Week 9 Tutorial

Tutorial Section

Tutorial Time

Tutorial TA Name

Tutorial Structure

- Introduction
- Question 1
- Problem Solving Framework
- Question 2
- Problem Solving Framework
- Q&A

Question 1

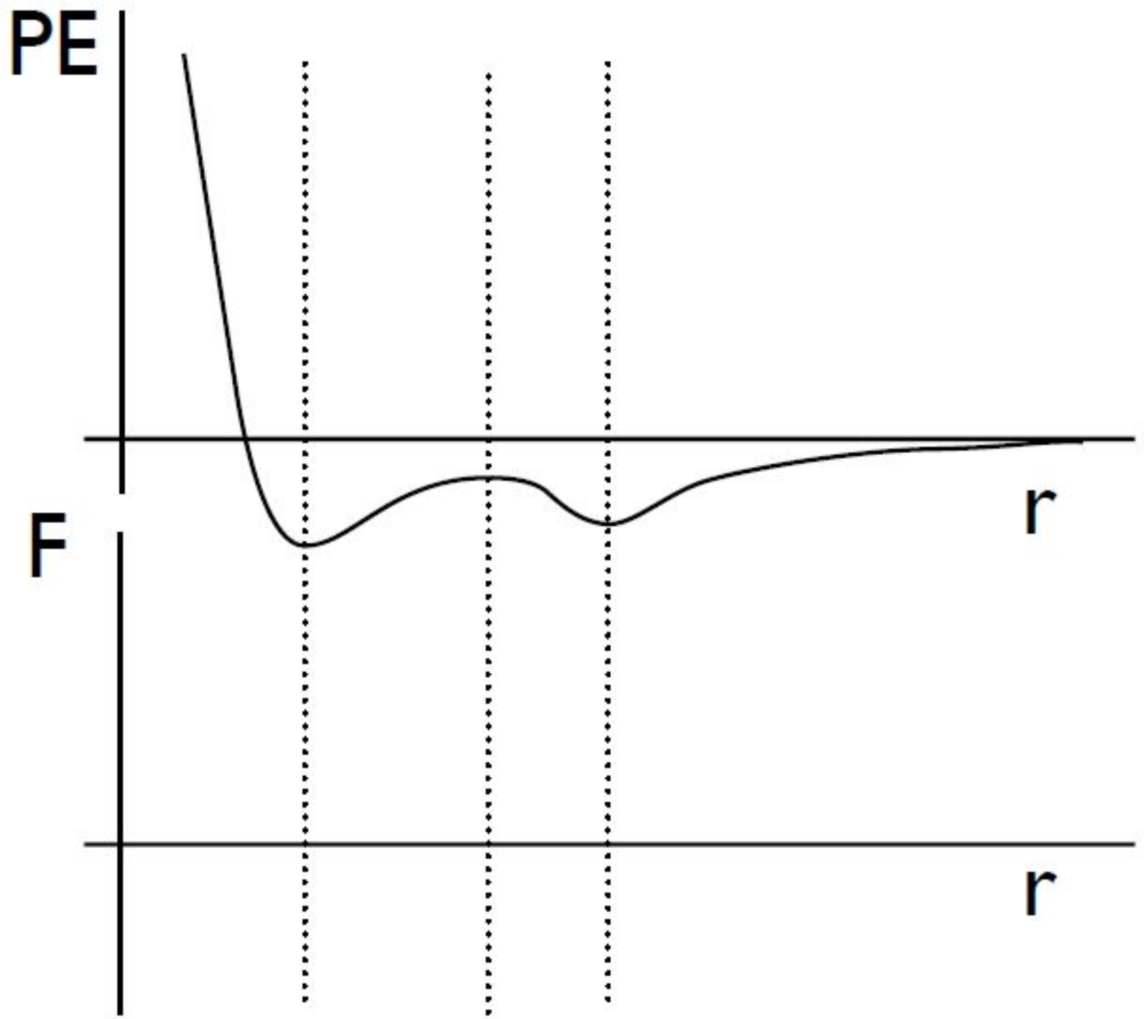

FIG. 1:

1. The potential energy of a particle in a conservative potential is shown in Fig. 1. Sketch the force diagram as a function of radius for this particle. Use the provided dashed lines to guide your diagram. /5

Problem Solving Framework

PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH **16,** 010123 (2020)

Template for teaching and assessment of problem solving in introductory physics

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1. Framing

- Visual Representation
- Assumptions and Simplifications
- Relevant Concepts
- Information Needed
- Similar Problems

2. Planning

- Solution Plan
- Rough Estimate

3. Execution

Carry-out Plan for solving
- Work in algebra/symbols until the BITTER end
- Plug in numbers at the LAST step

4. Answer Checking

- Compare to Estimate
- Units Check
- Limits Test
- Getting (UnStuck)

Reference: Template for teaching and assessment of problem solving in introductory physics

1. Framing

2. Planning

3. Execution

4. Answer Checking

1. Framing

- Visual representation: draw tangent lines to represent the slope at different r
- Assumptions and simplifications: NA
- Relevant concept: the relationship between potential energy vs conservative force
- Information needed: change of potential energy
- Similar problems: draw potential change with a given situation

2. Planning

- Rough estimate: By looking at how the potential energy changes you can estimate whether the energy is increasing or decreasing, and further determine whether the conservative force is positive/negative/0. (points where F=0 are already labelled)
- Solution plan: At different r, draw tangent line to estimate slope of PE vs r, then use $F=-d(PE)/dr$ to estimate the force; then connect all the dots with a smooth line.

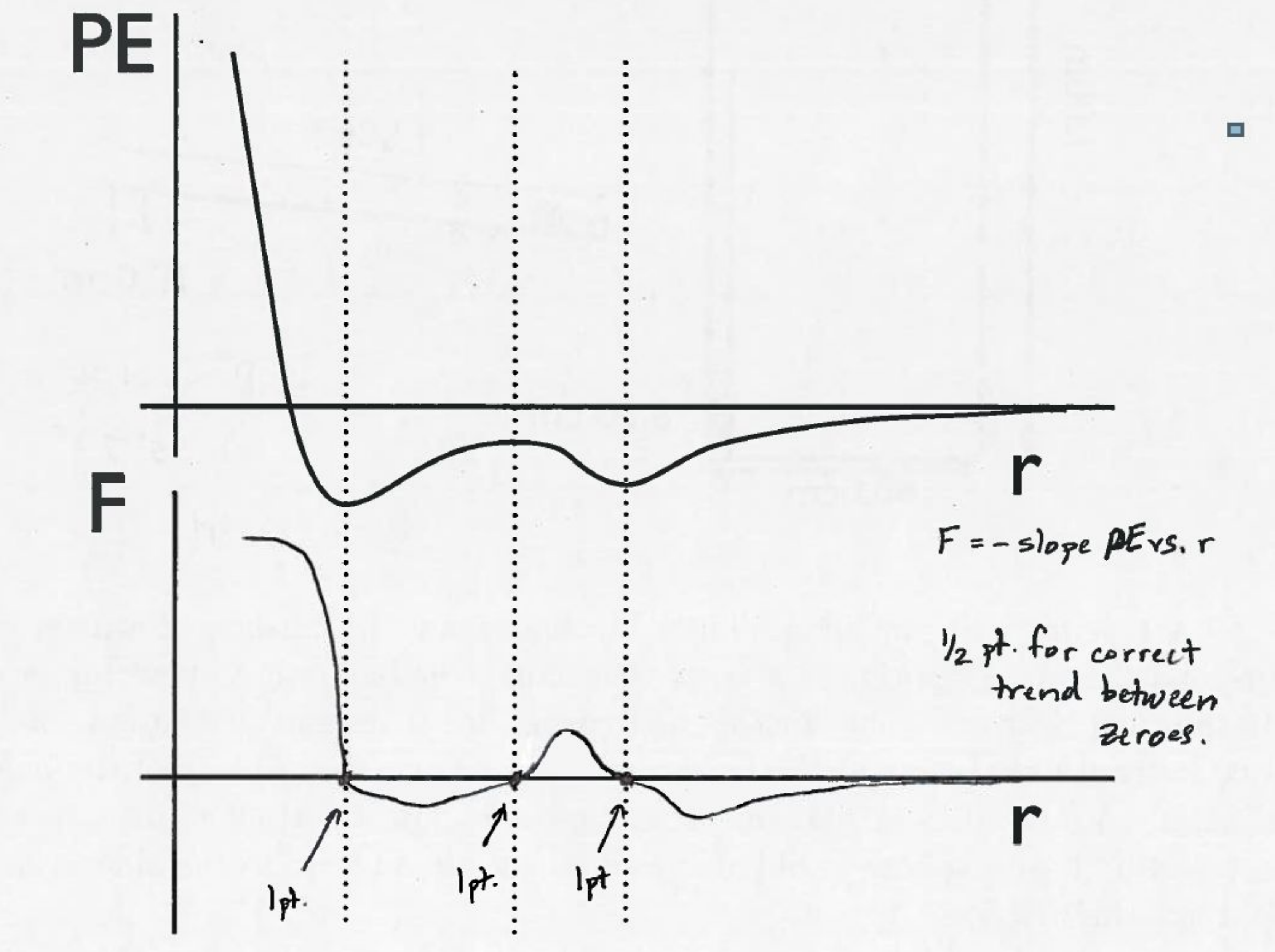
3. Execution

- See solution on slide 11

4. Answer Checking

- Compare to estimates: compare the force to your rough estimates
- Units: Add units to axes, if applicable
- Limits: Not applicable
- Getting (UnStuck)?

Solution



PE
r
F
r
F = - slope PE vs. r
1/2 pt. for correct trend between zeroes.
1pt.
1pt.
1pt

Question 2

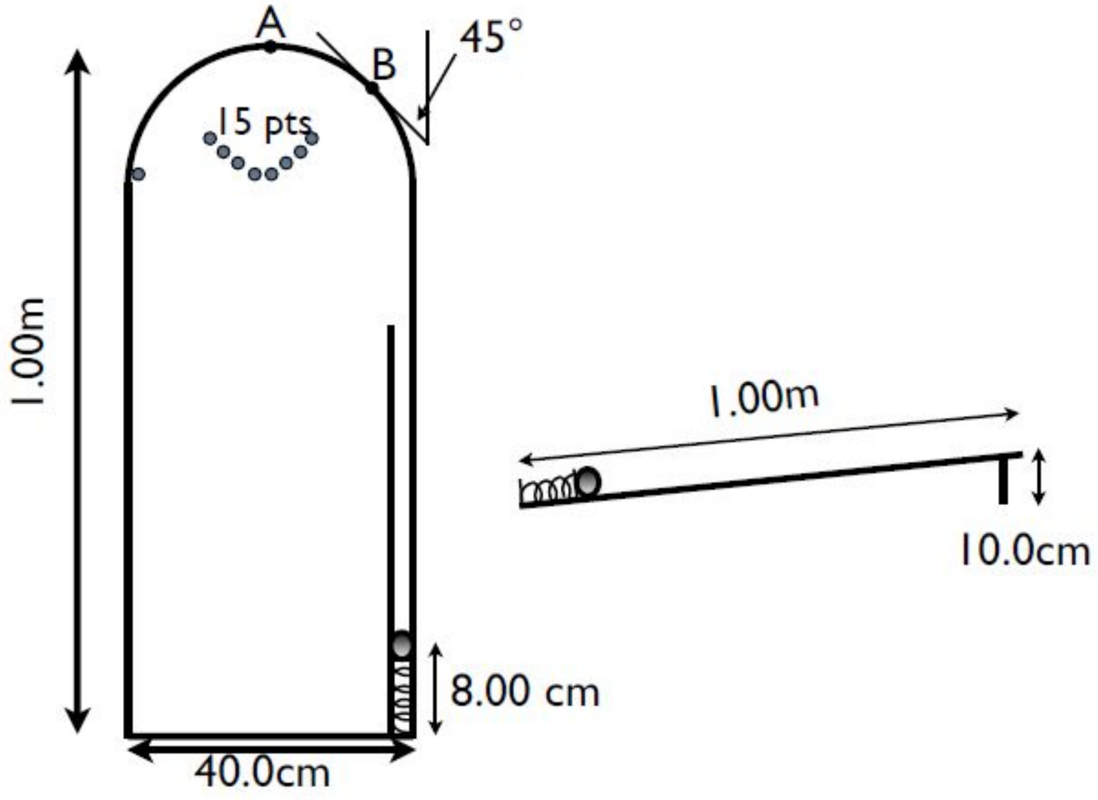
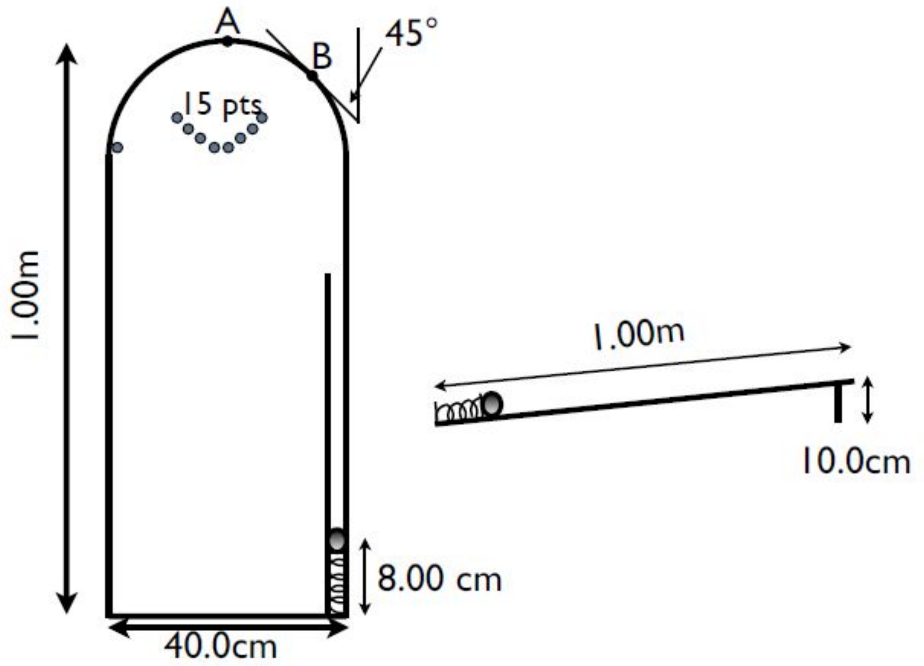


FIG. 2:

2. A precursor of pinball machines involved manually pushing down on a ball suspended atop of a spring in a track that allows the ball only to travel up a ramp as shown in Fig. 2. The unstretched spring has a length of 8.00 cm, over the 1.00 m length of the board the track rises by 10.0 cm, and the top of the board is circular, with a radius of 20.0 cm. Treating the ball as a particle of mass $m = 16.0$ g, (treating it as a sphere would give a small additional term to the kinetic energy) and ignoring friction,

(a) Write the free body diagram for the ball at the top of the loop (show only the rz axes), and use this to solve for the minimum speed required by the ball at this point for the ball to remain in circular motion at the top of its arc. /10

Question 2



(b) Can the normal force due to the walls of the track ever do work on the ball? Explain your answer. /3

(c) If the spring was initially compressed to a length of 3.00 cm prior to its release, and it had the minimum speed to remain in circular motion when it reached the top, find the value of the spring constant, k. /6

A ball leaving the wall at position B will land for 15 points.

(d) What value does the normal force (from the ends of the track) take at the point where the ball first leaves the wall? /1

1. Framing

2. Planning

3. Execution

4. Answer Checking

1. Framing

- Visual representation: think of the trajectory of the ball, draw FBDs
- Assumptions and simplifications: no friction considered
- Relevant concept: centripetal acceleration, FBDs, conservation of the energy
- Information needed: mass of the ball, trajectory of the ball
- Similar problems: FBD analysis, spring problems, calculation of potential energy

2. Planning

- Rough estimate: It’s going to be hard to roughly estimate this one without calculation. But a good start point is to read through the questions, think of the whole trajectory, and draw FBD if necessary.
- Solution plan: a) draw FBD and write down the equation for centripetal force, then solve for minimum speed; c) write down the equation for energy conservation the solve for the spring constant

3. Execution

- See solution

4. Answer Checking

Compare to estimates: NA

Units: confirm that you are using consistent units (i.e. N for forces and m/s for velocity, kg for mass) and check that your unit conversions are correct if there is any

Limits: test if the velocity is smaller than the minimum velocity required, would the ball still be able to remain circular motion?

Getting (UnStuck)?

Solution

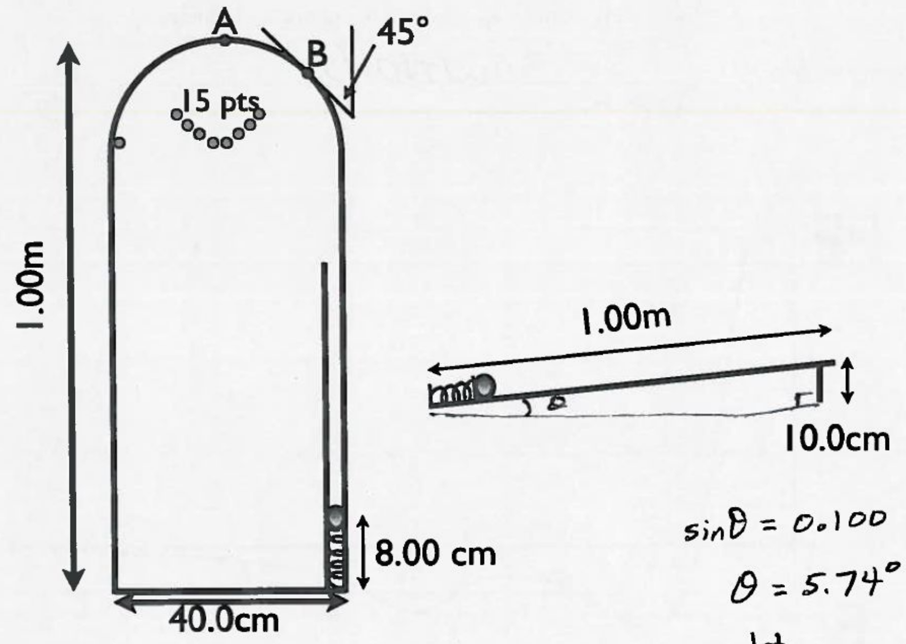


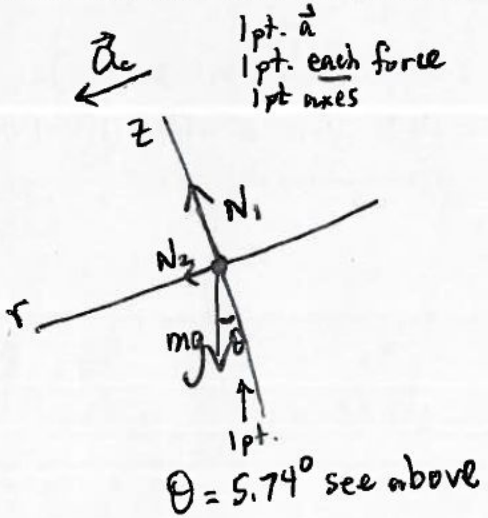
FIG. 2:

$\sin\theta = 0.100$

$\theta = 5.74^{\circ}$

1pt.

(a) Write the free body diagram for the ball at the top of the loop (show only the rz axes), and use this to solve for the minimum speed required by the ball at this point for the ball to remain in circular motion at the top of its arc. /10



$$\frac{mv^2}{r} \overset{\text{1pt}}{=} mg\sin\theta + \underbrace{N_2}_{\text{“} = 0 \text{” for the minimum speed.}}$$ 1pt.

$$v_{min}^2 = \underset{\substack{\uparrow \\ 9.80\,m/s^2}}{g}\;\underset{\substack{\uparrow \\ 0.200m}}{r}\;\underset{\substack{\uparrow \\ 5.74^{\circ}}}{\sin\theta} \Rightarrow v_{min} = 0.44\,m/s$$

1pt.

(b) Can the normal force due to the walls of the track ever do work on the ball? Explain your answer. /3

The ball moves parallel to the walls of the track, so no, the normal force due to the walls of the track cannot do work on the ball. 1pt.

The normal force and displacement are perpendicular 1pt.

$$W = \underbrace{F_{\parallel}}_{\text{parallel component to } \vec{d}} d = 0.$$ 1pt.

Solution

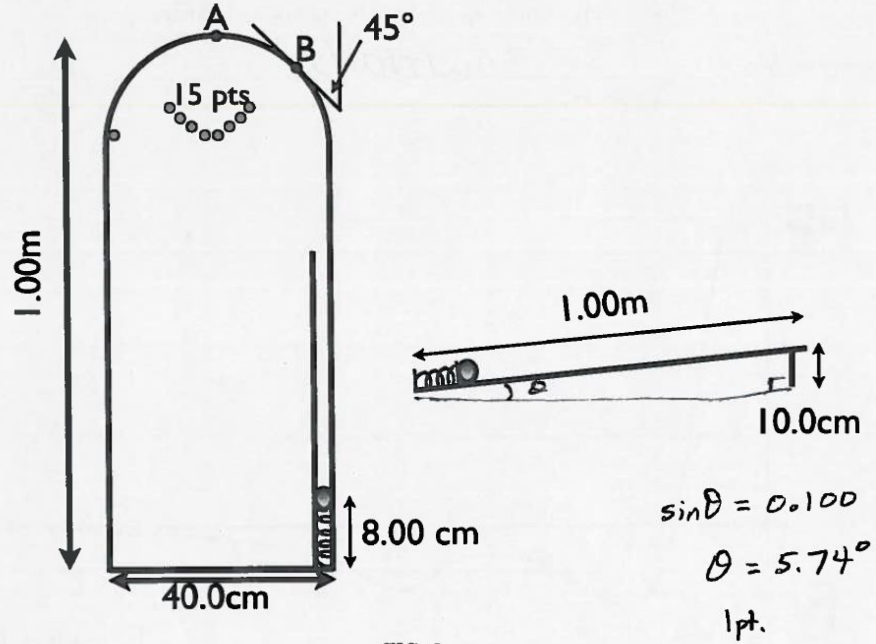


FIG. 2:

(c) If the spring was initially compressed to a length of 3.00 cm prior to its release, and it had the minimum speed to remain in circular motion when it reached the top, find the value of the spring constant, k. /6

$\Delta x = 0.05\,m$ from equilibrium

$$PE_{s_i} = \underbrace{\tfrac{1}{2}k(\Delta x)^2}_{(1pt.)} = KE_f + PE_{g_f} = \underbrace{\tfrac{1}{2}m v_{min}^2}_{(1pt.)} + \underbrace{mg\Delta h}_{(1pt.)}$$

$v_{min} = 0.44\,m/s$

$$\Delta h = (1.00m - 0.03m)\sin(5.74°) = 0.09m \quad (1pt.)$$

$$m = 0.0160\ kg$$

$$k = \frac{2}{(0.05m)^2}(0.0160kg)\left(\tfrac{1}{2}(0.44\,m/s)^2 + (9.8\,m/s^2)(0.09m)\right) \quad (1pt.)$$

$$= 12.5\,N/m \quad (1pt., consistent)$$

A ball leaving the wall at position B will land for 15 points.

(d) What value does the normal force (from the ends of the track) take at the point where the ball first leaves the wall? /1

The normal force will be zero wherever the ball first leaves the wall.