Appendix A

Introduction to 6.270

6.270 is a hands-on, learn-by-doing class in which participants design and build a robot that will play in a competition at the end of the class. From the student's perspective, the goal of the class is to design a robotic machine that will be able to navigate its way around the playing surface, and successfully interact with game objects, including the opposing machine.

The machines in MIT's Introduction to Design class (2.70) are controlled by humans wielding joysticks. They are not robots—they are machines.

The machines built by students of 6.270 *are* robots. They are fully autonomous entities, operating under their own battery power with a microprocessor in control. Once a 6.270 contest round begins, there is no human intervention. The design of a 6.270 robot is a complex task, because an entry must be designed intelligently with respect to mechanical, electronic, and control factors.

From the perspective of its creators, the goal of 6.270 is to teach students about engineering and design by giving them the hardware, software, and information they need to design and implement an operational robot.

The course includes concepts and applications that are related to various MIT engineering classes, but 6.270 has no formal curriculum, no material that must be "covered." This allows the class to have a great deal of flexibility, which it hands back to its students. We hope is that the course inspires students to learn whatever material is most exciting to them and challenges them at whatever level is most appropriate. If one student focuses on hardware issues while another tackles puzzling software problems, the course is a success to both of them.

There are no formal prerequisites for 6.270. We've found that people can learn everything they need to know by working with each other, being introduced to some material in class, and mostly, by hacking on their robots. All members of the MIT community, from frosh to grad students, staff, or even professors, are encouraged to register and take the class.

6.270 does require that its students be prepared to put forth a real effort! We expect most students to spend about eighty hours over the month of IAP building their robots. We've also noticed that people who make a real commitment to the class are more confident, feel more involved, and have a lot more fun. So: if you going to take 6.270, be ready for a month-long immersion into robotics.

A.1 Registration Policy

All entrants will be organized into teams. There are a couple of reasons for this. First, we find that people learn a lot in the close and intense relationship of a small team. Second, we think the class would be too much work for one person to handle by his or her self.

You are encouraged to form a team of two to four people and register together. You may also register alone, in which case we will find you a team with two other people.

The lottery for this year's class was held on October 28th, 1991. Between the opening of enrollment in late September and that date, one hundred and seventeen (117) teams consisting of three hundred and forty-one (341) individuals had registered for the class.

Registration in the class was limited to fifty (50) teams. We would have accepted more students if resources permitted us but they do not.

A.2 Kit Fee and Toolkit Fee

Your 6.270 kit, which is yours to keep at the end of the contest, will be valued at about \$500. The class is mostly financed by our commercial sponsors (namely Microsoft, Motorola, LEGO, and Polaroid) and the Course Six department, but part of the budget is derived from the entry fee.

This year the entry fee is \$50 per team, the same as last year. *You may have heard or read differently due to a change from earlier versions of our registration materials, but this figure is the correct one!* We have managed to keep student costs down as a result of the strong financial commitment that has been given to the class from the Course Six department.

We encourage you to start thinking now about the fate of your kit after the contest. In the past, we have observed some teams having great difficultly in deciding which team members should have stewardship of the kit or various parts of the kit. We don't have any easy answers for this hard problem, but we do suggest that you open the question earlier rather than later.

Separate from the 6.270 kit, a complete set of electronic hand tools will be reserved for purchase by your team. This kit will include a soldering iron, diagonal cutters, long nose pliers, wire strippers, a multimeter, and several other useful implements.

The 6.270 tool kit will have a retail value between \$75 and \$100; we expect to sell the kits for between \$40 and \$50 (we can give you these prices due to the quantity discounts we get in purchasing for the class). *You will be expected to either provide your own electronic assembly tools or purchase the standard tool kit.*

A final word about contest costs: if it is difficult for you to afford the contest costs, both the 6.270 kit and the toolkit are returnable (if in good condition) for a refund. If you would like to take the class, but you cannot afford to put up the money to register for the class and buy the toolkit, come talk to the organizers. We can probably work something out.

A.3 Team Organization

In many ways, the quality of the interactions of the members of your team will profoundly affect the quality of your overall experience in 6.270. Over the past years of 6.270, we have seen many different students and many different team dynamics.

There are important questions to be answered when thinking about the organization of your 6.270 team:

- Will each participant be responsible for one portion of the design? Conversely, will all participants take part in all activities?
- How will major design decisions, like the overall machine strategy or physical configuration, be made? Will there need to be a consensus amongst all of the team members before these types of decisions will be made?
- How will disputes be resolved?
- Which team members will keep which parts of the 6.270 kit at the end of the course?

These are tough questions that have no pat answers. It is recommended that questions like these be taken seriously, and that each team spend time discussing these issues at the start of the course. Each team should come up with a solution that works best for them.

As mentioned earlier, teams may have two, three, or four students. However, we *strongly recommend* teams of two or three students. It has been our observation that most teams of four tend to end up having a real "working team" of two or three persons. We would rather that you form a team of two or three people who are really committed to working together than you form a team of four with a less strong commitment.

If you are taking the class for credit, we will require that this suggestion be followed: persons who are taking the class for credit must be members of teams of two or three people.

A.4 6.270 Alumni

If you have taken 6.270 before and you are taking it again, you will be expected to assist by working as a laboratory TA. Alums will be expected to work about four hours *per week* for the class. Alternate duties to working as a lab TA include: helping to build the game board, and other general support activities. If you're an alum, we will expect you to have a genuine and positive attitude about this service work.

Alumni had the same chance in the lottery as other registrants.

A.5 Credit Guidelines

6.270 is offered as MIT course 6.190 for six units of P/F credit. Taking the class for credit is optional. The class will entail a lot of work whether or not it is taken for credit; signing up for credit will give you official recognition for taking the class. If you sign up for credit but then do not complete the requirement, your registration will be dropped; it will be as if you never signed up in the first place.

Our job as instructors is to ensure that credit is properly awarded to students deserving of it. Our basic assumption is that anyone who is in the class is going to be doing a lot of work; the guidelines should add only a little bit of overhead to you in reporting your work to us. Hopefully, you may even learn a little more by going through the process, which includes reporting your progress through the course.

As mentioned in the registration guidelines, team size for students registering for credit will be limited to two or three members. This is because of our (mostly true) observation that it's very hard for a team of four members to fairly distribute work amongst themselves.

The following requirements for credit have been established:

- **Individual Written Reports.**

  Each individual desiring credit must turn in a series of three weekly written reports. These will be due at the end of each week.

  The written design report must state explicitly what *you* have contributed to the progress of your robot. This should include:

  - actual construction work, programming, or other tangible results that you have done;
  - ideas you have contributed to the design of your robot (whether they have been implemented or not);
  - plans for the next week of work.

The purpose of the individual report is to get a sense of what each person on a team is contributing to the design, so it's important to make sure we know what you've done.

- **Team Video Reports.**

  In addition to the individual reports, a team video report will be done once per week.

  A video station will be set up in the 6.270 lab area. To make your report, you and your team can simply go to the camera and make a brief presentation on the status of your robot. This presentation should focus on issues that the team has worked on together, such as the current state of the robot, the strategy of the robot, and how the team arrived at consensus (or not!) on particular issues.

  Hopefully, the video station concept will make the design reporting a fun and painless process. Any ideas presented to the camera *will remain confidential* for the duration of the contest.

- **Team Interview.** During the final week of IAP, your team will have a 20 minute meeting with the contest organizers to discuss your participation in the class: what you learned, what you didn't learn, what you liked about it, what you didn't like.

  The purpose of the interview is two-fold. Most importantly, it serves as an opportunity for you to give us (the organizers) feedback about the course and your learning experience so that we can continue to improve the class format. Secondly, it helps us make sure that people who are receiving credit actually did some work.

  The interview is required for all individuals who will receive credit, but we hope that people who aren't registered for credit will participate as well.

- **Completed Robot.** Your team must "show" a robot the day of the contest. Its functionality (or lack of) has no affect on your receiving credit for the work you have done; the combination of the design reports and the team interview will be the main indicators of your participation.

- **Program Listing.** You must turn in a copy of the program that your robot uses in the contest.

These course requirements are meant to be useful to both you, the course participant, and the instructors, who will be authorizing credit. You should have no problem at all receiving credit if all of the requirements are satisfied. If you have any questions about your standing in the course at any time, feel free to ask any of the instructors for feedback.

Please note that there is no leeway on any of the due dates, due to the scheduling constraints of the Registrar and the sanity of the organizers. Please do not ask for extensions.

A.6 Schedule

The schedule of activities between the start of IAP and the eve of the contest is very tight. You will have to work steadily and with determination to produce a working machine by the end of the course. In no fashion do we, the contest organizers, say that this course is not time consuming! However, since it is IAP, was can assume it is the main time-sink you've signed up for.

There will be about 150 students taking the 1992 6.270 course, making it the largest course taught during IAP. Since much of the learning we believe occurs with a hands-on interactions, the class will be too large as a whole to teach on this basis. Therefore we have several class meeting formats, including lectures, recitations, and lab.

We recommend that you attend all of the lectures and recitations (for the section you are in). We will deal with administrative and "bug fix" matters at the beginning of each meeting, so if are not finding these sessions helpful, you can leave after this practical information is disbursed.

- **General Lecture** The function of the general lecture to teach the basics of what is going on during that week of the course. The lecture will be held on **Tuesday** nights in room 34-101 from 7-10 pm. We do not expect all the lectures to take the entire three hours, but some may.

- **Catch-Up Help Session** This informal class will be designed for those people who may feel that they are not up to speed in a certain area. For example, we may go over general microprocessor architecture, programming, fundamentals behind sensors. It is not necessary to go to these lectures, but they will be fun and you may even learn something. These lectures will be held on **Sunday** at 7:00 pm, in Room 34-101.

- **Recitations** Some material will be presented in recitations rather than in lectures, to encourage a more interactive format. There will be three recitation sections, meeting on Wednesday and Thursday evenings.

  The class will be divided into three groups to approximately sort people of comparable background levels. **Section B** (beginning) will meet **Wednesday** nights from 7:00 pm to 8:30 pm. **Section I** (intermediate) will meet **Thursday** nights from 7:00 pm to 8:30 pm. **Section A** (advanced) will meet **Thursday** nights from 8:30 to 10:00 pm. Sections will be selected to match contestants' choice as best as possible. Please do not change recitation sections unless you are trading places with someone else in the class.

- **Laboratory Time**

  This is supervised time for building your robot. Lab time will be most critical when working on your microprocessor and other circuit boards. After that, building motors and sensors will be important. During the final week, testing machines on the table will be the focus of lab activity.

  Labs will be held on the 6th floor of building 38 during the day time and in the Chu Lounge (38-201) when at night.

A.6.1 Important Dates

Before reading the listing the full month of meetings, please note following *very important* meetings:

Parts-Sorting Session. Attendance to this session is mandatory: all teams must provide four person-hours of manual labor helping to sort out the kit parts. Usually this session is a lot of fun as you get introduced to other people in the class and see all of the electronic goodies.

Date, Time, and Place: Monday, January 6th, 10:00 am to 4:00 pm, Building 38.

Official Orientation Meeting. Attendance to this session is mandatory: each team must have at least 50% of its members in attendance. In this session, we go over the contest rules, organization of the class, and hand out the kits.

Date, Time, and Place: Tuesday, January 7th, 2:00 pm to 5:00 pm, Room 34-101.

The Contest, First Round. Your machine must compete in the first round to qualify for the second round.

Date, Time, and Place: Saturday, February 1st, 6:00 pm, Room 34-101.

Robot Impounding and Party. All work on robots will cease at *7 o'clock P.M., Sunday the Second of February.* Robots will be impounded at *The Chu Lounge, 38-201.* A party will ensue.

The Contest, Second Round. Robots will be released from impoundment at 5:00 pm, Monday February 3rd. You must check your robot into 26-100 by 6:00 pm. Good luck!

Date, Time, and Place: Monday, February 3rd, 7:00 pm, Room 26-100.

Figure A.1 illustrates the month's schedule in pictorial form.

6.270 IAP '92

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Jan 5	**6** **Parts-Sorting.** Bldg. 38 10am-5pm	**7** **1st Meeting!** 34-101 5-8pm	**8** **Supervised Lab** 10am-4pm, 38-600 **B Recitation** 34-101, 7-8:30pm	**9** **Supervised Lab** 10am-4pm, 38-600 **I Recitation** 34-101, 7-8:30pm **A Recitation** 34-101, 8:30-10pm	**10** **Supervised Lab** 10am-4pm, 38-600
12 **Intro to 6811 'C'** 34-101, 7-9pm	**13** **Supervised Lab** 12n-4pm, 38-600	**14** **Supervised Lab** 12n-4pm, 38-600 **LEGO Lecture.** 34-101, 7pm	**15** **Supervised Lab** 12n-4pm, 38-600 **B Recitation** 34-101, 7-8:30pm	**16** **Supervised Lab** 12n-4pm, 38-600 **I Recitation** 34-101, 7-8:30pm **A Recitation** 34-101, 8:30-10pm	**17** **Supervised Lab** 12n-4pm, 38-600
19	**20** **Martin Luther King Day** *(No scheduled activities.)*	**21** **Supervised Lab** 12n-4pm, 38-600 **Robust Programming.** 34-101, 7pm	**22** **Supervised Lab** 12n-4pm, 38-600 **B Recitation** 34-101, 7-8:30pm	**23** **Supervised Lab** 12n-4pm, 38-600 **I Recitation** 34-101, 7-8:30pm **A Recitation** 34-101, 8:30-10pm	**24** **Supervised Lab** 12n-4pm, 38-600
26	**27** **Supervised Lab** 12n-4pm, 38-600	**28** **Team Interviews** 34-30x, 7-10pm	**29** *(Last Day of IAP.)* **Team Interviews** 34-30x, 7-10pm	**30** *(Reg Day.)* **Team Interviews** 34-30x, 7-10pm	**31** *(First Day of Classes.)*
Feb 1 **Contest Round 1** 34-101 6pm **Feb 2** **Robot Impounding** Chu Lounge 6pm	**3** **The Contest!** 26-100 6pm	**4**	**5** *(resume life)*	**6**	

Figure A.1: Pictorial Schedule of the Month's Activities

A.6.2 Detailed Schedule of the Month's Activities.

Monday, January 6. Part-Sorting Meeting. *10:00a to 4:00p, Building 38.* Sort kits. Mandatory attendance as mentioned above.

Tuesday, January 7.

- **First meeting.** *2:00p to 5:00p, 34-101.* Hand out kits, go over month's schedule, go over rules, get psyched.

Wednesday, January 8.

- **Lab.** *10:00a to 4:00p, 6th floor of bldg. 38.* Supervised lab time. Begin building microprocessor board! Soldering demonstrations every 1 hour.
- **Section B, Meeting 1.** *7:00p to 8:30p, 34-101.* Introduction to microprocessor board, demonstration of sample robots, brainstorming of contest design solutions, Q & A.

Thursday, January 9.

- **Lab.** *10:00a to 4:00p, 6th floor of bldg. 38.* Supervised lab time. Continue building microprocessor board. Soldering demonstrations every 2 hours.
- **Section I, Meeting 1.** *7:00p to 8:30p, 34-101.* See description of Meeting 1, above.
- **Section A, Meeting 1.** *8:30p to 10:00p, 34-101.* See description of Meeting 1, above.

Friday, January 10.

- **Lab.** *10:00a to 4:00p, 6th floor of bldg. 38.* Supervised lab time. Finish microprocessor board; begin testing it.
- **VIDEO DESIGN REPORT #1 DUE.** Complete in lab.

Saturday, January 11.

- **Lab.** *10:00a to 4:00p, 6th floor of bldg. 38.* Supervised lab time. Continue testing microprocessor board.

Sunday, January 12.

- **Lab.** *10:00a to 4:00p, 6th floor of bldg. 38.* Build battery charger board and LEGO-ize some motors.

- **DESIGN REPORT #1 DUE.**
- **Special Lecture: Introduction to C Programming.** *7:00p to 8:30p, 34-101.* This lecture will introduce the 'C' language to people who have never used it before.

Monday, January 13.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Build light sensor, touch sensor, reflectance sensor.

Tuesday, January 14.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Build Motor Switch Board. Start Expansion Board, IR transmitter board, and wire IR receivers.
- **Lecture: The Art and Science of LEGO.** *7:00p to 10:00p, 34-101.* Learn about designing sturdy structures and effective gearboxes with LEGO Technics parts. Short lecture plus lots of workshop time.

Wednesday, January 15.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Continue Expansion Board, wiring sensors. Begin building robot.
- **Section B, Meeting 2.** *7:00p to 8:30p, 34-101.* Introduction to 6811 C environment. Simple control of motors and sensors. Printing to the LCD screen. 6.270 'C' libraries.

Thursday, January 16.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.*
- **Section I, Meeting 2.** *7:00p to 8:30p, 34-101.* See description of Meeting 2, above.
- **Section A, Meeting 2.** *8:30p to 10:00p, 34-101.* See description of Meeting 2, above.

Friday, January 17.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Finish Expansion Board. Test it. Continue building robot.
- **VIDEO DESIGN REPORT #2 DUE.**

Saturday, January 18.

- *No scheduled activities.*

Sunday, January 19.

- **WRITTEN DESIGN REPORT #2 DUE.**
- **Catch-Up Help Session.** *7:00p to 10:00p, Chu Lounge (38-201).*

Monday, January 20.

- **Martin Luther King Day.** *No scheduled activities.*

Tuesday, January 21.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.*
- **Lecture: Robust Robot Programming.** *7:00p to 10:00p, 34-101.* How to program your robot so that it deals well with a dynamic, unpredictable environment.

Wednesday, January 22.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Things are done electronics-wise. You are finishing mechanical design.
- **Section B, Meeting 3.** *7:00p to 8:30p, 34-101.* Multi-tasking in the 6811 C environment. Performing sensor filtering techniques with processes.

Thursday, January 23.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.*
- **Section I, Meeting 3.** *7:00p to 8:30p, 34-101.* See description of Meeting 3, above.
- **Section A, Meeting 3.** *8:30p to 10:00p, 34-101.* See description of Meeting 3, above.

Friday, January 24.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Robot is fully constructed; you are working on final programming.
- **VIDEO DESIGN REPORT #3 DUE.**

Saturday, January 25.

- *No scheduled activities.*

Sunday, January 26.

- **WRITTEN DESIGN REPORT #3 DUE.**
- **Catch-Up Help Session.** *7:00p to 10:00p, Chu Lounge (38-201).*

No more evening class meetings.

Monday, January 27.

- **Lab.** *12:00n to 4:00p, 6th floor of bldg. 38.* Robot is beginning to work as an integrated unit.

Tuesday, January 28.

- **Team Interviews, Day 1.** *7:00p to 10:00p, locations to be announced.* Twenty minute interview per team, one of three days only.

Wednesday, January 29.

- **Last day of IAP.**
- **Team Interviews, Day 2.** *7:00p to 10:00p, locations to be announced.* Twenty minute interview per team.

Thursday, January 30.

- **Registration day.**
- **No Lab.**
- **Team Interviews, Day 3.** *7:00p to 10:00p, locations to be announced.* Twenty minute interview per team.

Friday, January 31.

- **First day of classes.**
- **Evening Lab.** *7:00p to 12:00m, Chu Lounge (38-201).*

Saturday, February 1.

- **Lab.** *10:00a to 5:00p, Chu Lounge (38-201).*

- **First Round of the Contest.** *6:00p, Room 34-101.*

Sunday, February 2.

- **Last-Chance Lab.** *12:01a to 7:00p, Chu Lounge (38-201) and surrounding areas.*
- **Robot Impounding.** *7:00p to 8:00p, Chu Lounge (38-201).* **All robots that will compete in the contest must be turned in at this time.**
- **Party.** *8:00p, location TBA.*

Monday, February 3.

- **The 6.270 Contest, Round 2.** *6:00p to 10:00p, 26-100.* Good luck, everyone!

A.7 Robo-Cup Contest Rules

This year's contest is "Robo-Cup Soccer," a game played by two autonomous robots.

A.7.1 Object

Have your robot place more balls into its goal within a 45 second period.

A.7.2 Balls

- The balls will be practice golf balls. These are plastic balls, similar in weight to ping-pong balls, but slightly larger and with less bounce.
- One point will be awarded for each ball in your robot's goal when the contest ends. It does not matter which robot caused a ball to enter your robot's goal.
- The balls will be dispensed six inches away from the wall at designated drop points.

  The balls will be dispensed when the corresponding touch sensor has been activated. The dispenser will allow one ball to be dispensed once every five seconds.
- You may place one ball into your robot before the start of the contest round.
- The balls are inert and all have identical properties.
- Robots may gather balls "into" their body.
- The balls may not be altered or destroyed in any way.

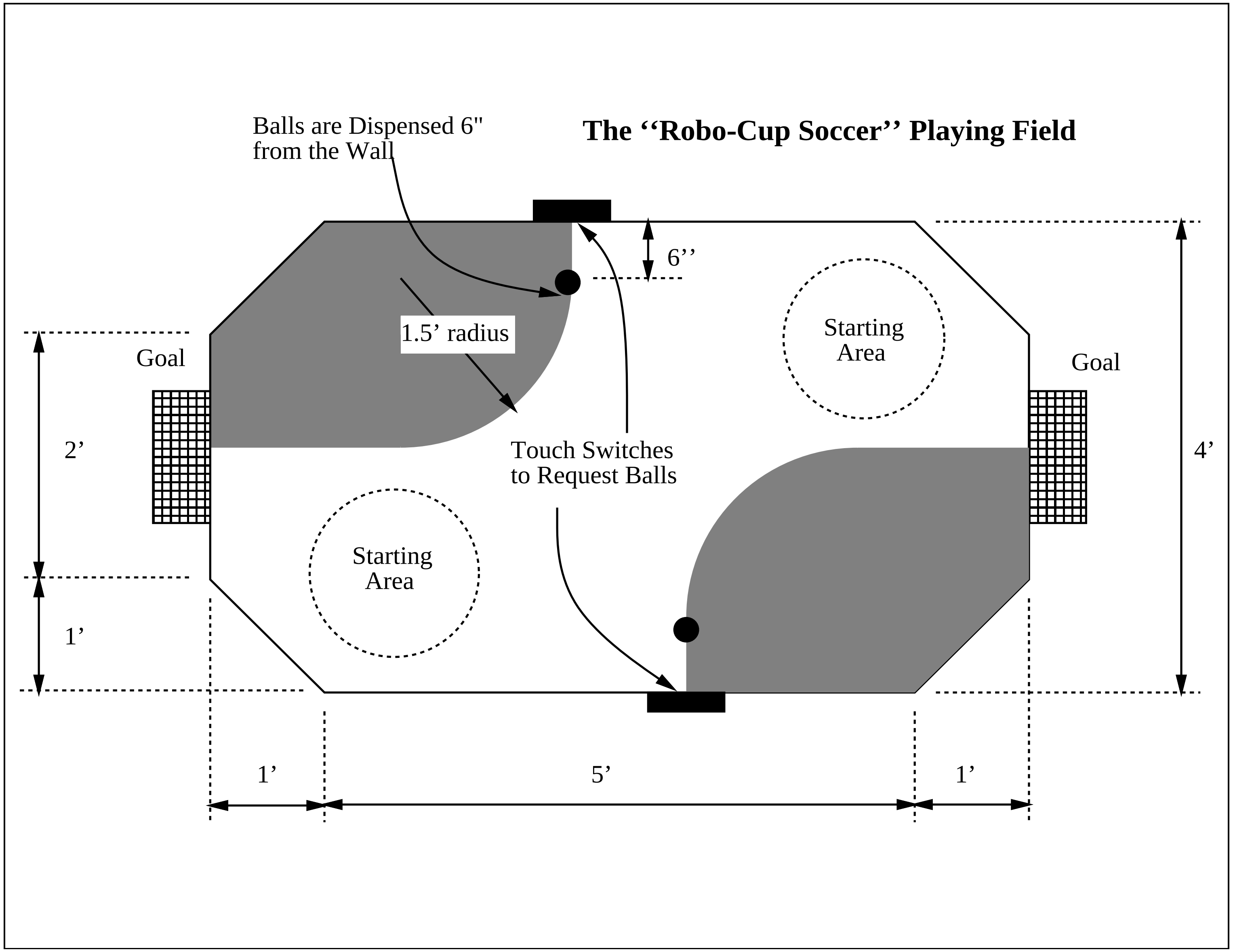

Figure A.2: Robo-Cup '92 Contest Playing Field Specification

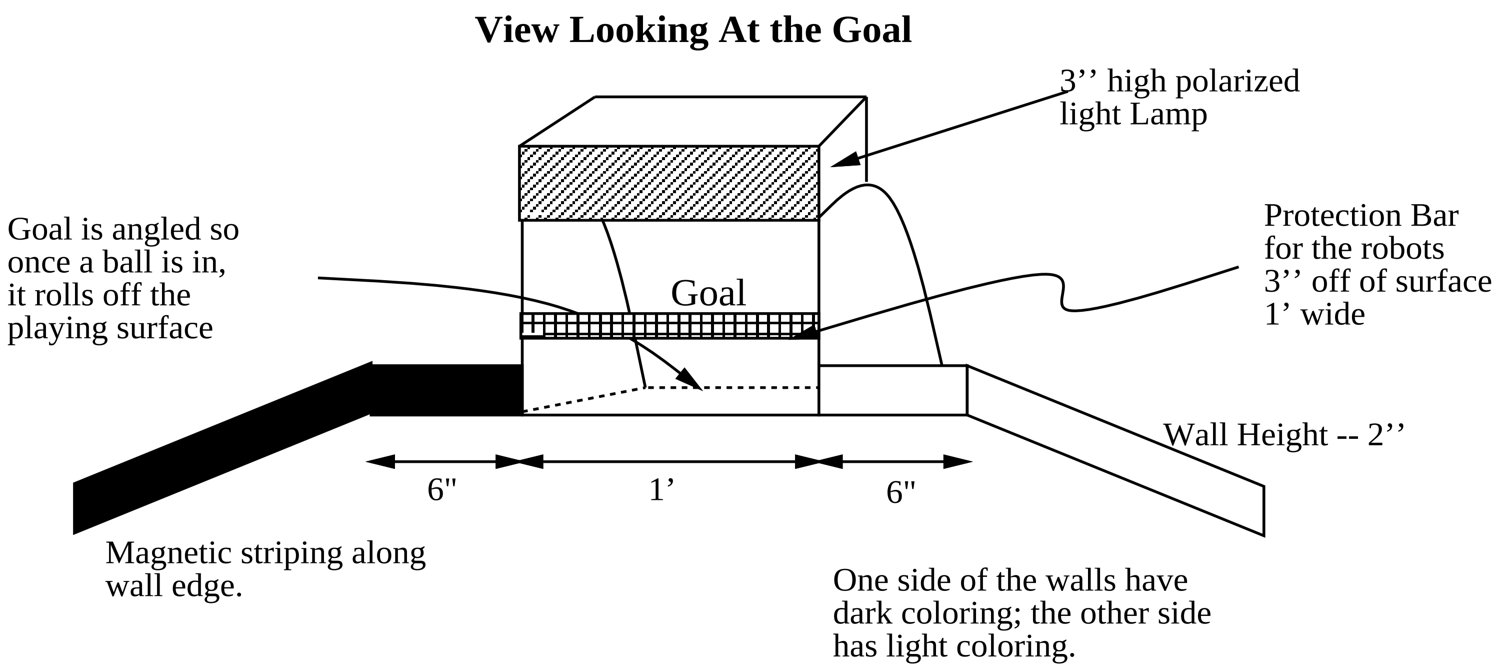

Figure A.3: Robo-Cup ’92 Contest Goal Specification

A.7.3 The Goal

- Your robot's goal is defined as the goal which is furthest from the robot's starting position.
- The goal is one foot wide and eight inches high with a barrier post that is one inch wide at a height of three inches above the surface.

  See Figure A.3 for an illustration of the goal.
- Your robot may not advertently place anything inside either of the goals except the balls.
- The surface inside of the goal will be sloped so that the balls will roll into the goal when they cross the goal line.

A.7.4 Period of Play

- The powered portion of a round will last 45 seconds. After the machines are started, they will have 45 seconds to apply battery power to their actuators.
- The round ends when all machines and balls come to rest.
- The round will be started by the judges turning on the starting lights, located underneath the table in the center of each robot's starting circle, for the first one second of the round.
- The contestants will place the machines on the playing field within the designated starting circles. The robots may be placed in any orientation within the starting area.
- The contestants will have 30 seconds to place their machines on the field from the time the judges call them.
- The contestants must stand a given distance away from the playing field. Any contestant who touches their machine during the round of play will automatically be disqualified their robot from the round.
- The machines must have their own internal clock (software will be provided to do this) that cuts off power to the motors at the end of 45 seconds. Any machines that continue to supply actuator power after 45 seconds will be disqualified.
- The contest will be an double elimination competition held over two nights. Machines must qualify for the second night of competition, as follows:

- *Night 1.* All machines will play one round. If a machine loses its round against an opponent, it will run against an inert placebo. If it cannot win against the inert placebo after two tries, it will not qualify for the second night of play.
- *Night 2.* The main competition. Machines will play until they lose twice. Loss against opponent from the first night is included.

- All rounds will have two robot players.

A.7.5 Control

- All entries must be solely controlled by their onboard computer. There can be no human intervention once the round begins.
- After the start of the contest, there can be no change to the robot's program or configuration switches made by the contestants.
- No parts or substances may be deliberately dumped, deposited, or otherwise left to remain on the playing surface. A machine that appears to have be designed to perform such a function will be disqualified.
- Machines are not allowed to destroy their opponent's microprocessor board.
- Machines cannot try to destroy other machines' broadcast or detection beacons.

A.7.6 Infrared Beacon

All robots are required to carry an infrared transmitter. This transmitters acts as a beacon so that robots can locate each other on the playing field. The following rules describe the functionality of the infrared beacon.

- All entries must carry an infrared beacon that is capable of broadcasting infrared (IR) light at modulated at either 100 Hertz or 125 Hertz with a 40,000 Hertz carrier (hardware is provided to do this).
- Machines failing to meet the infrared transmission specification, or in any way modifying or jamming their transmission frequency during the round of play will be disqualified.
- Judges will assign frequencies for IR emitters to the machines in the beginning of each round by setting the robot's DIP switch 1. If the switch is one, the robot must broadcast 100 Hertz infrared light. If the switch is zero, the robot must broadcast 125 Hertz infrared light. Software will be provided to do this.

- The IR broadcasting beacon must be located at exactly one foot (12 inches) above the surface of the playing field when mounted on the robot.
- The beacon must be located so that its center is never more than four inches (measured horizontally) from the geometric center of the microprocessor board.
- The beacon cannot be deliberately obstructed, or be designed in such a way that "accidental" obstructions are probable.

A.7.7 The Contest Playing Table

Figure A.2 illustrates the Robo-Cup playing field.

Polarized Light Goal Lamps

- Goals will have panels that emit polarized light at one of two orientations: a +45 degree and −45 degree (with respect to the vertical) polarization (see Figure A.3).
- The setting of DIP switch 1 will indicate which polarization angle is emitted by the robot's goal. If the switch is one, the robot's goal will be the one with the positive polarization. If the switch is zero, the robot's goal will the the one with negative polarization.

Wall Striping

- The two sides of the playing field will be coded with light or dark visible striping on the lower inside edge of the playing field wall.
- All wall edges will also be coded with magnetic strips.

Ball Dispensers

- The ball dispensers will drop balls at a distance of 15 inches above the designated drop points.
- Robots may obtain balls from either ball dispenser.
- Ball dispensers will dispense balls at a rate not greater than one ball per five seconds.
- Depressing the touch bumper near to the ball dispenser causes a ball to be dispensed as soon as is possible given the dispensing rate mentioned above.
- The touch bumper must be released before a subsequent ball can be dispensed.

A.7.8 Structure

- All kits contain exactly the same components, with the exception that some LEGO parts may be colored differently in different kits.

- Only LEGO parts and connectors may be used as robot structure. LEGO rubber bands are counted as LEGO parts; therefore, LEGO rubber bands *may* be used to provide structural support to your machine.

- LEGO pieces may not be glued together.

- LEGO pieces may not be altered in any way, with the following exceptions:

  1. The grey LEGO baseplate may be altered freely.
  2. LEGO pieces may be modified to facilitate the mounting of sensors and actuators.
  3. LEGO pieces may be modified to perform a function directly related to the operation of a sensor. An example: Holes may be drilled into a LEGO wheel to help make an optical shaft encoder.

- String may not be used for structural purposes.

- The wooden dowel may be used only as a tower to mount the infrared transmitters and any receivers.

- A non-LEGO part may be attached to at most five LEGO parts via glue.

- Cardboard, other paper products, and tape may be used for the purpose of creating optical shields for light sensors.

- Wire may only be used for electrical purposes, and not structural.

- Rubber bands may be glued to LEGO wheels or gears to increase the coefficient of friction.

- Only the LEGO rubber bands and thin rubber bands may be used to provide stored energy.

- Contestants may not alter the structure of their entry once the contest has begun, but may repair broken components between rounds if time permits.

- The dimension of the machine may not exceed an imaginary 1 foot cube at the start of each round. Only the IR transmitting and receiving beacons and the bend sensors may protrude outside this volume. Entries may however expand once the round has begun.

- Entries may not drag wires between two or more structurally separate parts of their robot.

  One portion of the robot is considered structurally separate from another if when the machine is lifted from a supporting surface and held from the other portion, the two portions are supported mainly by wire.

- No lubricants may be used.

- Cable ties may not be used for structural purposes.

- Some parts in the 6.270 kit are considered tools and may not be used on the robot. Examples are: the red plastic parts container; the small rectangular parts container; the soldering iron sponge. If there is any question about whether an object is a "kit part" or a "tool part," ask the organizers.

- Any machine that appears to be a safety hazard will be disqualified from the competition.

A.7.9 The $10 Electronics Rule

To encourage creativity, contestants may spend up to $10 of their own funds for the purchase of additional electronic components used in their design. Other than this rule, robots must be designed completely from standard kit parts. The following conditions apply to all non-kit-standard electronic additions:

- The following components, categories of components, or varieties of circuitry are *disallowed:*

  - Batteries of any variety.
  - Motor driver circuitry, including relays, power transistors, or any other replacements or modifications to the standard motor driver circuitry.

- No single part may cost more than $2.

- Resistors rated less than 1 watt and capacitors valued less than 100 μF may be used freely, without accounting toward the $10 total.

- Contestants who add *any* non-kit parts to their project must turn in a design report that includes: description of the modification, schematic of all added circuitry, and store receipts for parts purchases. This design report must be turned in to the organizers by 5:00 pm, Friday, January 31, 1992. *Any machines found with added circuitry that has not been documented in this fashion will be disqualified.*

- If a contestant wishes to use an electronic part which has been obtained through other means than retail purchase, an equivalent cost value to the part will be assigned by the organizers. Contestants must obtain this cost estimate *in writing* from the organizers and include it in the design report mentioned above.

A.7.10 Scoring

- Each ball entering the upper goal area will be awarded three points. Each ball entering the lower goal area will be awarded two points. The winner will be the machine with points at the end of the round.
- In rounds containing a placebo, the contestant's robot must score at least one ball into its goal in order to be declared the winner of that round.
- If no goals are scored a double loss will be awarded by the judges.
- If there is a tie at the end of the round, the win will be determined as the robot that has more balls on the half of the playing field nearer to its goal.
- A double win may be awarded at the judges' discretion.
- The judges will decide any discrepancies in the contest play.

A.7.11 Organizers

- Contestants may approach the organizers in privacy to consult about possible designs that may be questionable under the rules listed above. These designs will not be divulged to any of the other contestants.
- Final arbitration of any rule disputes before the day of the contest (February 3rd) will be decided by the contest organizers—Fred Martin, Pankaj Oberoi, and Randy Sargent.

A.8 Parts List

This section lists all of the parts in the 1992 6.270 kit, including pricing and source information.

The prices indicated for most parts represent large quantity discounts of up to 50% off of the singe-quantity price.

Other prices are estimates for parts that were donated to the contest: The following companies donated parts at no charge to the contest: Motorola, Gates, 3M, Methode, and AGE.

LEGO Systems, Inc. provided parts to the contest at approximately a 50% to 70% discount off the retail price. Some of these parts were obtained packaged from the USA division; for these parts, stock numbers are indicated in the parts listing. Other LEGO parts were hand-picked for the 6.270 contest from the LEGO factories in their home country of Denmark.

Overall, the LEGO component of the 6.270 kit would be valued between \$150 and \$200 retail.

#PER KIT	PART REF	DESCRIPTION	COST EA	COST KIT	SUPPLIER	PART NUM
		INTEGRATED CIRCUITS				
1	U1	68HC11A0 microprocessor	$7.00	$7.00	Motorola	industry
1	U2	62256LP 32K static RAM	$7.00	$7.00	Motorola	industry
1	U3	74HC373 transparent latch	$0.50	$0.50	Motorola	industry
1	U4	74HC138 3-to-8 decoder	$0.30	$0.30	Motorola	industry
2	U5, U17	74HC374 8 bit latch	$0.40	$0.80	Motorola	industry
1	U6	74HC244 8 bit bus driver	$0.40	$0.40	Motorola	industry
1	U7	74HC132 quad schmitt trigger	$0.30	$0.30	Motorola	industry
1	U8	74HC4053 triple SPDT switch	$0.50	$0.50	Motorola	industry
1	U9	74HC10 triple 3-input NAND	$0.30	$0.30	Motorola	industry
1	U10	74HC390 dual decade counter	$0.50	$0.50	Motorola	industry
1	U11	LM386 power op-amp	$0.70	$0.70	Motorola	industry
1	U12	74HC04 hex inverter	$0.30	$0.30	Motorola	industry
3	U18,U19,U20	74HC4051 8PST analog switch	$0.50	$1.50	Motorola	industry
3	U13,U15,U21	SGS-Thomson L293D motor driver IC	$1.95	$5.85	Active	L293D
2	U14,U16	SGS-Thomson L293B motor driver IC	$1.90	$3.80	Nu Horizons	L293B
		TRANSISTORS				
2	Q1,Q2	MPS2222A general-purpose transistor	$0.07	$0.14	Motorola	
		DIODES AND LEDs				
5	D1,7,8,9,10	1N4001 power diode	$0.05	$0.25	Motorola	
5	D2,D3,D4, D5,D6	1N4148 signal diode	$0.01	$0.07	EBC	51-04148
1	BR1	bridge rectifier	$0.25	$0.25	All	FWB-201
14	LED1,2,3,4,5,6,13 15,17,18,21,22	HLMP1700 hi efficiency red LED	$0.10	$1.40	R&D	393
11	LED7,8,9,10,11,14, 16,19,20	HLMP1790 hi efficiency green LED	$0.23	$2.53	Active	HLMP1790
1	LED12	HLMP1719 hi efficiency yellow LED	$0.23	$0.23	Active	HLMP1719
8	LED23-30	clear lens mini red LED	$0.06	$0.52	EBC	55-32010
8	LED31-38	Motorola MLED71 infrared LED	$0.22	$1.76	Motorola	MLED71
		INDUCTOR				
1	L1	1uH high current inductor	$0.5355	$0.54	Digikey	M7010
		RESISTIVE DEVICES		$2.70		
2	R14,15	1K resistor, 1/8 watt	$0.0230	$0.05	Digikey	1.0KE
3	R6,16,17	2.2K resistor, 1/8 watt	$0.0230	$0.07	Digikey	2.2KE
1	R5	3.3K resistor, 1/8 watt	$0.0230	$0.02	Digikey	3.3KE
3	R4,8,10	10K resistor, 1/8 watt	$0.0230	$0.07	Digikey	10KE
6	R1,2,7,9,12,13	47K resistor, 1/8 watt	$0.0184	$0.11	Digikey	47KE
1	R3,	100K resistor, 1/8 watt	$0.0230	$0.02	Digikey	100KE
1	R11	2.2M resistor, 1/8 watt	$0.0230	$0.02	Digikey	2.2ME
2	R18,R19	7.5 ohm, 5 watt power resistor	$0.272	$0.54	Digikey	7.5W-5
2	R20,R21	15 ohm, 2 watt power resistor	$0.108	$0.22	Digikey	15W-2
2	RP1,10	47K x 9 common (V) resistor pack	$0.15	$0.30	EBC	20-19547
1	RP2	47K x 4 common (V) resistor pack	$0.07	$0.07	EBC	20-14547
1	RP3	1K x 3 isolated (E) resistor pack	$0.09	$0.09	EBC	20-23410
1	RP4	1K x 5 common (V) resistor pack	$0.15	$0.15	EBC	20-15410
1	RP5	22K x 3 isolated (E) resistor pack	$0.09	$0.09	EBC	20-23522
1	RP6	1K x 7 common (V) resistor pack	$0.12	$0.12	EBC	20-17410
1	RP7	1.2K x 4 isolated (E) resistor pack	$0.12	$0.12	EBC	20-24410
2	RP8,9	47 ohm x 4 common (V) resistor pack	$0.07	$0.15	EBC	20-14247
1	RP11	47K x 7 common (V) resistor pack	$0.15	$0.30	EBC	20-17547
2	VR1,2	47K trimmer potentiometer	$0.32	$0.65	EBC	21-21550

Figure A.4: 6.270 Parts Listing, Page One of Four

		CAPACITORS				
1	C3	4700pF monolithic capacitor	$0.10	$0.10	Active	31066
9	C4,7,8,10,12,16, 17,18,19	0.1uF monolithic capacitor	$0.11	$0.99	Active	SR205C104KAA
1	C14	1uF tantalum capacitor	$0.20	$0.20	Sprague	
1	C6	2.2uF tantalum capacitor	$0.20	$0.20	Sprague	
2	C9,11	4.7uF tantalum capacitor	$0.20	$0.40	Sprague	
2	C1,C2	10uF tantalum capacitor	$0.20	$0.40	Sprague	
1	C5	47uF electrolytic capacitor	$0.09	$0.09	EBC	65-24746
1	C15	220uF electrolytic capacitor	$0.16	$0.16	EBC	67-22256
1	C13	470uF electrolytic capacitor	$0.24	$0.24	EBC	67-24756
		OSCILLATION				
1	XTAL	8.000 MHz ceramic resonator	$0.7091	$0.71	Digikey	PX800
1	PIEZO	beeper element	$0.70	$0.70	Time Elex	PKM17EPP-4001
		SWITCHES				
1	SW1	CKC5100 DPDT slide switch	$0.928	$0.93	Digikey	CKC5100-ND
1	SW2	red pushbutton switch	$0.83	$0.83	Mouser	10KB-011
2	SW3,4	micromini pushbutton switch	$0.33	$0.66	Mouser	10KB-010
1	SW5	4 position DIP switch	$0.40	$0.40	MPJA	SW-1355
2	SW6,7	mini slide switch	$0.26	$0.52	Mouser	10SP001
4	SW8,9,10,11	3 position slide switch	$0.33	$1.33	All	SSW-11
		CONNECTORS				
4	J1,3,4,5	2.1mm DC power jack, PC mount	$0.34	$1.36	Mouser	16PJ031
1	J2	4-pin modular jack, PC mount	$0.45	$0.45	All	MT-4J
2		2.1mm DC power plug	$0.30	$0.60	All	DCSID
4		36x1 female strip header	$2.00	$8.00	3M	
4		36x1 male strip header	$1.25	$5.00	3M	
1		4-pin modular plug	$0.18	$0.18	All	CMP-4
1		DEC-style modular plug	$0.35	$0.35	Altex	MP-6D
1		modular-to-spade-connector cord	$0.55	$0.55	Mendelson	550-5729F
1		DB-9 female connector	$0.30	$0.30	Mendelson	240-1100F
1		DB-9 connector hood & hardware	$0.55	$0.55	Mendelson	240-1091F
		INTEGRATED CIRCUIT SOCKETS				
1	PLCC1	52 pin PLCC socket	$2.75	$2.75	Methode	
1	DIP11	8-pin DIP socket	$0.03	$0.03	EBC	33-13084
3	DIP7,9,12,	14-pin DIP socket	$0.06	$0.18	EBC	33-13144
6	DIP4,8,10,18,19,20	16-pin DIP socket	$0.07	$0.41	EBC	33-13164
3	DIP13,15,21	16-pin machined DIP socket (gold)	$0.556	$1.67	Digikey	ED3316
3	DIP5,6,17	20-pin DIP socket	$0.09	$0.26	EBC	33-13204
1	DIP2	28-pin DIP socket	$0.12	$0.12	EBC	33-13284
		BATTERY & CHARGER				
6		2 volt, 2.5 A/hr lead acid cell	$3.00	$18.00	Gates	
1		12v, 1.2A DC adapter	$3.25	$3.25	Edlie	TC626-8
		SENSORS (and supporting electronics)				
4		Sharp GP1U52X sensor	$1.30	$5.20	Time	GP1U52X
8		resistive bend sensor	$0.25	$2.00	AGE	
5		super mini switch	$0.15	$0.75	MPJA	SW-1409
2		Omron D2F-L mini switch	$0.65	$1.30	All	SMS-282
5		lever micro switch	$0.15	$0.75	MPJA	3182-SW
4		125K pot	$0.19	$0.76	Elex Goldmine	G923
2		10K linear pot	$0.25	$0.50	All	LSP-10K
4		digital hall effect switches	$0.39	$1.56	R&D	#239
4		break-beam optical switch	$0.50	$2.00	Motorola?	
10		330 ohm, 1/8 watt resistors	$0.0184	$0.18	Digikey	330KE
4		super bright clear lens red LED	$0.25	$1.00	Elex Goldmine	A1012
4		super bright green LED	$0.25	$1.00	Elex Goldmine	A1018
2		mini high brightness lamp (3 to 6v)	$0.22	$0.44	Elex Goldmine	A1036
6		CdS photocell	$0.22	$1.32	Elex Goldmine	G990
6		reflective IR sensor	$0.50	$3.00	All	OSR-4
2		small magnet	$0.33	$0.67	All	MAG-3
		MOTORS AND SOLENOIDS				
6		Polaroid 5v motor	$5.00	$30.00	Polaroid	

Figure A.5: 6.270 Parts Listing, Page Two of Four

	MISCELLANEOUS				
1	4-AA cell battery holder	$0.80	$0.80	All	BH-4AF
1	16x2 LCD display (non-backlit)	$8.00	$8.00	Timeline	16x2 LCD
3	heat sink	$0.393	$1.18	Digikey	HS125
0.033	heat shrink tubing, 1/8" (60' spool)	$21.95	$0.73	MCM	95-310
0.05	heat shrink tubing, 1/4" (40' spool)	$21.95	$1.10	MCM	95-320
1	17-bin parts caddy	$2.75	$2.75	MCM	21-1665
2	red cylindrical parts caddy	$0.40	$0.80	Elex Goldmine	G727
1	miniature parts case	$0.39	$0.39	Edlie	TD2110-16
3	hex nylon spacers, 1/2" x 6-32	$0.17	$0.51	Mouser	561-L6.50
6	nylon screws, 1/4" x 6-32	$0.05	$0.30	Mouser	561-J632.25
2	nylon screws, 1/2" x 4-40	$0.05	$0.10	Mouser	561-J440.5
2	nylon nuts, 4-40	$0.08	$0.16	Mouser	561-H440
1	5-minute epoxy	$2.33	$2.33	Radio Shack	64-2313
1	super glue	$1.15	$1.15	MCM	20-350
1	6.270 kit box	$2.00	$2.00	Staples?	
0.1	releasable head cable ties (per 100)	$8.90	$0.89	MCM	21-1415
8	4-conductor modular phone cable	$0.05	$0.36	All	4C/F
8	9-conductor ribbon cable (feet)	$0.14	$1.14	Digikey	HC09M-ND
0.01	2-conductor power cable (feet)	$0.03	$0.00	R&D	#B102
	TOOLKIT				
1	Tenma grounded soldering iron	$6.25	$6.25	MCM	21-940
1	extra tip for soldering iron	$1.15	$1.15	MCM	21-435
1	soldering iron stand	$4.10	$4.10	MCM	21-180
1	"nippy" cutters	$4.95	$4.95	MCM	22-1050
1	wire strippers	$3.10	$3.10	MCM	22-555
1	desoldering pump	$4.75	$4.75	MCM	21-590
1	helping hands unit	$4.00	$4.00	MCM	21-425
1	mini needle nose pliers	$3.90	$3.90	MCM	22-575
1	soldering iron tip cleaner sponge	$0.33	$0.33	Elex Goldmine	S2035
1	orange utility knife	$1.25	$1.25	Radio Shack	64-1868
2	safety goggles	$2.00	$4.00	MCM	21-855
	LEGO PARTS				
1	small pulley, stop bush			LEGO USA	1314
1	piston rod			LEGO USA	1315
0.5	connector peg			LEGO USA	1316
1	chain link			LEGO USA	1317
1	8-, 16-, 24-tooth gears			LEGO USA	1318
2	24-, 40-tooth gears			LEGO USA	1319
0.5	bevel gears			LEGO USA	1320
1	worm gear, gear rack			LEGO USA	1321
1	O-ring, pulley wheels			LEGO USA	1322
1	large tire, small tire, hubs			LEGO USA	1323
1	rubber bands			LEGO USA	1324
1	4-, 6-, 8-long axles			LEGO USA	1325
1	10-, 12-long axles			LEGO USA	1326
1	1x3, 1x4 plates			LEGO USA	1327
1	1x6, 1x8 plates			LEGO USA	1328
1	2x3, 2x4 plates			LEGO USA	1329
1	2x6, 2x8 plates			LEGO USA	1330
1	1x2, 1x4 Technic beams			LEGO USA	1331
2	1x6, 1x8 Technic beams			LEGO USA	1332
2	1x12, 1x16 Technic beams			LEGO USA	1333
1	u-joint, piston, round plate			LEGO USA	1339
1	angle plate, hinge, turntable			LEGO USA	1338
2	misc. Technic parts			LEGO USA	1345
0.33	24x24 base plate (three units)			LEGO USA	1348

Figure A.6: 6.270 Parts Listing, Page Three of Four

2	81.6x15 tires	LEGO Denmark	factory
2	hub for 81.6x15 tire	LEGO Denmark	factory
4	hinged plates	LEGO Denmark	factory
4	1x5 plate with end holes	LEGO Denmark	factory
4	20x30mm tires	LEGO Denmark	factory
4	hubs for 20x30 tires	LEGO Denmark	factory
12	1x2 plate (black)	LEGO Denmark	factory
12	2x2 plate (black)	LEGO Denmark	factory
12	2x2 plate (black), flat top	LEGO Denmark	factory
4	optosensor encoder wheels	LEGO Denmark	factory
6	4x6 plate (assorted colors)	LEGO Denmark	factory
6	4x12 plate (assorted colors)	LEGO Denmark	factory
6	6x6 plate (assorted colors)	LEGO Denmark	factory
6	6x12 plate (assorted colors)	LEGO Denmark	factory
4	1x4 flat tile (black)	LEGO Denmark	factory
6	1x8 flat tile (black)	LEGO Denmark	factory
1	4x4 turntable (black)	LEGO Denmark	factory
12	toggle joint with tooth	LEGO Denmark	factory
20	2x2 brick, assorted colors	LEGO Denmark	factory
20	2x3 brick, assorted colors	LEGO Denmark	factory
60	2x4 brick, assorted colors	LEGO Denmark	factory

TYPE	INDEX	COMPANY INFORMATION
manufact	3M	3M
retail	Active	Active Electronics orders: (617) 932-4616
surplus	All	All Electronics Corp. P.O. Box 567, Van Nuys, CA 91408 orders: (800) 826-5432 info: (818) 904-0524 fax: (818) 781-2653
retail	Altex	Altex Electronics, Inc. 11342 IH-32 North, San Antonio, TX 78233 orders: (800) 531-5369 info: (512) 637-3200 fax: (512) 344-2985
retail	EBC	Electronic Buyer's Club
surplus	Edlie	Edlie Electronics 2700 Hempstead Turnpike, Levittown, NY 11756-1443 orders: (800) 645-4722 info: (516) 735-3330 fax: (516) 731-5125
surplus	Elex Goldmine	The Electronic Goldmine
manufact	Gates	Gates Energy Products, Inc.
retail	MCM	MCM Electronics 650 Congress Park Dr., Centerville, OH 45459-4072 orders: (800) 543-4330 info: (513) 434-0031 fax: (513) 434-6959
surplus	Mendelson	Mendelson Electronics Co, Inc. 340 East 1st St., Dayton, OH 45402 orders: (800) 422-3525 info: (513) 461-3525 fax: (513) 461-3391
manufact	Methode	Methode, Inc.
manufact	Motorola	Motorola Semiconductor, Inc.
surplus	MPJA	Marlin P. Jones & Assoc., P.O. Box 12685, Lake Park, FL 33403-0685 orders and info: (407) 844-8236 fax: (407) 844-8764
manufact	Polaroid	Polaroid, Inc.
surplus	R&D	R&D Electronics 1224 Prospect Avenue, Cleveland, OH 44115 orders: (800) 642-1123 info: (216) 621-1121 fax: (216) 621-8628
retail	Radio Shack	Radio Shack 178 Alewife Brook Pkway, Cambridge MA 02138 (617) 491-2925 attn: Don
distr'er	Time Elex	Time Electronics
surplus	Timeline	Timeline Inc. 1490 W. Artesia Blvd., Gardena, CA 90247 orders: (800) 872-8878 info: (213) 217-8912 fax: (213) 532-6304

Figure A.7: 6.270 Parts Listing, Page Four of Four