ECE 110L
Integrated Design Challenge
Spring 2016

BOE-lympics

The BOE-lympics are here! After kil[g]o-years of excited anticipation, anxious letter-writing, and colorful sign-making, the International BOE-lympic Committee (IBC) has finally chosen Duke University in Durham, North Carolina as the host location for the 2016 BOE-lympic games!

On Monday, April 25th, 2016 at 4:30pm, sports enthusiasts, electrical engineers, and professors will be pouring into the Nello Teer building, having traveled from far and near in the hopes of obtaining evening a mere glimpse of the highly revered sports events that comprise the BOE-lympics.

The IBC has requested that the Duke ECE 110L Fundamentals of Electrical and Computer Engineering class, construct a team of robotic judges to ensure fair outcomes for six of the events. Your challenge as a class is to design, create, and test a team of BOE-bot judges that will evaluate each nation's athletes fair and square.

Each event is contained in its own Olympic ring, with one BOE-bot judge assigned to each event. Each judge will begin by parading around the event room, circumnavigating a darkly colored ring. Once the judge has completed at least one circle, the judge will enter the ring and sense the information present from the elements inside the ring. The different elements inside each ring will determine the score of each athlete. The judges will declare a score of 2, 1, or 0 (Gold, Silver, or Bronze, respectively).

The judges will then need to communicate their scores with the other judges on the field. The team of judges will sum these scores to determine which medal to give out to the nation competing. By taking the modulus 3 of the sum, the resulting 0, 1, or 2 will correspond to a bronze, silver, or gold medal, respectively for the country competing. This final score should be represented by each Bot with a clearly displayed binary 00, 01, or 10 so that if and when the judges award a perfect score, the nation competing will receive a perfect 10/10.

Once the Bot judges decide to award an overall medal to the country in play (based on the sum of individual event scores), they must complete the following as a lab section team:

- ✓ **Gold medal** (all Bot displays read "**10**")—All Bots must **sing the national anthem** of the winning country
- ✓ **Silver medal** (all Bot displays read "**01**")—All Bots must perform a **light show** honoring the runner-up competitors
- ✓ **Bronze medal** (all Bot displays read "**00**")—All Bots must perform a **coordinated dance** to encourage the third-place team to train harder in 4 years

It is up to you to ensure that the BOE-bot judges are expertly programmed to execute their task in a timely manner. While you will be timed, accuracy in sensing and obtaining the correct scores is the most important objective.

The Teams

Welcome BOE-bot judges! Your laboratory section comprises a Team of judges. Each team will be divided into groups of two students each; each group being responsible for the construction of one BOE-Bot to compete in the BOE-lympic event assigned to it. Groups on the same team will collaborate to find the final result of the competing nations (00, 01, or 10).

Parading Around The Ring

So that the competitors and spectators of each and every nation recognize your importance, each judge must circumnavigate the ring enclosing its event. **All of the robots on a team must be activated within a total of 3 seconds of each other at the start.** Each judge may begin at any location on the entire board, but must complete one full circle around its own ring. You may choose to have your judge begin on the ring itself, on a hash mark, on the connecting lines, or not on any lines at all. The judge must complete one full circle before subsequently entering the ring to determine the score of the competitors.

Figure 1: The BOE-lympic Stadium

Event 1: DIVING, Blue Ring

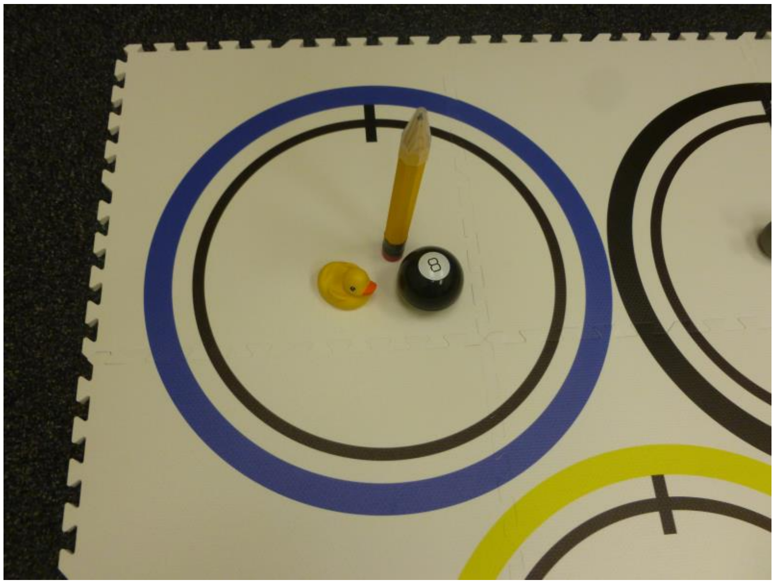

Figure 2: The Diving Pool of the BOE-lympic Stadium

The diving event of the BOE-lympics is represented by the blue ring. Located in the upper left-hand corner of the BOE-lympic Stadium, the diving event is connected to the yellow ring by a connector line. At the center of the ring is an X, marking the location of each competitor. The athlete will perform one of the following three stunts:

- ✓ Cannonball (represented by the Magic 8 Ball)—Bronze(0)
- ✓ Pencil Dive (represented by the wooden pencil)—Silver (1)
- ✓ Swan Dive (represented by the rubber ducky)—Gold (2)

Your task is to correctly determine which stunt the athlete is performing. The cannonball receives a score of 0 (bronze), the pencil dive receives a score of 1 (silver), and the swan dive receives a score of 2 (gold). You must not only accurately obtain the score of the competitor, but also must then clearly display that value using the methods at your disposal in the laboratory.

Event 2: WEIGHTLIFTING, White Ring

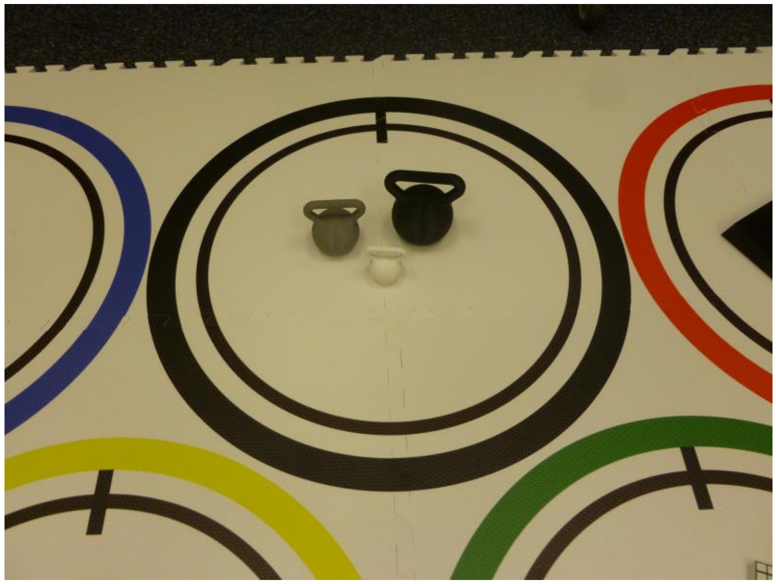

Figure 3: The Weightlifting Ring of the BOE-lympic Stadium

The weightlifting event of the BOE-lympics is represented by the black ring. Located between the blue and red rings of the BOE-lympic Stadium. Inside the ring can be 1 of 3 kettle bells. The kettle bells are 3 distinct shaded colors and some contain magnets. Your task is to correctly identify how much each athlete is lifting. There are 3 possible weights the competitors must lift:

- ✓ 100 pounds (White, smallest kettlebell, not magnetized)—Bronze (0)
- ✓ 200 pounds (Gray, medium kettlebell, moderately magnetized)—Silver (1)
- ✓ 300 pounds (Black, largest kettlebell, strongly magnetized)—Gold (2)

Your task is to determine how many barbells the athletes must lift. Lifting 100 pounds receives a score of 0 (bronze), 200 pounds receives a score of 1 (silver), and 300 pounds receives a score of 2 (gold). There will never be more than one kettlebell in the ring at a time during the event. You must not only accurately obtain the score of the competitor, but also must then clearly display that value using the methods at your disposal in the laboratory.

Event 3: CYCLING, RED RING

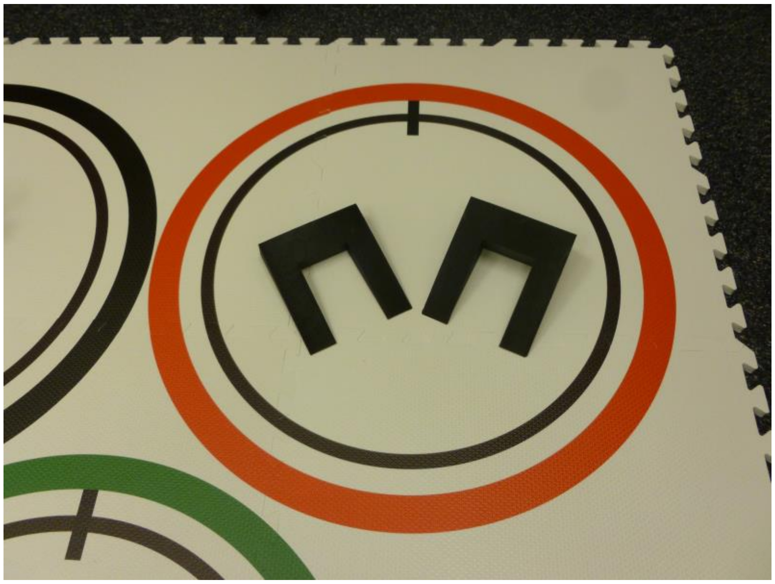

Figure 4: The Cycling Track of the BOE-lympic Stadium

The cycling event of the BOE-lympics is represented by the red ring. Located in the upper right-hand corner of the BOE-lympic Stadium. Inside the ring is a ramp for the competitor to climb. There are three grades of the ramp:

- ✓ Track (flat, no grade)—Bronze (0)
- ✓ Road (moderate grade)—Silver (1)
- ✓ Mountain (steep grade)—Gold (2)

Your task is to correctly determine which race the competitor is cycling. The track racer receives a score of 0 (bronze), the road racer receives a score of 1 (silver), and the mountain racer receives a score of 2 (gold). You must not only accurately obtain the score of the competitor, but also must then clearly display that value using the methods at your disposal in the laboratory.

Event 4: BASKETBALL, Yellow Ring

Figure 5: The Basketball Court of the BOE-lympic Stadium

The basketball event of the BOE-lympics is represented by the yellow ring. Located on the left-hand side of the middle row, the basketball event is connected to both the blue and white rings by connector lines. Inside the ring is a half-court with the baseline, key, and three-point line drawn in. A basketball-shaped magnet covering an RFID tag will mark where the shot was taken. The final shot can be one of three different shots:

- ✓ Free Throw (placed above the lay-up line below the hoop)—Bronze (0)
- ✓ Two-Pointer (placed on the free-throw basket circle)—Silver (1)
- ✓ Three-Pointer (placed outside the three-point line)—Gold (2)

There is a vertical backboard placed at the baseline of the arc which may be useful to your Bot. Your task is to correctly identify where on the court the game-winning shot was taken. A free throw receives a score of 0 (bronze), a two-pointer receives a score of 1 (silver), and a three-pointer receives a score of 2 (gold). The 3 possible RFID tag ball locations are as shown in the picture above. The basketball will always been in-line with the basket and the hash mark on the perimeter circle. It will never be placed on the three-point line, but behind it. It will be very clearly in one of the above-mentioned zones. You must not only accurately obtain the score received, but also must then clearly display that value using the methods at your disposal in the laboratory.

Event 5: COURT SPORTS, Green Ring

Figure 6: The Courts of the BOE-lympic Stadium

The court sports of the BOE-lympics are represented by the green ring. Located on the right-hand side of the middle row of the BOE-lympic Stadium, the court sports are connected to both the white and red rings by connector lines. The center of the ring contains a rectangular court. The competitors will be playing one of three different events in this ring:

- ✓ Badminton (White court with appropriate line marking)--Bronze(0)
- ✓ Tennis (Gray court with appropriate line marking)—Silver (1)
- ✓ Volleyball (Black court with appropriate line marking)—Gold (2)

Your task is to correctly determine which sport the athletes are playing. The badminton players receive a score of 0 (bronze), the tennis players receive a score of 1 (silver), and the volleyball players receive a score of 2 (gold). You must not only accurately obtain the score of the competitor, but also must then clearly display that value using the methods at your disposal in the laboratory.

Awarding of Medals

The final task of the team of judges is to determine what medal to award to the competing nation. After all of the judges give out their scores in each individual event, they will need to communicate this information to the other judges. The judges must sum each of their scores of 0, 1, or 2 and take the modulus 3 of this sum. The resulting number must be converted to binary.

If the binary result is **10**, then the nation has received both a perfect 10 and a **Gold medal**! To honor the winning nation, the judges will **sing their national anthem** together. The song must be the same for the entire team of judges if they score the first place team with 10/10.

If the binary result is **01**, then the nation has received the **Silver medal**! In celebration, each of the judges must put on a **light show** for the team. All the judges must display lights if they score the second place team with a 01/10.

If the binary result is **00**, then the nation has received the **Bronze medal**! The third-place nation still has some work to do, so to encourage the team, the judges must perform a **coordinated dance**. All the judges must dance if they score the third place team with a 00/10.

Creativity in these final routines will add to a team's score. Good communication and coordination will receive the most credit. It must be easily concluded from the resulting sound, display, or movement which of the three medals the team of BOE-bot judges gave out. The judges cannot, for example, dance while singing, since this would not be a distinct manifestation of the three options.

Design Project Grading Criteria

Deliverable	Responsible	Due Date	Percent
Status Updates & Participation			***Total 10%***
Status Updates (due as 3 min. presentation in lab)	Group	Weekly in lab (*weeks of* Mar. 7, 28, Apr. 4, 11, 2016)	10% (2.5% each)
Documentation			***Total 30%***
Conceptual Design Report (due in lab)	Group	*Week of Feb*. 29, 2016	10%
Final Design Report (5:00pm, in lab)	Group	*on Wed*. Apr. 27, 2016 5:00pm	20%
Demonstrations			***Total 50%***
Communication (in lab)	Team	*Week of Mar. 7,* 2016	10%
Separate Line Following, Information Gathering, & Communication (in lab)	Group	*Week of Mar.*.8, 2016	10%
Integrated Sensing, Processing, Navigation, & Communication (in lab)	Group	*Week of Apr.*. 4, 2016	10%
Team Sensing, Processing, Navigation, & Communication(in lab)	Team	*Week of Apr.* 11, 2016	10%
Full System (in lab)	Team	*Week of Apr*. 18, 2016	10%
Oral Design Explanation and Defense			***Total 10%***
Oral Defense (in lab)	Group	*Week of Apr*. 18, 2016	10%
			Total 100%

Terms: **Groups—**Groups are comprised of 2-3 students each (and 1 Arduino BOE-Bot!)
Teams—Teams are comprised of an entire lab section; there are as many Teams as there are lab sections in ECE 110L.

Conceptual Design Report Grading Criteria
(Group Report)
Due: Week of Feb. 29, 2016 (at beginning of assigned lab section)

Note: Groups MUST submit Components Request and INCLUDE confirmation-e-mail with final version (Components Request site: http://ecelab.pratt.duke.edu)

Team Members:____

1. Introduction	**Possible**	**Earned**
Grand Overview of Team Challenge	5	
Group Robot Problem Statement or Task	5	
Group and Team Objectives and Deliverables	10	
Total	***20***	
2. Planning and Management		
Gantt Chart (Project Schedule, Milestones, Task Assignments)	15	
Written description of Gantt chart (incl. ind. group member contributions & recorded time spent in lab by each ind.)	15	
Cost estimate	10	
Total	***40***	
3. Technical		
Trade Study Results (at least 3 sensors compared)	40	
Total	***40***	
Total Score	***100***	

*** Report should include a cover page with title, group name and membership, date, and Community Standard statement (signed by all).**

*** See additional handouts for a description of how to complete a Pros and Cons evaluation as part of a Trade Study and how to construct a Gantt Chart.**

Weekly Status Report Format
(Group Presentations in lab)

Due: Week of Mar. 7, 2016 (based on Conceptual Design report)
Week of Mar. 28. 2016 (through Line Following, Info. Gathering, & Communication)
Week of Apr. 4, 2016 (through Integrated Sensing, Proc., Nav., & Communication)
Week of Apr. 16, 2015 (through Team Sensing, Proc. , Nav., & Communication)

Weekly status reports are due 4 times during the IDC and are prepared by each robot group (groups are 2-3 robot designers assigned to 1 Bot).

Weekly Status reports include the following and should be presented as a **3 min overhead presentation** to your Team. Each member of the group must contribute and speak:

1.) **Progress summary** (3 sentences or fewer)—What have you done this week? Why is it important? What are your next steps?
2.) **Code**—Annotate code with comments to share with Team. Highlight code snippets to emphasize as being added or modified that week
3.) **Gantt chart**—Up-to-date showing accomplishments, milestones, and what is left to be done. Be sure to include planning bars (planned work) and progress bars (actual work)
4.) **Cost of Bot**—To-date cost of all parts on Bot

Demonstration Grading Criteria
(Team and Group Demonstrations)
Each occurs at beginning of lab in the week listed below

Each robot group will be evaluated for each demonstration as follows:

Communication requires that all robots and can send and receive a signal from one another.

Line Following spot check—squiggly line test requires that the robot can follow a pre-printed squiggly line in lab reliably and without significantly deviating from the line or getting off-track.

Line Following & Information Gathering requires that each robot be able to line follow around its circle and also separately demonstrate that it can detect the sensory objects and information required to successfully complete its individually assigned phase of the Challenge.

Integrated Sensing, Processing, & Navigation requires that each robot be able to successfully sense the information present in its individually assigned phase of the Challenge, use this information to complete the phase, and circumnavigate it's circle from start to finish on its own.

Team Sensing, Processing, & Navigation requires that the entire team of robots be able to simultaneously sense the information present in all of the phases of the Challenge, use this information to complete the phases, and navigate from start to their finishes.

Full System repeats the Team Sensing, Processing, & Navigation demonstration and adds the optional requirement in the final week of the IDC to earn up to 7 points as a Team by having all 5 robots collectively determine the missing continent and the sum of their phase numbers (0-5) to determine the "next biggest Grand Challenge."

Four (4) criteria will be used to assess demonstration performance as outlined on the next four pages. These are **Performance, Functionality, Reliability & Robustness,** and **Technical Knowledge**.

Demonstration Grading Criteria

Lab Section Time: ____________________

Teaching Assistant: ____________________

Demo TA(s): ____________________

Group Members:____________________

Olympic Ring:
- **[ ] Diving event**--BLUE
- **[ ] Kettle bells**--BLACK
- **[ ] Cycling**--RED
- **[ ] Basketbal**l--YELLOW
- **[ ] Court Sports**--GREEN

Performance: How many sequential trials can the Bot complete without inter- or intra-trial intervention / correction / adjustment?

Week of Mar. 7, 2016—Communication Demo (Team score—all 5 Bots)

Task	Trial 1	2	3	4	5	Score (Sum)
Tx						
Rx						
Display						

5/5 excpt.l 100%, 4/5 v. good 96%, 3/5 avg. 93%, 2/5 low avg. 87%, 1/5 needs work 84%, 0/5 poor < 81%

Week of Mar. 21, 2016—Line Following spot check—Squiggly line test (Group demo)

Task	Trial 1	2	3	4	5	Score (Sum)
Line Follow						

Week of Mar. 28, 2016—Separate Line Follow., Info. Gather. & Comm. (Group/Team)

Task	Trial 1	2	3	4	5	Score (Sum)
Line Follow						
Sense object						
Communication (Tx,Rx,Display)						

Week of Apr. 4, 2016—Integrated Sens., Proc., Nav., & Communication (Group/Team)

Task	Trial 1	2	3	4	5	Score (Sum)
Line Follow						
Sense object						
Communication (Tx,Rx,Display)						

Week of Apr. 11, 2016—Team Integrated Sens., Proc., Nav. & Communication (Team)

Task	Trial 1	2	3	4	5	Score (Sum)
Diving						
Kettle bells						
Cycling						
Basketball						
Court Sports						

For this demonstration (out of 5) each robot must (1) line follow entire phase, (2) properly sense object, (3) display number obtained, (4) transmit (Tx) communication (5) receive (Rx) communication

Functionality: Do individual system components (i.e., individual sensors) function appropriately? Are system components well-integrated (if appropriate)? Are performance objectives met (e.g., correct maze exit located, Bot arrives at the table)?

Complete 1 form for each bot—Weeks (1) through (5) of IDC

[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*
Weak—you can do better (<87%)	**Okay—minor revisions needed (90%)**	**Acceptable Performance—Well done! (93%)**	**Perfect—very nicely done! (96%)**	**Wow!—Competition ready! (100%)**
[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]
No Individual components function correctly	One or more Individual components function correctly	One or more Individual components function correctly	All individual components function correctly	All individual components function correctly
[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]
Nothing is integrated and major adjustments/intervention is needed	Some of the needed components/sensors are integrated	Some or all of the needed components/sensors are integrated	All of the needed components/sensors are well-integrated	All of the needed components/sensors are well-integrated
[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]
No Performance objectives met	Some Performance objectives are met with <u>some major or minor</u> adjustments/intervention needed	Most Performance objectives met with <u>little</u> adjustments/intervention needed	All Performance objectives met with only <u>minor</u> adjustment/intervention	All Performance objectives met <u>without</u> adjustment/intervention

Reliability & Robustness: Has the system been designed to function properly across the range of expected conditions (e.g., various light levels, noise levels)? Has the system been designed to detect and recover from errors (e.g., errors in measurement)?

Complete 1 form for each bot—Weeks (1) through (5) of IDC

[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*
Weak—you can do better (<87%)	**Okay—minor revisions needed (90%)**	**Acceptable Performance—Well done! (93%)**	**Perfect—very nicely done! (96%)**	**Wow!—Competition ready! (100%)**
[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]
Design is essentially "hard coded"	Design is minimally adaptable (mostly hard coded)	Design addresses one or more sources of variability	Design is highly adaptable	Design incorporates solutions for every possible condition
[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]
Unable to adapt to reasonable variations in operating conditions	Not likely to reliably operate except in "ideal" conditions or small deviations from ideal	Likely to operate reliably under some non-ideal conditions	Likely to work in a wide range of conditions	Thoroughly tested and shown to be robust
[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]
No/little room for error, unable to recover from any error	Potential sources of error have been identified, but solutions have not been incorporated	Potential sources of error have been identified and steps have been taken to prevent at least one of these errors.	Potential sources of error have been identified and steps have been taken to prevent more than one of these errors from arising, but recovery algorithm has not been implemented.	A wide range of possible errors have been considered, steps have been taken to avoid such errors, and an effective recovery algorithm is in place

Technical Knowledge & Understanding: How well does the group understand the functionality and purpose of system components (i.e., individual sensors) and the overall technical design (hardware and software)?

Complete 1 form for each bot—Weeks (1) through (5) of IDC

[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*	[ ][ ][ ][ ][ ] *(1)(2)(3)(4)(5)*
Weak—you can do better (<87%)	**Okay—minor revisions needed (90%)**	**Acceptable Performance—Well done! (93%)**	**Perfect—very nicely done! (96%)**	**Wow!—Competition ready! (100%)**
No group member has a thorough technical understanding of the system's sensors or overall design	As a group, the system's sensors and overall design are understood at a cursory level	All group members have a thorough technical understanding of <u>at least one</u> system sensor and the overall design, and a cursory understanding of all other system sensors	All group members have a thorough technical understanding of <u>at least one</u> system sensor and, as a group, all system sensors and the overall design are thoroughly understood	All group members have a thorough technical understanding of all system components and the overall design algorithm.

IDC Full-System Scoring
(Team)
Due: Week of Apr. 18, 2016

The Integrated Design Challenge (IDC) Full-System demonstration is the culminating event of the laboratory experience in this course. The IDC will challenge you as a team to show your performance in all areas of achievement including individual robot performance and overall team performance.

Team scores are based upon successfully COMPLETING the challenge and performing the final medal ceremony. Maximum scores will be given to teams having all 5 robots complete the challenge and all performing the medal ceremony correctly. Challenge scoring will be calculated as follows:

- Each robot, after parading around their ring and obtaining the correct medal value (0-2), must **clearly display its obtained number** (90%)
    - Each Individual Robot—completes parading around ring (30 pts), senses object correctly in ring (30 pts), displays the correct number, 0-2 (30 pts)

Completing the above successfully will earn the team up to 90 (out of 100) points in the final demonstration.

To earn up to an additional 10 points, **all robots** must do the following:

- Complete the final award ceremony—sing, lights, or dance--together (1 pt per bot, up to 5 pts per team) with the team score (00, 01, or 10) displayed (1 pts. per bot up to 5 pts)

Time: *Only* if two or more teams score *exactly* the same number of points above will the time it takes the team to complete the challenge be a factor—the faster time team will rank higher.

IDC Full System Scoring Sheet

Week of Apr. 18, 2016—Full System Demo (Team)

Task		Trial 1	2	3	4	5
Diving--BLUE.	Parade (+6)					
	Sense—0-2 (+6)					
	Display—0-2 (+6)					
Kettle bells--BLACK	Parade (+6)					
	Sense—0-2 (+6)					
	Display—0-2 (+6)					
Cycling--RED	Parade (+6)					
	Sense—0-2 (+6)					
	Display—0-2 (+6)					
Basketball--YELLOW	Parade (+6)					
	Sense—0-2 (+6)					

	Display—0-2 (+6)					
Court Sports--GREEN	Parade (+6)					
	Sense—0-2 (+6)					
	Display—0-2 (+6)					
+5 sing, lights, dance						
+2 ‘00’, ‘01’, ‘10’						
Score (Sum)						

For this demonstration, as with Team Integrated Sensing, (out of 5) each robot must (1) line follow entire phase, (2) properly sense object, (3) display number obtained, (4) transmit (Tx) communication (5) receive (Rx) communication

Oral Defense
(Group Defense)
Due: Week of Apr. 18th, 2016

Lab sect.______________ **Lab Time:** __________
Demo TA: ____________________ **Lab TA:** __________

Group Members: ____________________ ____________________
Phase of Challenge: ____

Sensors & Purpose: *QTI* (Sensor 1) — *Line following* (Purpose)

** Indicate which sensor queried for Technical Knowledge (show work on reverse)*

____________ *(Sensor 2)* ____________ *(Purpose)*

____________ *(Sensor 3)* ____________ *(Purpose)*

____________ *(Sensor 4)* ____________ *(Purpose)*

1. Defense of Design	**Possible**	**Earned**
Justification of Design Choices	10	
Alternatives considered and depth of testing	10	
What would be done differently next time?	10	
Total	***30***	
2. Technical Knowledge of System		
Sensors implemented in design*	25	
How information is processed in design	25	
Arduino Code used in design	20	
Total	***70***	
Total Score	***100***	

Comments:

Final Design Report Grading Criteria
Due: 5:00pm, Wednesday, Apr. 27th, 2016 (Teer 210/216 Laboratory)

Final reports should be written in the format of a formal laboratory report. Each group should submit one report. Pages must be numbered.

Recall that in formal, technical writing, third person is the preferred written perspective. It is common for students, upon learning to write an effective laboratory report including all five sections, to experience a sense of redundancy across the report sections. The Abstract summarizes the important elements of the exercise including results and conclusions in a very concise manner. The Introduction provides background and motivation for the experimental procedure. The Experimental Procedure and Results section provides details of the experimental process that would allow another person to reproduce the results presented. The Analysis and Discussion section provides theoretical analyses and compares the theoretical results with the experimental results as well as a critical interpretation and evaluation of these results. The conclusion ties together the elements of the entire report and provides closure. All formal scientific papers provide information in this manner.

The report should include a discussion of the following topics (in the appropriate section of the report):

I. Abstract

An abstract is a concise summary of the entire report that highlights the most important findings and conclusions. Although abstracts should be limited to no more than 275 words, effectively written, they should enable the reader to know what was performed and why, along with the most important results and conclusions.

A well-written Abstract will achieve the four-fold criterion of:
- Clarity
- Conciseness
- Accuracy
- Completeness

II. Introduction

The Introduction is the second section of a formal laboratory report, following the Abstract. The Introduction provides a backdrop for the entire experiment and should provide enough information to adequately place the experiment into context with prior work. Describe the objective(s) of your experiment (you will refer to these again later in the Discussion and/or Conclusion section) and summarize what you did. A good Introduction also provides whatever background theory, formulas and equations, or previous research/experiments that the reader needs to know in order to understand the work presented in the laboratory report.

An effective Introduction will address the following questions:

1. What is the problem?

- ***Describe*** the overall Challenge as your team was faced with it

2. Why is it important?

- What do you hope to get out of this Challenge? What tools and resources will be used to solve this challenge?

3. What solution (or step toward a solution) do you propose?

- Briefly ***describe*** your individual robot's contribution to the successful completion of the overall Challenge. Where does your Bot fit in? What will your robot do and how will it do it?
- Consider real-world applications your robot might connect to. How could it be used in a practical challenge of a similar nature?

III. Experimental Procedures and Results

Experimental Procedure and Results is the third section of a formal laboratory report, following the Abstract and Introduction. In most laboratory exercises you will be required to make measurements. In the Experimental Procedure and Results section, you are to present your experimental set-up, experimental procedure, and measurements. Documenting your procedure is important so that you and others can replicate your experiment.

Generally, you should state what equipment, electronic components, and other hardware/software were used and provide all diagrams and schematics necessary to illustrate your experimental set-up. You should show, as a Figure, any sub-circuit you are referring to in the report. Full circuit diagrams can be included as an appendix. **Only discrete elements that you populate on your board need to have schematic diagrams. You do not need to provide schematics for sensory modules.** State what was measured. Data should be presented in the form of either a table or a graph. Provide figures, tables, graphs, diagrams, and appendices as appropriate to present your experimental procedure and results. Procedural detail should be kept as concise as possible but must enable others to reproduce every experimental result that you present in your report.

The Experimental Procedures and Results section is best written in a chronological format. Note that it is perfectly acceptable to reference a single table, list of code, or diagram placed within the report (e.g. Appendices, Analysis and Discussion, etc…) It is not necessary to repeat the same or a similar table or diagram more than once. However, if parts of the referenced document merit a more thorough description (e.g. "In the second DO… LOOP of the robot code (below), …"). It is also perfectly acceptable to reference pre-existing work in your report. As always, cite all work that is not original to you. The Experimental Procedures and Results section should include the following information for ***each week*** of the Challenge:

1. How did you study the problem?

- Briefly ***explain*** **Design considerations**, including constraints and requirements and conceptual designs that were considered.

2. What did you use?

- ***Describe*** as part of a **Detailed design** - including detailed descriptions (and supporting documentation such as circuit diagrams and code) of hardware and software - what equipment, electronic components and other hardware/software you used.

3. How did you proceed?

- ***Explain*** the steps you took in implementing your design in the completion of your robot
- **Design justification**, including design choices and alternative designs that were considered but not selected (e.g., use your trade study to support choices), data collected/analyzed in making design decisions (e.g., how were thresholds set, frequency of operation chosen, etc.), challenges, and solutions

4. What did you observe?

- **Testing and design evaluation**, including sensor, integration, and reliability demonstration results, discussion of issues/challenges identified during testing/demo and solutions.
- Your complete raw data should be included in an Appendix.

IV. Analysis and Discussion

Analysis and Discussion is the fourth section of a formal laboratory report, following the Abstract, Introduction, and Experimental Procedure and Results. This section is arguably the most essential section of a laboratory report. The Analysis and Discussion section is where thoughtful consideration and critical refection on the experiments and simulations you have done is presented. This should go beyond simply answering the questions posed in the laboratory manual (although this is necessary). Comment on what you learned in performing the experiment, both through what went right and, perhaps more importantly, what went wrong. Often, you will need to make use of experimental data from the previous section to support the calculations presented here. **Full credit will only be given to Analysis and Discussion sections that demonstrate independent thought and evidence of a critical evaluation of the experiment and its results.**

An Analysis and Discussion section for this report should include:

- **Statement of cost**, including a discussion of ways costs might have been reduced or the design streamlined given more time and resources
- **Analysis of final design** as a whole. Any areas of improvement? Persistent issues? You need not repeat your Design Justifications for individual weeks in their entirety. You may find it useful to reference previously written Design Justifications for this purpose. There are certain considerations that it was necessary to make in the design of the overall robot. Those considerations should be dealt with here.
- **Proposed design changes and improvements** including the changes you would have made given more time and resources. If no changes, what made your robot perform perfectly?

V. Conclusion

The Conclusion is the fifth and final (regular) section of a formal laboratory report, following the Abstract, Introduction, Experimental Procedure and Results, and Analysis and Discussion. The conclusion must effectively tie together the objectives, experimental results, and analysis. You must state whether the objectives of the exercise were fulfilled and briefly state the reasons for your claim. You should address each objective separately.

Final Design Report Grading Criteria
Due: 5:00pm, Wednesday, Apr. 27th, 2016 (Teer 210/216 Laboratory)

****** Staple this form to the FRONT of your Final Design Report******

	Possible	Earned
I. Abstract • Clarity • Conciseness • Accuracy • Completeness	**8**	
II. Introduction 1. What is the problem? 2. Why is it important? 3. What solution do you propose?	**15**	
III. Experimental Procedures and Results For ***each week*** of the Challenge: 1. How did you study the problem? 2. What did you use? 3. How did you proceed? 4. What did you observe?	**35**	
IV. Analysis and Discussion • Statement of cost • Analysis of final design • Proposed design changes and improvements	**20**	
V. Conclusion • Effectively ties together obj., exp. results, and analysis • States whether obj. met and why (address each separately)	**10**	
Supporting documentation – complete circuit diagrams, entire Arduino Code, pictures of Bot and sensors used on Bot	**5**	
Overall document quality – spelling correct, grammar, paragraph breaks, easy to follow order and format, Tables, Figures, Graphs, and Formulas properly labeled	**7**	
Total Score	***100***	

Supporting documentation (e.g., Arduino code, complete circuit schematics) can be included in an Appendix.

*** Report should include a cover page with title, group name and membership, date, pages numbered, and Community Standard statement (signed by all).**