Problem Set 2: Kinematics in One and Two Dimensions

Design Engineering Challenge: "The Big Dig" 2.007 Contest
Scoring Strategies: Travel Times to Scoring Zones

PROBLEM 1: The contest table "big dig" has several means of scoring positioned on various parts of the table. Therefore, evaluating the time to travel from the start point to the different scoring locations is essential for selecting the best strategy. Assuming a fairly moderate value for the machine's acceleration of 0.25g, where g=9.81 m/s^2 and measuring the various distances on the table (all are available online), time can be calculated.

Equation of motion:

$$X = \frac{1}{2}aT^2 + V_oT$$

Where:

X = total distance traveled by the car (m)

a = acceleration of the car (m/sec^2) =0.25*9.81 = 2.45 m/sec^2

T = duration of travel (sec)

V_o = initial velocity (m/sec) = 0 m/sec, machine starts from rest.

$$\therefore T = \sqrt{\frac{2 \times X}{a}}$$

a. To get to the rotating ball-laden platter
   X_a = 15.00"+30.00"= 1.14 m
   T_a = 0.97 sec

b. To get to the mass-scoring bins
   X_b = 61.25"= 1.56 m
   T_b = 1.13 sec

c. To get to the rotating paddle stations
   Note to get to the rotating paddles you need to go almost straight from the starting point to the green ramp and then up the ramp. Length of the ramp = 21.00" at an angle = 15$^?$ ➔ distance traveled along the ramp = 21.00/cos(15$^?$)

   X_c = 27.00"+21.00"/cos(15$^?$)= 1.24 m
   T_c = 1.01 sec

d. To get to the time-stop buttons
   X_d = 27.00"= 0.69 m
   T_d = 0.75 sec

e. To get to the tunnels
   X_d = 30.00"+55.50"= 2.17 m

$T_d = 1.33$ sec

PROBLEM 2: Take the analysis from part one and consider the various scoring potentials. Do this by putting them face to face and sighting the advantages and disadvantages to reach the best strategy that will most likely win. Since it takes almost the same time to get to the various scoring locations, you should use the scoring algorithm to help determine the scoring potential of each design strategy.

Scoring Equation:

Score = Scoring Multiplier x [(Mass + 100 grams) x (Cumulative Rotation + 1 radian) + Discrete Points]

Study where each term comes from how to double it or make it x 100,000 and how will each term affect the final score. You are the designers now, so you are now free to decide what you want and where you want it while developing your individual ideas. Remember the term KISS, Keep It Super Simple. You don't want to end up with a great design that you don't know how to build or takes forever to build (time is money).

Here are three strategies:

(1) Move fast, score once, and block your opponent
(2) Move fast, score a lot and ignore/dodge your opponent
(3) Move as fast as possible with as much mass as possible to score big initially and then be free to score more, or go after your opponent

(Please note that various students might add up there own strategies and hence deserve extra credit)

Weighted Selection (Modified Pugh) Charts

A good procedure to compare various strategies is to use a weighted selection chart, also known as a Pugh chart. The goal of these charts is to identify a "best design" using a straightforward linear weighting scheme. The ability to select function requirements and place relative weights on a design based on analysis and risk assessment is a fundamental part of the design process and the basis of a successful machine. After selecting the best design, ideas from the other designs can be included in the best design to improve its score.

To create these charts, the following procedure can be used:

1) Perform analysis, brainstorming, and PREPs by the team members on the strategies. Revise strategies as necessary based on the PREP sessions.
2) Apply a desirability value or weight to each parameter that affects the performance of a component in a design. This weight should indicate the relative importance of each of the function requirements to each other. One design or strategy can be assigned all zeros as a baseline. The scores of the other designs are scored relative to this baseline.
3) Assess how well each strategy meets each functional requirement and "grade" each strategy using the following scheme:
   - ++ Much better than the baseline (datum) [+2]

+ Better than the baseline [+1]
0 Same as the baseline [0]
- Worse than the baseline [-1]
-- Much worse than the baseline [-2]

4) Add up the total score for each design or strategy. In a weighted selection chart, the total score should be the summation of (weight factor * the number of +/– scores for each function requirement) for each design. Numerical values can be used instead of +/- signs in spreadsheets.
5) If one design has a high score for one function requirement, this may identify a positive attribute in a competing design that can be blended into the best design.

Table 1 - Weighted Selection Chart with Baseline

Functional Requirement	Weight	Design 1	Design 2	Design 3	Design 4
Accuracy	3	0	+	0	+
Ergonomics	1	0	-	-	+
Cost	1	0	0	+	+
Flexibility	1	0	0	-	+
Robustness	2	0	+	-	-
Manufacturability	1	0	+	0	-
Serviceability	1	0	+	+	0
Total + and -		0	6	-2	3

Table 2 - Weighted Selection Chart without Baseline

Functional Requirement	Weight	Strategy A	Strategy B	Strategy C
Speed	1	++	++	0
Mass delivered	1	--	+	0
Opponent Score	1	++	--	+
Complexity of Design	2	-	-	+
Score	2	+	+	+
Total + and -		2	1	5

In Table 2, the analysis performed to create the selection chart suggests that Strategy C is the best strategy and will proceed to the next design step. Students are expected to explain how they reached the values they assigned in the chart through analysis or logical reasoning. Hence, selection charts from different members in a PREP group may choose different strategies as the best choice. Each choice is correct if the chart is logically explained in sufficient detail.

PROBLEM 3: After deciding on a strategy, assess the risks of how to deal with the opponent's strategy during the competition. There are many ways to answer this problem. A good method is to use a table that compares your strategy to your opponents.

Opponent Strategy

Own Strategy

Strategies	Strategy a	Strategy b	Strategy c
Strategy a	0	+	-
Strategy b	-	0	-
Strategy c	++	++	0

A score of zero when two same strategies are facing each other implies that competition is based on better mechanical designs, rather than different strategies. In this example, strategy C will be the best no matter what the opponent chooses as strategy.

Please see TA for questions or comments regarding this homework set or other 2.007 related matters.