Screwdriver multi-tool
 - Sensors and Passives including Sharp IR, Sonic (3), LED circuits (2)
 - Electronics kit (resistors, LEDs, buzzers, potentiometers, switches, pushbuttons, etc.)
 - Connecting wires (male-male, female-female, and male-female)
 - Etc.
- Pass out the following, which have been purchased by students:
 - Teensy 3.2 microcontroller
 - Programming cable
 - Teensy 3.2 Pinout Card
- In a couple of weeks, pass out the rest of the equipment purchased by the students:
 - PRT3 Motherboard kit
 - 6 NiMH AA Batteries and Battery Pack

E.1.3. Laser Cutting Introduction – Making a Nameplate for Your Shelf Space

1. Open the document, “**Laser Cutter Tutorials for students**”, which can be found on **Canvas** or on my book’s website at <http://www.pcrduino.com/resources/#handouts>.
2. **Together as a class:**
 1. We did the first part of the above tutorial together in class -- learning how to use RDWorks.
 2. In the above tutorial, navigate to Section 7.b. (“**7.b. eMachineShop 2D CAD Software**”) and setup the eMachineShop software. Follow along in the tutorial and ask for help when needed.
 3. Next, navigate to Section 10 (“**10. Student Project: Name Plate for Shelf using eMachineShop and RDWorks**”) and read how to use eMachineShop to create a nameplate for your shelf. Follow along in the tutorial and ask for help when needed.
 4. Turn in the RDWorks (RLD) file via Canvas when done.
3. **Laser cut/engrave your nameplate**
 1. Follow the steps in the tutorial to set up your piece.
 2. Your instructor will walk you through the process of actually cutting the material.

E.1.4. SketchUp Introduction

1. To use SketchUp, you have three options:
 1. If you use a GS laptop, just open SketchUp.
 2. If you have your own computer, download SketchUp 2017
Make: <https://www.sketchup.com/products/sketchup-make>
 3. Or you can use the online version, which can be a bit slow and buggy: <https://app.sketchup.com/app>
4. Open the tutorial, “How to 3D Print at George School”. You can find it on **Canvas** or on my book’s website at <http://www.pcrduino.com/resources/#handouts>.
5. Setup your SketchUp IDE. (See the "SketchUp Setup" link in the tutorial document.)
6. Follow your teacher as you explore the SU tools. (See the "Playing Around with SketchUp Tools" link in the tutorial document.)

E.1.5. 3D Printing Introduction – Making a Decal/Nameplate for Your Toolbox

1. Open the document, “How to 3D Print at George School”, which can be found on **Canvas >> Files >> 3D Printing & CAD Files**.
2. **Together as a class:**
 1. Go over the **SketchUp Setup** section of the document.
 2. Follow the steps in the **Playing Around with SketchUp Tools** section of the document.
3. **Create a decal/nameplate for your toolbox shelf**
 1. Follow the steps in the **Your First REAL SketchUp Design** section of the document.
 - Design a nameplate using SketchUp
 - Export the file as an STL File
4. **Turn the decal/nameplate STL file into G-Code using Repetier**
 1. Follow the steps in the **Repetier Host Software Instructions** section of the document.
5. **Print your nameplate**
 1. Follow the steps in the **Prusa i3 Printer Instructions** section of the document.
 - Load the file(s) on an SD card and print it using the 3D printers

E.1.6. Progress Quiz: Lab Tour Quiz – Vocabulary #1

1. **All Students:** Take the **Chapters 1-4 Progress Quiz**. Ask your teacher for the quiz materials.

E.1.7. Chapter 1 – Introduction to Physical Computing

We will learn this chapter together in class, but you will solve some of the Challenge Problems on your own. (Of course, you may ask for assistance!)

1. If you have not yet done so, do the following:
 - Create folder named **Teensy Sketches** for your Arduino coding projects.
 - Install the Arduino IDE @ <https://www.arduino.cc/en/Main/Software>
 - Install the Teensyduino @ https://www.pjrc.com/teensy/td_download.html
 - Allow the computer time to recognize the new Teensy hardware
 - Play with the Blink sketch
2. We will learn this chapter together in class. Specifically, we will cover the following sections:
 - **All Students:** Sections 1.1-1.6
3. After you have covered the chapter as a class, your instructor will ask you to answer the following **highlighted** Challenge Problems **orally**:
 - **All Students:** 1, 2, 4, 5, 8, and 9
4. Try to answer the following **highlighted** Challenge Problems yourself using your **Teensy** microcontroller:
 - **All Students:** 10, 11, and 13

E.1.8. Chapter 2 – Serial Output and Intro to Functions

We will learn this chapter together in class, but you will solve the following Challenge Problems on your own. (Of course, you may ask for assistance!)

Together as a class, cover the following sections in the text:

- **All Students:** Sections 2.1 - 2.5

Answer the following **highlighted problems**, which will be graded:

- **All Students:** 5, 7, 8, and 12

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.9. Chapter 3 - Data Types, Variables, and Constants

According to your own needs and learning styles, read/skim/peruse/digest **Chapter 3: Data Types, Variables, and Constants** so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 59), Sections 3.2-3.8
- **Intensive:** all pages (Introduction (p. 59), Sections 3.1-3.9)

Answer the following **highlighted problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 3, 5, 7, 8, 10-12, 14, 16, 17, 21, 24, 27, and 30
- **Intensive:** 1-3, 5, 7-19, 22-26, 31, and 32 (a or b for the MJ2() function -- you do **not** have to do both!)

For any problems that ask for a *predicted* outcome, record your predicted output on the following worksheet, which can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **Intermediate:** Vol 1 Chapter 3 - INTERMEDIATE Challenge Problem Prediction Worksheet.docx
- **Intensive:** Vol 1 Chapter 3 - INTENSIVE Challenge Problem Prediction Worksheet.docx

For the predicted problems, do **not** enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

For any coded questions, copy and paste your **code** and its **output** at the end of the worksheet's Word document before turning it in. You may ask your instructor to check your solution code and output.

Save your worksheet and upload the document via Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.10. Chapter 4 – Arithmetic and Rounding

According to your own needs and learning styles, read/skim/peruse/digest **Chapter 4: Computer Arithmetic and Rounding** so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group and the order in which we suggest you read them:

- **Intermediate:** Introduction (p. 97), Sections 4.9, 4.1, 4.2, 4.5-4.9
- **Intensive:** Introduction (p. 97), Sections 4.9, 4.1, 4.2, 4.4-4.9

Before answering the following questions, review this short, helpful video on how to properly echo variables to the Serial Monitor for word problems:

- https://www.youtube.com/watch?v=5CLAf_wvzNM&feature=youtu.be

Before answering the questions below, you must be aware of something called **integer division**, which is covered in Section 4.3 on page 103. It states that when you are dividing two *integers*, the decimal is truncated (i.e., removed) and whatever is left over is the result. For example, on a calculator $4/3 = 1.33333$, but because 4 and 3 are *integers*, the result of the integer division is simply 1. To get it right, use floating point numbers such as $4.0/3.3$. Take another example: $1/2$; On a calculator $1/2 = 0.5$, but in code, $1/2$ is integer division and is truncated to 0. See? Be careful with equations such as $A = \frac{1}{2}bh$ or $V = \frac{4}{3}\pi r^3$. That is, enter them as: $A = \frac{1.0}{2.0}bh$ and $V = \frac{4.0}{3.0}\pi r^3$. **Therefore, you will almost always want to perform your mathematical operations with floating-point numbers!**

Answer the following **highlighted problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 2a-2d (have your teacher grade these now), 5, 13, 16 (you must confirm your answers are correct with Google or another online converter), 21, and 31.
 - For any students who think they may study business or finance in the future, we recommend trying to solve problems 40 and 41 on your own time.
- **Intensive:** 2a-2g (have your teacher grade these now), 3-4 (see your teacher for answers to these questions), 6, 14, 16 (you must confirm your answers are correct with Google or another online converter), 21, 31, and 43.
 - For any students who think they may study business or finance in the future, we recommend trying to solve problems 40 and 41 on your own time.

Turn in your work by copying and pasting your **code** into a **MS Word** document (with 10p font and narrow margins, please) and copying and pasting your code's **output** into another **MS Word** document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.11. Progress Quiz: Chapters 1-4

1. **All Students:** Take the **Chapters 1-4 Progress Quiz**. Ask your teacher for the quiz materials.

E.1.12. Soldering Introduction

1. Watch and read the following TWO links to learn how to solder. You must do this away from the classroom (e.g., at home, library, dorm, etc.) before you will be allowed to do any soldering on your own.
 1. <https://www.youtube.com/watch?v=f95i88OSWB4&feature=youtu.be>
 2. <https://www.instructables.com/id/How-to-solder/>
2. Test your new-found soldering skills with practice circuit boards, resistors, and solid wire.

E.1.13. Pushbutton Circuit Board Fabrication and Testing

1. Build, solder, and test a **Pushbutton Circuit Board**
 1. Assemble the Button Board:
 - <https://youtu.be/vKRZfZUgDFE>
 2. Test the Button Board:
 - <https://youtu.be/cMNkt80uCTs>

E.1.14. Hall Effect (Magnetic Field Sensor) Circuit Board Fabrication and Testing

1. Build, solder, and test a **Hall Effect (Magnetic Field Sensor) Circuit Board**
 1. Assemble the Hall Effect board:
 - <https://youtu.be/P8EBYC81s6U>
 2. Test the Button Board:
 - <https://youtu.be/a91PdIHtV8Q>

E.1.15. Chapter 5 – Functions and Arguments

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 5: Functions with Arguments* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here are the suggested sections for each group and the order in which we suggest you read them:

- **Intermediate:** Introduction (p. 121), Sections 5.1, 5.2, and 5.4 (*omit* the subsection entitled "A Non-Void Function with Arguments")
- **Intensive:** Introduction (p. 121), Sections 5.1-5.5

Before answering the following questions, review this short, helpful video on how to properly echo variables to the Serial Monitor for word problems:

- https://www.youtube.com/watch?v=5CLAf_wvzNM&feature=youtu.be

Answer the following **highlighted problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 1, 2, 4, and 5.
- **Intensive:** 1, 2, 4, 14, 16, 22, and 34.

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.16. PRT3 Motherboard Build and Fabrication and Testing

1. Build and solder your Patton Robotics **PRT3 motherboard** as you watch this video instruction, which is about 20 minutes long.
 - i. <https://youtu.be/KtwOZAMM1c0>
2. Test the Button Board:
 - i. Load "**Blink.ino**" into your Teensy that is inserted into your newly made PRT3 Motherboard.
 - ii. Connect a piezo buzzer between **signal pin #13** and ground.
 - iii. You will know that it is connected correctly if the buzzer beeps in time with the LED. (Unplug the buzzer to avoid headaches!)
 - iv. (*Optional*) Alter the frequency in code.

E.1.17. Chapter 13 - An Intro to Electronics and Getting to Know the PRT3 Motherboard

1. **Together as a class**, go over the important points of the following sections of *Chapter 13 - An Intro to Electronics and Getting to Know the PRT3 Motherboard*. and then answer any Challenge Problems listed:
 - a. **Sections 13.1 - 13.2 (pp. 530-535)**
 - i. Voltage, resistance, and electrical current
 - ii. Electrical energy and mAh
 - iii. Circuit schematic symbols
 1. **Challenge Problems: 18 and 19**
 - iv. Using a digital multi-meter (DMM) to measure voltage
 1. **Challenge Problems: 5 and 6**
 - v. Using a digital multi-meter (DMM) to measure resistance
 1. **Challenge Problems: 8 and 11**
 - vi. Resistor color codes
 1. <https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code-4-band>
 2. **Challenge Problems: 9**
 - vii. Using an analog ammeter to measure electrical current of a demonstration circuit
 1. **In-class demo:** see page 535
2. **On your own**, answer the following Challenge Problems:
 - a. **Challenge Problems: 17, 21, and 20 (a, e, and i)**
 - b. *Compare your answers to the above questions with your instructor's answers.*
3. **Together as a class**, go over the important points of the following sections in the chapter and then answer any Challenge Problems listed:
 - a. **Section 13.3 (pp. 535-538)**
 - i. Wires; Color conventions; Proper connecting methods
4. **On your own**, answer the following Challenge Problems:
 - a. **Challenge Problems: 14, 15, 16, and 25**
 - b. *Compare your answers to the above questions with your instructor's answers.*
5. **Together as a class**, go over the important points of the following sections in the chapter and then answer any Challenge Problems listed:
 - a. **Sections 13.4 (first part) (pp. 538-541)**
 - i. PRT3; PRT3 power source; Header pins for signal, power, and ground
6. **On your own**, answer the following Challenge Problems:
 - a. **Challenge Problems: 23, 24** (refer to image on page 540), and **25**
 - b. *Compare your answers to the above questions with your instructor's answers.*
7. **Together as a class**, go over the important points of the following sections in the chapter and then answer any Challenge Problems listed:
 - a. **Sections 13.4 (second part) (pp. 541-545)**
 - i. Jumpers and shorting blocks
 - ii. PRT3 overview
 - iii. Measuring PRT3's output voltages (work in pairs; you'll need a DMM, two male-female wires, and two male-male wires.)
 1. **In-class demo:** see pages 542-545.
 - iv. Principle components of the Teensy/PRT3 Motherboard (see figures on page 542 or page 545).
 1. **Challenge Problem: 28 (left-side only)**
8. **On your own**, answer the following Challenge Problems:
 - a. **Challenge Problems: 22 and 30**
 - b. *Compare your answers to the above questions with your instructor's answers.*

E.1.18. Chapter 14 – Getting Started with Circuits

1. Together as a class, we will go over the important points of *Chapter 14 - Getting Started with Circuits*:

- A **quick** tour through resistors, capacitors, diodes, LEDs, buzzers, audio transducers, transistors.
- Examine Table 14.1
- Breadboard “theory” and a friendly “quiz”: Figures 14.21, 14.22, 14.23.
- Quickly discuss **resistors in series (pages 566-567)**:
- Grab three resistors from your box and measure them with a DMM.
- Looking only at Figure 14.34, build the circuit on your breadboard.
- Measure the equivalent resistance, R_s , with your DMM.
- Compare your value to Equation 14.1.
- Quickly discuss **resistors in parallel (pages 567-568)**:
- Grab three resistors from your box and measure them with a DMM.
- Looking only at Figure 14.38, build the circuit on your breadboard.
- Measure the *equivalent resistance*, R_p , with your DMM.
- Compare your value to Equation 14.3.
- Mention Ohm’s Law for current and past physics students, but we will not cover this material in any depth.

2. Do the following Challenge Problems together as a class:

- **21, 23, 24, and 6** (classroom demo with video and breadboard with jumper wires (not alligator wires) for this problem!)

E.1.19. Progress Quiz: Chapter 14

1. **All Students:** Take the **Chapter 14 Progress Quiz**. Ask your teacher for the quiz materials.

E.1.20. Chapter 15 – Creating Sound and Light with a Breadboard and PRT3 as the Voltage Source

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 15 - Creating Sound and Light with a Breadboard and PRT3 as the Voltage Source* so that you are able to successfully answer the following questions and Challenge Problems. (You can skip "Section 15.5. Making Your Own Light Diffusers".) Carefully read and perform all the steps with your own microcontroller.

- **Intermediate students:**
 - **Build the buzzer circuits shown in Figures 15.4 and 15.11.** Try to build them without looking at the photographs of the built circuits, for you will be required to build them without images on the exam! After each circuit is built, have your instructor check them!
 - **Build the LED circuits shown in Figure 15.23.** Try to build it without looking at the photographs of the built circuits, for you will be required to build them without images on the exam! After the circuit is built, have your instructor check it!
 - **You should be *able* to solve all of the following Challenge Problems. However, you are only *required* to turn in the highlighted and underlined problems below.**
 - Make sure that you have your instructor check any circuit that you build **before** you apply power!
 - For any written work, check your answers with your teacher. (You will not "turn in" anything.)
 - 3, 4, 5, 6, 18, 20, 21, and 22.

- **Intensive students:**
 - **Build the buzzer circuits shown in Figures 15.4, 15.11, and 15.13.** Try to build them without looking at the photographs of the built circuits, for you will be required to build them without images on the exam! After each circuit is built, have your instructor check them!
 - **Build the LED circuits shown in Figure 15.23.** Try to build it without looking at the photographs of the built circuits, for you will be required to build them without images on the exam! After the circuit is built, have your instructor check it!
 - **You should be *able* to solve all of the following Challenge Problems. However, you are only *required* to turn in the highlighted and underlined problems below.**
 - Make sure that you have your instructor check any circuit that you build **before** you apply power!
 - For any written work, check your answers with your teacher. (You will not "turn in" anything.)
 - 3, 4, 5, 6, 18, 20, 21, 22, 23, and 24.

E.1.21. Chapter 7 – Advanced Mathematics

This chapter is for Intensive students only.

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 7: Advanced Mathematics Programming* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here are the suggested sections and the order in which we suggest you read them:

- **Intensive:** Sections 7.2, 7.3, 7.5, and 7.6

Answer the following **highlighted problems**. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intensive:** 1, 4, 11, 26, 31, and 32.

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.22. Chapter 6 – Serial Keyboard Input and Modular Programming

If you haven't already, create a folder named "modules" where you normally store your program files.

Next, navigate your browser to **Canvas >> Files >> Modules for GS Students**, and copy the "SKIF.ino" file into the **modules** folder you just created. Alternatively, you can download the file from my book's website at <http://www.pcrduino.com/downloads/>. (Having this module will save you from having to enter all the SKIF commands by hand!)

According to your own needs and learning styles, quickly **skim** *Chapter 6: Serial Keyboard Input and Modular Programming* and learn how to use the SKIF commands that are discussed in the chapter. Spend a bit more time on **Section 4, Modular Programming with Tabs**, which will teach you how to make your own modules from scratch. The SKIF commands that are discussed within the chapter are given to you in the SKIF.ino module, as explained in the above step. When the book asks you to build the SKIF module, I recommend that you simply use the provided module that you downloaded, rather than typing in the code by hand.

You should be *able* to solve all of the following Challenge Problems. However, you are only *required* to turn in the **highlighted and underlined** problems below, which will be graded.

- **All Students:** 1, 4, 3 (do Problem 13 in Chapter 4 using the SKIF functions).
- **If you are far ahead in your work and you are up for a challenge**, you *may* wish to do Challenge Problem #43 in Chapter 4 using the SKIF functions. For this problem, the current SKIF functions are unable to read scientific notation. Therefore, you will either need to ask the user to first enter the mantissa and then the exponent, or you will need to create your own `readScientificNotation()` function to solve this problem. Good Luck!

Have your instructor examine and grade your solution code before proceeding.

Turn in your work by copying and pasting your code into a MS Word document (with 10pt font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents via Canvas. You do **not** need to turn in any module files here.

E.1.23. Progress Quiz: Chapters 5-6

1. **All Students:** Take the **Chapters 5 & 6 Progress Quiz**. Ask your teacher for the quiz materials.

E.1.24. Chapter 8 – Random Numbers

If you haven't already, create a folder named “**modules**” where you normally store your program files.

Next, navigate your browser to **Canvas >> Files >> Modules for GS Students**, and copy the “randomModule.ino” file into the **modules** folder that you created in Chapter 6. Alternatively, you can download the file from my book's website at <http://www.pcrduino.com/downloads/>. (Having this module will save you from having to enter all the random module commands by hand!)

According to your own needs and learning styles, skim the following sections of *Chapter 8: The Random Number Generator* and learn how to use the random number commands that are discussed in the chapter. Spend a bit more time on **Section 8, Some Real-World Examples Using Random Numbers**, and you may want to incorporate the randomModule.ino module when working these examples. (This module is created in Section 9 of the chapter.)

You should be *able* to solve all of the following Challenge Problems. However, you are only *required* to turn in the **highlighted and underlined** problems below, which will be graded.

- **All Students:** 6, 8, 19

Have your instructor examine and grade your solution code before proceeding.

Turn in your work by copying and pasting your code into a MS Word document (with 10pt font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents via Canvas. You do not need to turn in any module files here.

E.1.25. Chapter 16 – Creating Sound & Light with digitalWrite()

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 16: Creating Sound and Light with digitalWrite()* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 599), Sections 16.1-16.4 (skip page 612), 16.5
- **Intensive:** Introduction (p. 599), Sections 16.1-16.4 (skip page 612), 16.5, 16.6, 16.8

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **All Students:** Vol 2 Chapter 16 - Challenge Problem Worksheet.docx (Challenge Problems 1-4, 7, 8)

For the worksheet problems, do **not** enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 9, 11, 34 (use one tricolor RGB LED), 38 (make one pattern)
- **Intensive:** 10, 11, 34 (use one tricolor RGB LED), 35, 38 (make one pattern)

(Chris in 2019-20, replace #11 with the new #14)

Turn in your work by copying and pasting your **code** into a **MS Word** document (with 10p font and narrow margins, please) and copying and pasting your code's **output** into another **MS Word** document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.26. Chapter 10 – While- and Do-While Loops

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Creating Sound and Light with digitalWrite()* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 247), Sections 10.1-10.2 (do Examples 1, 2, 4-11), 10.3 (do Examples 14 and 15), and 10.4 (do Applications 1, 2, and 4)
- **Intensive:** Introduction (p. 247), Sections 10.1-10.2 (do Examples 1-11), 10.3 (do Examples 14 and 15), and 10.4 (do Applications 1, 2, and 4)

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **All Students:** Vol 1 Chapter 10 - Challenge Problem Prediction Worksheet no If-Then.docx (Challenge Problems 1-12, 15, 16)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

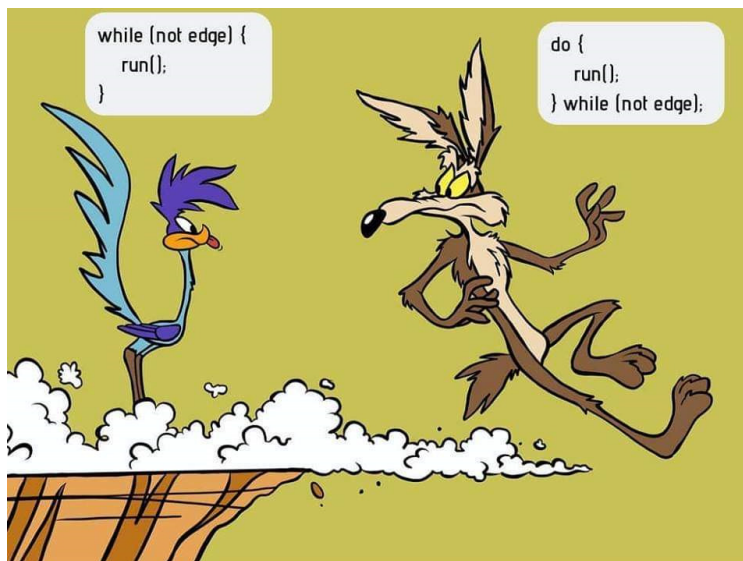
Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 17, 21, 28, 42
- **Intensive:** 17, 21, 23, 28, 42, 43, 62

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

Now that you've completed Chapter 10, you should find this cartoon hilarious:



E.1.27. Chapter 11 – For-Loops

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *For Loops* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 303), Sections 11.1-11.2 (do Examples 1-3, 5-7, 9, 11, and 12), 11.3 (do Applications 1 and 6).
- **Intensive:** Introduction (p. 303), Sections 11.1-11.2 (do Examples 1-3, 5-12), 11.3 (do Applications 1 and 6).

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **Intermediate:** Vol 1 Chapter 11 - INTERMEDIATE Challenge Problem Prediction Worksheet No If-Then.docx (Challenge Problems 1-8)
- **Intensive:** Vol 1 Chapter 11 - INTENSIVE Challenge Problem Prediction Worksheet No If-Then.docx (Challenge Problems 1-11)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 25, 40, 52
- **Intensive:** 25, 27, 40, 43, 45, 53, 56

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.28. Chapter 16 – Re-do with For-Loops

Reading Material

Now that you understand how to use **For-Loops**, return to **Chapter 16 Section 4 page 612** and study "The Elegant, Efficient Solution", which uses a for-loop to control an LED bar graph.

- **Intermediate:** Introduction (p. 303), Sections 11.1-11.2 (do Examples 1-3, 5-7, 9, 11, and 12), 11.3 (do Applications 1 and 6).
- **Intensive:** Introduction (p. 303), Sections 11.1-11.2 (do Examples 1-3, 5-12), 11.3 (do Applications 1 and 6).

Coded/Practical Challenge Problems

Return to **Chapter 16** and answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 15
- **Intensive:** 15, 28

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.29. Chapter 17 – Creating Sound & Light with Pulse Width Modulation using analogWrite and digitalWrite

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 17: Creating Sound & Light with Pulse Width Modulation using analogWrite() and digitalWrite()* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 637), Sections 17.1-17.4, 17.6.
- **Intensive:** Introduction (p. 637), Sections 17.1-17.6.

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **Intermediate:** Vol 2 Chapter 17 - Challenge Problem Worksheet.docx (Challenge Problems 2, 4-12)
- **Intensive:** Vol 2 Chapter 17 - Challenge Problem Worksheet.docx (Challenge Problems 2, 4-14)

For the worksheet problems, do **not** enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 19, 20, **21, 23**, 28
- **Intensive:** 19, 20, **21, 22, 23**, 28

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.30. Chapter 18 – Introduction to Servomotor Programming

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 18: Introduction to Servomotor Programming* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **All Students:** Introduction (p. 669), Sections 18.1-18.6

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **All Students:** Vol 2 Chapter 18 - Challenge Problem Worksheet.docx (Challenge Problems 1-19)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 20, **23, 27**, 29
- **Intensive:** 20, 22, **23, 27**, 29

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.31. Chapter 19 – Making Your Robot Move with Servomotors

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 19: Making Your Robot Move with Servomotors* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **All Students:** Introduction (p. 703), Sections 19.1-19.3, 19.5, 19.6
- *(Optional) For students who want their robot to move in straight lines: Section 19.4*

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **All Students:** Vol 2 Chapter 19 - Challenge Problem Worksheet.docx (Challenge Problems 1-13)

For the worksheet problems, do **not** enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 20, 21, 31, **33, 36**
- **Intensive:** 20, 21, 31, **33, 36**, 41

Turn in your work by copying and pasting your **code** into a MS **Word** document (with 10p font and narrow margins, please) and copying and pasting your code's **output** into another MS **Word** document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.32. Chapter 9 – If-Then Logic Statements

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 9: If-Then and Switch-Case Logic Statements* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 205), Sections 9.1-9.3, 9.4 (do Examples 1, 1-Revised, 2-5, 7, 9). Then study Self Tests 9-1, 9-2, and 9-3 on pages 209, 214, and 223, respectively.
- **Intensive:** Introduction (p. 205), Sections 9.1-9.3, 9.4 (do Examples 1, 1-Revised, 2-7, 9). Then study Self Tests 9-1, 9-2, and 9-3 on pages 209, 214, and 223, respectively.

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **Intermediate:** Vol 1 Chapter 9 - INTERMEDIATE Challenge Problem Prediction Worksheet No Select-Case.docx (Challenge Problems 1-8)
- **Intensive:** Vol 1 Chapter 9 - INTENSIVE Challenge Problem Prediction Worksheet No Select-Case.docx (Challenge Problems 1-13)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 19, 21, 29
- **Intensive:** 19, 21, 29

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.33. Progress Quiz: Chapters 8 & 9

- **All Students:** Take the **Chapters 8 & 9 Progress Quiz**. Ask your teacher for the quiz materials.

E.1.34. Chapter 10 – Re-do with If-Then Statements

Reading Material

Now that you understand how to use **If-Then statements**, return to **Chapter 10** and study the following pages according to your group.

- **All Students:** Section 10.2 Example 12 pages 262-264 "Breaking out of a Loop".
- **Intensive:** Section 10.2 Example 13 pages 264-266 "Nested While Loops".
- **All Students:** Section 10.4 Application 3 pages 272-273 "Two Heads are Better Than One".

Coded/Practical Challenge Problems

Return to **Chapter 10** and answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 13 & 14 (enter your predicted outcome as a comment in your code), 47
- **Intensive:** 13 & 14 (enter your predicted outcome as a comment in your code), 25, 47, 50

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.35. Chapter 11 – Re-do with If-Then Statements

Reading Material

Now that you understand how to use **If-Then statements**, return to **Chapter 11** and study the following pages according to your group.

- **All Students:** Section 11.3 Application 2 pages 317-318 "A Perfect Square".
- **All Students:** Section 11.3 Application 4 pages 319-320 "Heads or Tails".
- **All Students:** Section 11.3 Application 5 pages 321-322 "What are the Odds?".

Coded/Practical Challenge Problems

Return to **Chapter 11** and answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 12-16 (enter your predicted outcome as a comment in your code)
- **Intensive:** 12-16 (enter your predicted outcome as a comment in your code), 54, 59

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.36. Progress Quiz: Chapters 10 & 11

1. **All Students:** Take the **Chapters 10 & 11 Progress Quiz**. Ask your teacher for the quiz materials.

E.1.37. Chapter 20 – Infrared Range-Finding (Analog) Sensors

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 20: Infrared Range-Finding (Analog) Sensors* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **Intermediate:** Introduction (p. 745), Sections 20.1-20.4, Section 20.5 (do Applications 1, 3-5), Sections 20.6-20.7
- **Intensive:** Introduction (p. 745), Sections 20.1-20.4, Section 20.5 (do Applications 1-5), Sections 20.6-20.8
- **All Students:** Read *Appendix K - Limitations of the Sharp 2Y0A21 Infrared Sensor*.

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook's website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **Intermediate:** Vol 2 Chapter 20 - INTERMEDIATE Challenge Problem Worksheet.docx (Challenge Problems 1, 3-11, 22)
- **Intensive:** Vol 2 Chapter 20 - INTENSIVE Challenge Problem Worksheet.docx (Challenge Problems 1-12, 22, 24)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 13, 16, 21, 33*, 41
- **Intensive:** 13, 16, 17, 21, 31, 33*, 35, 42

*** Your instructor must visually inspect your tabletop/obstacle-avoidance robot!**

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.38. Chapter 21 – Environmental Sensing with Voltage Dividers and Other Analog Sensors

Reading Material

You may want to download the document entitled “**Vol 2 Chapters 21 and 22 - MESSING AROUND WITH SENSORS Worksheet.docx**” and fill it out as you read the chapter. The worksheet can be downloaded via Canvas or my textbook’s website at <http://www.pcrduino.com/resources/#handouts>.

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 21 :Environmental Sensing with Voltage Divider Boards and Other Analog Sensors* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.) Here is the suggested reading material for each group:

- **All Students:** **Introduction** (p. 787), **Sections 21.1, 21.2** (explore using the photoresistor/VDB and the infrared line sensor), **Section 21.3** (explore using a few of the following sensors: passive IR light detector, thermistor/VDB, potentiometer/VDB, 2-axis joystick, and magnetic field (Hall-Effect) sensor), and **Section 21.9**.
- *(Optional) Students Intent on Studying Science and Engineering in College who Want a Deeper Understanding of Quantitative Data Analysis: Sections 21.4-21.8*

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook’s website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **All Students:** **Vol 2 Chapter 21 - Challenge Problem Worksheet.docx** (Challenge Problems 8, 9, 12, 13, and 14.)
- *(Optional) Quantitative Analysis Problems: Vol 2 Chapter 21 - Quantitative Data Analysis Worksheet.docx* (Challenge Problems 15, 16, 19, 21, 22, and 26)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** **1***, 36, 42, 46, 50, and **55 (do this with everyone)**
- **Intensive:** **1***, **3**, 36, 42, 46, **49**, 50, and **55 (do this with everyone)**
- *(Optional) Quantitative Analysis Problems:* 31 (choose one output unit)

*** Your instructor must visually inspect your line-following robot!**

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to the next chapter.

E.1.39. Chapter 22 – Ultrasonic Rangers, Buttons, Whiskers, and Other Digital Sensors

Reading Material

According to your own needs and learning styles, read/skim/peruse/digest *Chapter 21: Sonic Rangers, Buttons, Whiskers, and Other Digital Devices* so that you are able to successfully answer the Challenge Problems below. (You may wish to first examine the problems and solve them as you read.)

You may want to download the document entitled “**Vol 2 Chapters 21 and 22 - MESSING AROUND WITH SENSORS Worksheet.docx**” and fill it out as you read the chapter. The worksheet can be downloaded via Canvas or my textbook’s website at <http://www.pcrduino.com/resources/#handouts>.

Here is the suggested reading material for each group:

- **All Students:** Introduction (p. 837), Sections 22.1-22.2, Section 22.3 (do Application 1), Section 22.5, Section 22.6 (you may **skip** the last part that discusses using the 8-button board), and Section 22.7.
- **Intensive:** Section 22.8 on using the whisker (bumper) switches to avoid obstacles.

Worksheet (Written) Challenge Problems

Either print the file below and turn in the physical copy, or download the file, answer the questions, and turn it in electronically via Canvas. The worksheet can be downloaded via Canvas or my textbook’s website at <http://www.pcrduino.com/resources/#handouts>. Open the file associated with your group.

- **All Students: Vol 2 Chapter 22 - Challenge Problem Worksheet.docx** (Challenge Problems 1-3, 5-9, and 12-14.)

For the worksheet problems, do not enter the code into the IDE and compile it. Instead, I want to see if you can *deduce* what the outcome will be, not *read* what the outcome is!

Coded/Practical Challenge Problems

Answer the following **highlighted Challenge Problems** according to your group. Questions which are *not* highlighted will **not** be graded, but you should know how to solve them!

- **Intermediate:** 15, **16**, **25***, 29, and **46***
- **Intensive:** 15, **16**, **18**, 19, **25***, 29, 46, **47***, and 54 (this whisker switch problem is *optional* for everyone not using the whisker for their final project)

*** Your instructor must visually inspect these robots!**

Turn in your work by copying and pasting your code into a MS Word document (with 10p font and narrow margins, please) and copying and pasting your code's output into another MS Word document (with narrow margins). Turn in both documents into Canvas.

Once your work has been handed in, you may proceed to working on your Third Term Project!!!

E.1.40. Design and 3D Print an LED Light Diffusion Dome

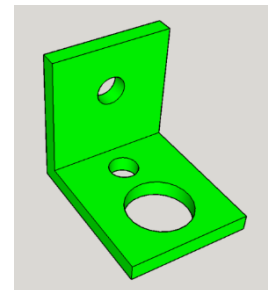
1. Read pages 590-591 for help with this.
2. **You may spend only one class period on this assignment.** If you need more time for this, you must do it outside of class.

E.1.41. Design and build a license plate for your OneBot with the Laser Cutter

1. **Design and build a license plate** for your OneBot, which will be fabricated on the **100-watt Boss Laser Cutter** in the lab.
 - a. You will do this using the RDWorks software. The software is free, but only works on a PC machine. You can download it here: <https://www.bosslaser.com/laser-software/>, or you may use a school computer for the design work.
 - b. The recommended dimensions are 60mm x 30mm (L x W)
 - c. You will need at least one hole to be tapped for a 4-40 screw. The **diameter** of this hole should be 2.261mm. This hole will mate to the 3D-printed license plate mount, which you will make in another assignment.
 - d. The "license plate" can be a vanity plate, nametag, or other fun and artistic identifier.
 - e. Cut the plate out of wood.
 - f. Use the speed and power settings that are appropriate for the type of wood you are using
 - g. **You may spend only one class period on this assignment.** If you need more time for this, you must do it outside of class.

E.1.42. Design and build a license plate for your OneBot with a 3D Printer

1. **Design and 3D-print a mount** for your license plate.
 - Review how to 3D print with the document, "How to 3D Print at George School.pdf", which is on **Canvas >> Files >> 3D Printing & CAD Files**
 - Make a simple L-bracket mount that will allow you to attach your laser-cut license plate to your OneBot. Pictured to the right is one suggestion.
 - The dimensions of the L-bracket are up to you. Sketch your design on paper, and use a vernier caliper to make any necessary measurements before you begin your design work.
 - How the license plate mounts to the L-bracket is up to you, but recall that the license plate has at least one 4-40 tapped mounting hole for this purpose.
 - The L-bracket can be secured to the OneBot in a number of ways. For example, the OneBot has a number of 4-40 tapped holes, 4-40 through holes, and a ¼" threaded rod for the tail wheel.
 - **You may spend only one class period on this assignment.** If you need more time for this, you must do it outside of class.



E.1.43. Design and Fabricate Your Own Circuit Board using ExpressPCB Software

1. **(Optional) ExpressPCB project:**
 - Design a printed circuit board
 - Order it for fabrication with the help of your instructor
 - Build/Solder it!

E.1.44. Final Independent Project!

1. With luck and hard work, you have arrived at this point by the beginning of Term 3. Apply all of what you learned during the first two terms and work on your final independent project.
2. The project must be approved by your teacher. The best ideas come from you! Follow your passion and let your brain mull it over for a while before settling on a project. Project ideas are due the first day of Term 3. If you are having trouble coming up with an idea for the final project, you can download the document “**Open House Details and Project Ideas**” from Canvas or from my book’s website at <http://www.pcrduino.com/resources/#handouts>.
3. You may work with one other student, but the workload must be divisible and the contributions of each student must be clearly evident.
4. The Final Project concludes each year at the **Annual Robotics Open House** on the Monday before graduation. It is open to the public from 6pm to 7pm. Plan to be present from 5:30 until 7:15. This event is **mandatory** for all robotics students! **Everyone must attend!**
5. The Open House will serve as your Final Exam. It consists of three parts:
 - i. **Participation in the Robotics Open House**
 - ii. **Creating a PowerPoint**
 - a. See PowerPoint Details below.
 - b. It is required that the PowerPoint be completed **before** the Open House. The PowerPoint presentation may help you during your Open House presentation.
 - iii. **Lab clean-up**
 - a. This takes place during the actual exam period during exam week. Expect to stay 2 hours.
6. You must display your project’s PowerPoint during the Open House. You should work on the PPT throughout the term. Follow the rubric, which is on canvas. The PowerPoint template “**Final Robotics Projects Template.pptx**” can be downloaded via canvas, or from my book’s website at <http://www.pcrduino.com/resources/#handouts>.
7. The PowerPoints counts for half of your exam grade and is due by the start of the Robotics Open House. You may *use* your PPT during the show, but you will **not** be making a formal presentation. The presentation will be very informal and fun! Imagine it like this: Bring your project to the Dining Hall and exclaiming, "Hey everybody, look what cool thing I made!" And then spend one or two minutes explaining what you made and showing it off. It's supposed to be fun!

E.1.45. PC&R Chapters with SKIPPED material (this material is not assigned to anyone)

All the stuff that was skipped:

For instructor's and interested students' information:

Chapter 9

- Section 4. Example 8. Using toUpper and toLower to force case. Probably OK to skip.
- Sections 5 & 6. Switch Case. Return to this if there's time!
- Challenge Problems 14, 15. And others that utilize Switch Case. Return to this if there's time!

Chapter 10

- Section 2. Example 3. Variable Overflow. Probably OK to skip.
- Section 4. Application 5. Going Vertical. OK to skip.
- Section 2. Application 6. Excel. Probably OK to skip.
- Section 5. On sequences and series. Math-centric kids may like this section.
- Section 6. RTC. Return to this if there's time - pardon the pun!
- Challenge Problem #52. RTC. Return to this if there's time!

Chapter 11

- Section 2. Example 4. Using a counter outside a loop. Probably OK to skip.
- Section 3. Application 3. RTC and If-Then. OK to skip if it is covered in Chapter 10 Section 6.
- Challenge Problem #42. RTC. OK to skip if it is covered in Chapter 10 Section 6.

Chapter 16

- Section 6. Laser. Sink/Source. Return to this?
- Section 7. Buzzer with three nifty solutions. Return to this? Good quiz material!
- Section 9. Making PCBs. OK to skip.

Chapter 17

- Section 7. Audio Transducer. OK to skip.
- Challenge Problem #35. Audio Transducer. Probably OK to skip.

Chapter 18

- Section 7. Using the Arduino Servo Library. OK to skip. I am not a fan of time-based servo motion.
- Challenge Problem #24. RTC.

Chapter 21

- Exploration with the following sensors: hygrometer, force, and flexion. Probably OK to skip.
- Challenge Problems that utilize the following sensors: hygrometer, force, and flexion. Probably OK to skip.

Chapter 22

- Section 3. Application 6. Obstacle avoidance with two ultrasonic sensors. Return to this?
- Section 4. Using the Arduino Ultrasonic Library. Intensive students may return to this if there's time!
- Section 6 – the last part that discusses using the 8-button board. OK to return to this if there's time.
- Challenge Problems that utilize the 8-button board and the pushbutton on the 2-axis joystick. OK to return to this if there's time.