

# **The Problem Corner**

Ivan Retamoso, PhD, *The Problem Corner* Editor Borough of Manhattan Community College iretamoso@bmcc.cuny.edu

The Purpose of **The Problem Corner** is to give Students and Instructors working independently or together a chance to step out of their "comfort zone" and solve challenging problems. Rather than in the solutions alone, we are interested in methods, strategies, and original ideas following the path toward figuring out the final solutions. We also encourage our Readers to propose new problems. To submit a solution, type it in Microsoft Word, using math type or equation editor, however PDF files are also acceptable. Email your solution as an attachment to The Problem Corner Editor <u>iretamoso@bmcc.cuny.edu</u> stating your name, institutional affiliation, city, state, and country. Solutions to posted problem must contain detailed explanation of how the problem was solved. The best solution will be published in a future issue of MTRJ, and correct solutions will be given recognition. To propose a problem, type it in Microsoft Word, using math type or equation editor, email your proposed problem and its solution as an attachment to The Problem Corner Editor <u>iretamoso@bmcc.cuny.edu</u> stating your name, institutional affiliation, city, state, and country. The best solution will be published in a future issue of MTRJ, and correct solutions will be given recognition. To propose a problem and its solution as an attachment to The Problem Corner Editor <u>iretamoso@bmcc.cuny.edu</u> stating your name, institutional affiliation, city, state, and country.

Greetings, fellow problem solvers!

I'm happy to share that I've obtained answers for both Problem 18 and Problem 19. I'm pleased to report that not only were all the solutions accurate, but they also demonstrated the application of effective strategies. My primary objective is to present what I consider to be the best solutions to contribute to the enhancement and elevation of mathematical knowledge within our global community.



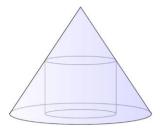
# SOLUTIONS TO PROBLEMS FROM THE PREVIOUS ISSUE

# Interesting "Cylinder inside Cone" problem

# Problem 18

Proposed by Ivan Retamoso, BMCC, USA.

What are the dimensions of the cylinder that can be placed inside a right circular cone measuring 5.5 feet in height and having a base radius of 2 feet to maximize its volume?



Note: Round yours answers to three decimals places.

# First solution to problem 18

# By Manvinder Singh, Borough of Manhattan Community College, India.

Our solver skillfully applies the essential relationship between the radius and height of the cylinder, along with the corresponding dimensions of the cone. This proportional connection is vital for placing the cylinder correctly inside the cone. Subsequently, our solver uses the derivative from Calculus to optimize the cylinder's volume.



# MATHEMATICS TEACHING RESEARCH JOURNAL241FALL 2023Vol 15 no 5

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| $\frac{dV}{dv_{ye}} = \frac{d}{dv_{ye}} \left[ \frac{\pi v_{oge}^{2} \left( 5 \cdot 5 - 2 \cdot 75 \cdot v_{ge}^{2} \right) \right]^{-1}}{dv_{ye}} \frac{dV}{dv_{ge}} = \frac{dv_{oge} \left( 5 \cdot 5 - 2 \cdot 75 \cdot v_{ge}^{2} \right) - 2 \cdot 75 \cdot v_{dv}}{dv_{oge}} \frac{dV}{dv_{oge}} = \frac{1}{2} \left( 11 \cdot v_{oge} - 8 \cdot 25 \cdot v_{oge}^{2} \right) \frac{dv_{oge}}{dv_{oge}} \frac{dV}{dv_{oge}} = \frac{1}{2} \left( 11 \cdot v_{oge} - 8 \cdot 25 \cdot v_{oge}^{2} \right) = 0}{\pi \tau} \frac{11 \cdot v_{oge}}{dv_{oge}} = \frac{8 \cdot 25 \cdot v_{oge}^{2} - 20}{v_{oge}} \frac{1}{2} \frac$ | sing this in the beight equation:<br>hype = S.S - 2.75 × 1.333<br>have = 1.83425<br>haye = 1.833 Just<br>anclusion:<br>re uplieder that marcinizes volume<br>uside the given care has a<br>adims of approximately 1.333 fet                                   |
| $\frac{dV}{drye} = \frac{d}{drye} \left[ \frac{\pi r_{0}^{2} q_{1} \left( 5 \cdot 5 - 2 \cdot 75 \cdot r_{0} q_{2} \right) \right]^{-1}}{drye} \frac{dV}{drye} \frac{dr_{0} q_{2} \left( 5 \cdot 5 - 2 \cdot 75 \cdot r_{0} q_{2} \right) - 2 \cdot 75 u}{drye} \frac{dV}{drye} = \pi \left( 11 \cdot r_{0} q_{2} - 8 \cdot 25 \cdot r_{0}^{2} q_{2} \right) \frac{dV}{dr_{0} q_{2}} \frac{dV}{dr_{0} q_{2}} = \frac{1}{r_{0}} \frac{dV}{dr_{0} q_{2}} \frac{dV}{dr_{0} q_{2}} = \frac{1}{r_{0}} \frac{dV}{dr_{0} q_{2}} \frac{dV}{dr_{0} q_{2} q_{2}} \frac{dV}{dr_{0} q_{2}} \frac{dV}{$   | anclusion the height equation:<br>have = 5.5 - 2.75 × 1.333<br>have = 1.83425<br>have = 1.833 fret<br>anclusion :><br>re affinder that marcinizes volume<br>uside the given care has a  |
| dV = 2 d [Trologe (S.S - 2.750 ge)]<br>druge druge (Trologe (S.S - 2.750 ge)]<br>dv = T (2rooge (S.S - 2.750 ge) - 2.750<br>druge<br>druge<br>dv = T (110 age - 8.250 ge)<br>druge<br>Set dV = 0:<br>druge<br>TT (110 age - 8.250 ge) = 0<br>TT (110 age - 8.250 ge) = 0<br>TT (110 age - 8.250 ge) = 0<br>TT (110 age - 8.250 ge) = 0<br>This gives us due solutions:<br>ruge = 0   ruge = 11<br>8.25<br>C  | sing this in the beight equation:<br>hype = S.S - 2.75 × 1.333<br>have = 1.83425<br>haye = 1.833 just<br>anclusion:<br>re uplieder that marcinizes volume<br>uside the given care has a<br>adius of approximately 1.333 fast<br>and a height of approximately |
| dV = 2 d [Trologe (S.S - 2.750 ge)]<br>drye drye (Trologe (S.S - 2.750 ge)]<br>dV = T (2rooge (S.S - 2.750 ge) - 2.750<br>drye<br>drye<br>drye<br>Set dV = 0:<br>drye<br>TT (110 age - 8.250 age) = 0<br>TT (110 age - 8.250 age) = 0<br>This gives us due solutions:<br>rage (11 - 8.250 age) = 0<br>This gives us due solutions:<br>rage = 0<br>rage =   | sing this in the beight equation:<br>hype = S.S - 2.75 × 1.333<br>have = 1.83425<br>haye = 1.833 Just<br>anclusion:<br>re uplieder that marcinizes volume<br>uside the given care has a<br>adims of approximately 1.333 fet                                   |

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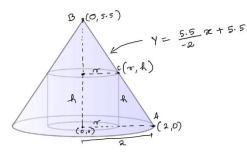


## Second solution to problem 18

# By Aradhana Kumari, Borough of Manhattan Community College, USA.

Our alternate solution is characterized by a meticulous attention to detail, a strong organizational structure, and a comprehensive justification for every step taken towards the ultimate solution. The sign of the second derivative is utilized to demonstrate that the volume of the cylinder reaches its maximum at the critical point.

Solution: Consider the picture below.



The equation of the line passing through the points

A (2,0) and B (0,5.5) is given as  $y = \frac{5.5}{-2} x + 5.5$ 

Since the point C (r, h) lies in the above line we have:

$$h = \frac{5.5}{-2} r + 5.5$$
  
$$h = -2.75 r + 5.5 \dots (eq 1)$$

The Volume V of a cylinder with radius r and height h is given as

$$V = \pi r^2 h$$

Substituting the value of h in the formula for volume of cylinder we get

$$V = \pi r^{2}(-2.75 r + 5.5)$$
  

$$V = -2.75 \pi r^{3} + 5.5 \pi r^{2} \dots (eq 2)$$

We differentiate equation given by (eq 2) with respect to r we get

$$\frac{dv}{dr} = -2.75 \pi (3r^2) + 5.5 \pi (2r) \dots (eq 3)$$

For Maxima or minima, we have  $\frac{dv}{dr} = 0$ 



i.e  $-2.75 \pi (3r^2) + 5.5 \pi (2r) = 0$ 

$$\pi r \left[ -2.75 \ 3r + 11 \right] = 0$$

Therefore, we have  $\pi r = 0$  or  $[-2.75 \ 3r + 11] = 0$ 

Since 
$$r \neq 0$$
 we have  $r = \frac{11}{8.25} \approx 1.33$ 

We differentiate equation given by (eq 3) we get

$$\frac{d^2v}{dr^2} = -2.75 \pi (6r) + 5.5 \pi (2) \dots (eq 4)$$

Substituting the value of  $r = \frac{11}{8.25}$  in the equation given by (eq 4) we get

$$\frac{d^2 v}{dr^2} = -2.75 \pi (6 \times \frac{11}{8.25}) + 5.5 \pi (2)$$
$$= -22\pi + 11 \pi$$
$$= -11\pi < 0$$

Hence  $r = \frac{11}{8.25}$  is a point of maxima.

Substituting the value of  $r = \frac{11}{8.25}$  in the equation given by h = -2.75 r + 5.5We get  $h = -2.75 \left(\frac{11}{8.25}\right) + 5.5 \approx 1.83$ 

Therefore, radius of the required cylinder is  $r = \frac{11}{8.25} \approx 1.33 ft$ Height of the required cylinder is  $h = -2.75 \left(\frac{11}{8.25}\right) + 5.5 \approx 1.83 ft$ 

#### "Largest cord in a circle" problem.

#### Problem 19

Proposed by Dr. Michael W. Ecker, (retired) Pennsylvania State University, USA.

Prove that the diameter of a circle is the largest possible size of a chord of said circle.

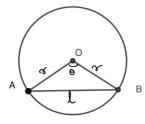


## First solution to problem 19

# By Aradhana Kumari, Borough of Manhattan Community College, USA.

Without loss of generality, our solver cleverly positions a cord of the circle with arbitrary length "horizontally" and finds its length in terms of a central angle and the radius of the circle. Finally, using the derivative from Calculus our solver maximizes the length of the cord, showing that it is indeed equal to the diameter of the circle.

Solution: Consider below Circle C with center O and radius r. Let AB be a chord of length *l*.



Let  $\angle AOB$  be  $\theta$ 

Using Cosine rule we have:

 $l^{2} = r^{2} + r^{2} - 2r^{2} \cos \theta, \quad 0 < \theta < 360^{\circ}$  $l = \sqrt{r^{2} + r^{2} - 2r^{2} \cos \theta} = \sqrt{2r^{2} - 2r^{2} \cos \theta} = \sqrt{2r^{2}(1 - \cos \theta)} = \sqrt{2r^{2}} \sqrt{(1 - \cos \theta)}$ 

Differentiate both side with respect to  $\theta$  we get

$$\frac{dl}{d\theta} = \sqrt{2r^2} \times \frac{1}{2} \times (1 - \cos\theta)^{-1/2} \sin\theta$$

For maxima and minima, we equate  $\frac{dl}{d\theta} = 0$ 

$$\sqrt{2r^2} \times \frac{1}{2} \times (1 - \cos\theta)^{-\frac{1}{2}} \sin\theta = 0$$
$$\sqrt{2r^2} \times \frac{1}{2} \frac{\sin\theta}{\sqrt{(1 - \cos\theta)}} = 0$$

Hence  $Sin \theta = 0$ ,

$$\theta = 180^{\circ}$$

$$\frac{d^{2}l}{d\theta^{2}} = \frac{d}{d\theta} \left( \sqrt{2r^{2}} \times \frac{1}{2} \times \left( 1 - \cos \theta \right)^{-\frac{1}{2}} \sin \theta \right)$$

$$= \frac{\sqrt{2r^{2}}}{2} \left( \left( 1 - \cos \theta \right)^{-\frac{1}{2}} \cos \theta + \left( \sin \theta \left( \left( \frac{-1}{2} \right) (1 - \cos \theta)^{-3/2} \sin \theta \right) \right) \right)$$

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When  $\theta = 180^{\circ}$  we get

$$\begin{aligned} \frac{d^2l}{d\theta^2} &= \frac{\sqrt{2r^2}}{2} \left( (1 - \cos 180^\circ)^{-\frac{1}{2}} \cos 180^\circ \\ &+ \left( \sin 180^\circ \left( (\frac{-1}{2})(1 - \cos 180^\circ)^{-3/2} \sin 180^\circ \right) \right) \right) \right) \\ &= \frac{\sqrt{2r^2}}{2} \left( (1 - \cos 180^\circ)^{-\frac{1}{2}} \cos 180^\circ \right) \\ &= \frac{\sqrt{2r^2}}{2} 2^{-1/2} (-1) < 0 \qquad (r > 0) \\ \frac{d^2l}{d\theta^2} < 0 \end{aligned}$$

Hence  $\theta = 180^{\circ}$  is a point of maxima.

Substituting the value  $\theta = 180^\circ$  in below equation we get

$$l = \sqrt{r^2 + r^2 - 2r^2 \cos 180^\circ}$$
$$l = \sqrt{r^2 + r^2 + 2r^2}$$
$$= \sqrt{4r^2}$$
$$= 2r$$

= diameter of the Circle C.

Hence diameter of the circle is the largest possible chord of said circle.

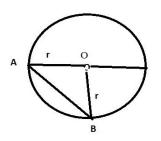
# Second solution to problem 19

# By Dr. Michael W. Ecker (The proposer) (retired) Pennsylvania State University, USA.

The proposer's solution takes a distinct approach, omitting the use of Calculus. Instead, it capitalizes on an essential condition regarding the lengths of a triangle's sides, specifically, that the length of one side cannot be greater than the sum of the lengths of the other two sides.

Typical chord *AB* is shown in circle *O*. If *AB* is not a diameter, then drawing radii *AO* and *BO* results in a triangle, *AOB*. The length of *AB* then is smaller than the sum of the lengths of the two other sides of triangle *AOB*. Those two sides have a total length of twice the radius, or 2r = d.





Hence, AB < d, as claimed. (Note: It does not matter how you draw AB. It's the argument, the proof, that matters here.)

#### **NEW PROBLEMS**

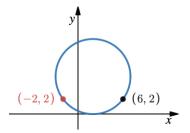
Dear fellow problem solvers,

I am confident that the resolution of problems 18 and 19 not only provided you with enjoyment but also granted valuable insights. Now, let's progress to the next two problems to continue this journey of exploration and learning.

#### Problem 20

Proposed by Ivan Retamoso, BMCC, USA.

Find the radius and the equation of the circle shown below.



#### Problem 21

Proposed by Ivan Retamoso, BMCC, USA.

Solve the equation below to find all real numbers *x* that satisfy:

$$\frac{8^x + 27^x}{12^x + 18^x} = \frac{7}{6}$$