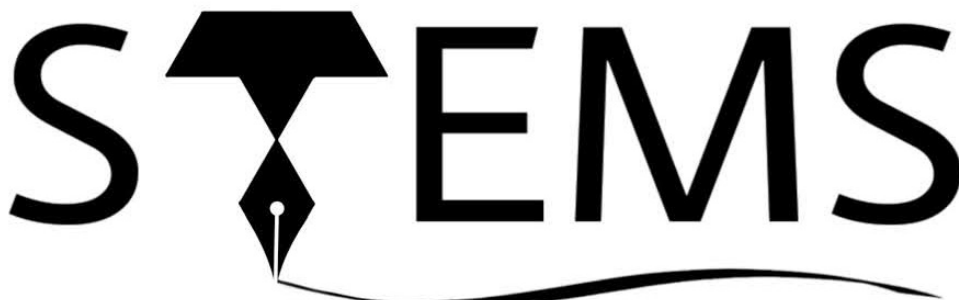




TESSELLATE PRESENTS



Scholastic Test of Excellence in Mathematical Sciences

## Physics Category A

Exam Date : 16th December, 2023  
Exam Timing : 9:00 AM IST - 12:00 PM IST



# Rules and Regulations

## Marking Scheme

1. The question paper contains **ten** questions, **eight** multiple choice type objective questions (**Part A**), and **two** subjective questions (**Part B**).
2. Each objective question has a single correct option as the answer.
3. For each objective question, **4 marks** is given for the correct answer, **0 marks** is given for no attempt, and **-1 marks** is given for an incorrect answer. Each subjective question is worth **20 marks**.
4. A candidate's submission for the **Part B** of the exam will be checked only if they are in the top 25 candidates for **Part A**.
5. Time duration is **3 hours: 9:00 AM IST - 12:00 PM IST**.  
Submit your answers on the Google form given below by **12:20 PM IST**.

## Miscellaneous

1. Use the google form: <https://forms.gle/aUoQsTj2CDrSe3sL6> , to submit your answers.
2. For **Part B**, you can either LaTeX or handwrite your solutions neatly.  
Submit a PDF file (either scanned or LaTeXed) **ONLY**. No other form of file submission will be accepted. Name your file "**physics.rollnumber**" (here rollnumber is the last 5 digits of the Transaction ID generated at the time of registration).
3. Make sure to keep the file size below the 10 MB limit. You can use online file compression services in case your file size exceeds 10 MB.
4. Use a good application to scan handwritten text into PDF. Kindly make sure that the answers are legible and that your furniture or flooring is not a part of the submission.
5. Solutions should be brief and should contain all the necessary details. Ambiguous or illegible answers will not gain credits. If you strike something out, strike it out properly so that it is clear to the evaluator what you want to be read. Please avoid overwriting your answers.
6. Do **NOT** post/share the questions appearing in the contest on any forums or discussion groups while the contest is live. It will result in immediate disqualification of involved candidates when caught.
7. Answers should be your own and should reflect your independent thinking process. Any form of plagiarism or failure to comply with the aforementioned regulations may lead to disqualification.
8. Responses to the google form will not be accepted after the time is up.

## Contact details

- For subject related queries, clearly mention your **category (A)** in the mail or WhatsApp text.
- For **subject related** queries, contact:
  - Official email ID: [stemsphysics2024@gmail.com](mailto:stemsphysics2024@gmail.com)



- Vedant Neema  
Email : **vedantn@cmi.ac.in**  
WhatsApp: +91 91658 06588
- Ananya Ranade  
Email: **ananyar@cmi.ac.in**  
WhatsApp: +91 95189 24237

**Note:** Use the personal emails only if the official email is unreachable. Use WhatsApp only if absolutely necessary, otherwise email is preferred.

- For **technical** queries, contact:
  - Official email ID: **tessellate.cmi@gmail.com**
  - Siddhant Shah  
Email: **siddhants@cmi.ac.in**



# Questions

## Part A

1. [4 marks] Anne, who uses +5D power (biconvex lens) spectacles, has decided to start attending swimming lessons. She wants to be able to see clearly underwater as well so she asks an optician to put lenses into her swimming goggles. What must be the power of these lenses?

$$n_{water} = 1.3, n_{glass} = 1.5, n_{air} = 1$$

Options: (a) 0.65 D (Correct) (b) 0.35 D (c) 0.45 D (d) 0.55 D

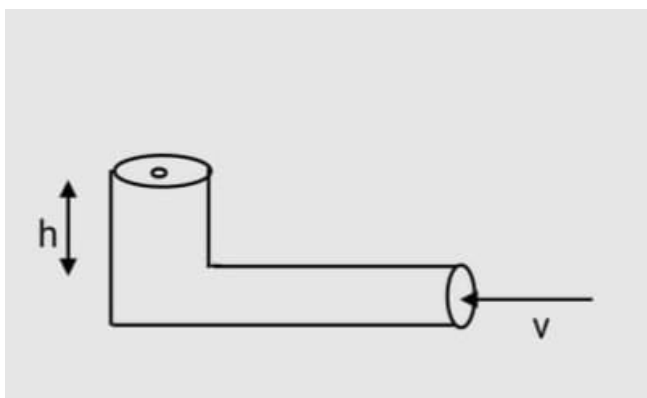
2. [4 marks] Which of these is false?

Options:

- (a) Sound waves don't create a net displacement on air. The air pressure acts as a restoring force.  
(b) Waves on the water surface don't create a net displacement of water. The surface tension and gravity act as restoring forces.  
(c) Sound is capable of transporting energy from one point to another.  
(d) Sound creates a net displacement on air. There is no restoring force. (Correct)
3. [4 marks] A uniform resistance wire ( $1\Omega$ ) of length 1m is given.  $k_n$  is a configuration formed by breaking the wire into  $n$  parts, forming circles of each wire and then joining them in parallel. What is the equivalent resistance of  $k_n$ ?

Options: (a)  $\frac{1}{4}$  (b)  $\frac{n^2}{4}$  (c)  $\frac{1}{4n}$  (d)  $\frac{1}{4n^2}$  (Correct)

4. [4 marks] Devon is playing with an object which his father made for him, shaped as below with a small hole on the closed upper end. He holds it underwater in a stream where the velocity with respect to the tube is  $v = 20m/s$ . What is the maximum height from the hole in the closed upper end to which the water spurts out? In the figure,  $h = 10m$  and  $v = 20m/s$ .  $g = 10ms^{-1}$





Options: (a) 20 m (b)  $20\sqrt{2}$  m (c) 10 m (Correct) (d) 40 m  
(Edited)

5. [4 marks] Which of the following are false?
- (i) When a real image is formed by a lens on a piece of cardboard, the cardboard may catch fire.
  - (ii) Either the side-view mirror or the mirror in the headlights of a car serves as a magnifier.
  - (iii) Using a single lens is more advantageous than using a combination of lenses with the same equivalent focal length.
  - (iv) The focal length of a biconvex lens is inversely proportional to the refractive index of the medium it is in.

Options: (a) (i), (iii), (iv) (b) (ii), (iii), (iv) (c) (iii), (iv) (Correct) (d) (ii), (iv)

6. [4 marks] Suppose there are  $N$  particles in a 3-dimensional box of length  $a$  ( $[0, a] \times [0, a] \times [0, a]$ ). We can divide this cube into smaller cubes of side length  $a/k$ . Putting  $k=3$ , you would find that the divisions on the cube would make it look like a standard Rubik's cube. What is the probability that the  $N$  particles are all in only one of these smaller cubes?

Options: (a)  $1/k^N$  (b)  $3^k/k^{3N}$  (c)  $3^k/k^N$  (d)  $3^k/N^3k$

(Question was skipped from grading because it wasn't clear if you needed to calculate the value for  $k=3$ . The original solution for  $k=3$  is (b).)

7. [4 mark] In pitch darkness, a car's headlights can illuminate a distance of 40m away. What is the maximum speed at which the car can drive so that it can come to a safe stop on seeing some obstacle in front, given the maximum deceleration of the car is  $5\text{m/s}^2$ ?

Options: (a) 25m/s (b) 40m/s (c) 30m/s (d) 20m/s (Correct)

8. [4 marks] A block of iron at  $60^\circ\text{C}$  is kept in contact with a block of gold at  $15^\circ\text{C}$ . Assuming heat is conserved between the blocks, find the equilibrium temperature. Heat capacity of Iron =  $450\text{ J/kg}^\circ\text{C}$ , and of Gold =  $130\text{ J/kg}^\circ\text{C}$ .

Options: (a)  $45^\circ\text{C}$  (b)  $50^\circ\text{C}$  (Correct) (c)  $37.5^\circ\text{C}$  (d)  $25^\circ\text{C}$



## Part B

1. [20 marks] Micheal jumps off a building of height 381m with a parachute. His speed when the parachute is deployed is 8m/s. Describe strategies to maximize and minimize the time required to reach the ground and calculate the time it takes.

### *Solution*

Maximise: wait till falling speed is 8m/s, then open parachute.

The wait is 0.8s in time or 3.2m in distance from the top. It takes a total of 38.58s to fall if g is assumed to be 10m/s<sup>2</sup>.

Minimize: Free fall with it taking 8.729s for g=10m/s<sup>2</sup>.

2. [20 marks] A bow is stretched back with a force F. Model the bowstring as two springs, both of spring constant k and natural length l, from the middle to the ends of the support. The bowstring is pulled a distance of x back with an arrow of mass  $m_a$  and released. Find the expression for the velocity of the arrow as a function of x.

(Edited)

### *Solution*

Here, F is a redundant variable. So multiple expressions are correct.

$$F = 2k(\sqrt{l^2 + x^2} - l) \frac{x}{l^2 + x^2}$$

$$v = \sqrt{\frac{2k}{m_a}(\sqrt{l^2 + x^2} - l)}$$

$$= F \sqrt{\frac{1}{4km_a} \left(1 + \frac{l^2}{x^2}\right)}$$

**END OF QUESTION PAPER**