cmi TESSELLATE PRESENTS 

STEMS

Scholastic Test of Excellence in Mathematical Sciences

Physics Category A

Exam Date : 25th January 2020
Exam Timing : 4pm - 7pm

Rules and Regulations

Marking Scheme

1. The question paper is divided in two parts -
   Objective (10 questions) + Subjective (3 questions).
2. Each objective question is worth **2 points**.
3. Each subjective problem is worth **10 points**.
4. There is no negative marking in any section.
5. **The subjective part will be graded only if you score above a certain cut-off (to be decided later) in the objective section of the paper**.
6. **For the final score, your total score (subjective + objective) will be taken into consideration.**

Solution guidelines

1. You are **NOT** required to show your work for the objective part of the paper.
   Only tick your option choices in a tabular format drawn on a blank sheet.
   A sample is shown below.

Q. No.	(a)	(b)	(c)	(d)
1		✓		
2			✓	
3		✓		
4	✓			
5				✓

Fig. - Sample objective answer submission

2. Provide a complete solution/proof for subjective questions. The solutions must be correct, original, detailed and clearly understandable for full credit.
   Partial credit might be awarded to incomplete proofs, based on the progress made towards solving the problem.
3. Draw clear, well-labeled diagrams wherever necessary.

Miscellaneous

1. Answers should be your own and should reflect your independent thinking process.
2. Do **NOT** post the questions on any forums or discussion groups. It will result in immediate disqualification of involved candidates when caught.
3. Answers should be written clearly, in a legible way. Formal proofs are required wherever asked for. Unclear reasoning might not be awarded points, draw clear diagrams wherever necessary.
4. Sharing/discussion aimed towards solving or distribution of problems appearing in the contest while the contest is live in any kind of online platform/forum shall be considered as a failure in complying with the regulations.
5. Any form of plagiarism or failure to comply with aforementioned regulations may lead to disqualification.

Contact details - ONLY for subject related queries

- Please do not call these people for technical problems or submission inquiries.
  Only if you find an ambiguity in a question and need clarification, use these contacts.
- As our phone numbers will be busy, **we prefer WhatsApp & email queries** instead. Only call us if absolutely necessary.
- Try to solve all your submission related doubts from information in the next page ONLY. We have included all details in the next section.

Sriram Akella - 7995855349	Prasanna Venkatesan - 9791310069
Query email - stems.2020.enq.phy@gmail.com	

- **Do NOT call any number to ask if your submission has reached us.**
  If you send your submission to the right email address with mentioned details, we will receive it. We will contact all participants who fail to submit, so please be patient.

How to submit your answers

1. Write the following details **as per your registration** on the first page of your submission file/photographs -

Name	:	Your full name
School/College name	:	
Class/Year of Study	:	Class 8, Class 11, Undergrad 1st year etc.
Registered Email address	:	
Mode of S.T.E.M.S. Registration	:	Online / Through School / Other (mention details)

2. Write all your answers on sheets of paper, following all the solution guidelines. Write the page number in the top right corner of every sheet.

3. Scan your answers or take clear photographs of your response sheets. Compile them into a single PDF file or send all pictures in the right sequence.

   If you have a limited file size issue when sending your submission, make a new Google Drive folder with title '**Your Name - Physics A submission**'.

4. Send the submission file or Google Drive link from your registered email -

Submission email address	:	**stems.2020.phy.a@gmail.com**
Subject of email	:	Physics Category A Submission - STEMS
Submission deadline	:	25th January 2020 - 19:00

Good luck, happy problem-solving!

Objective Questions

For **Problems 1-10**, each problem has **four** options, namely **(a), (b), (c), (d)**, of which ***only one*** is correct, **2 point** will be awarded for correctly answering a problem, **NO** negative marks shall be awarded for wrong answers/unattempted problems.

Problem 1. *A sphere has a mass $m_1 = 105$ grams when in air. When totally sunken in water, its apparent weight becomes $m_2 = 99$ grams. Determine the volume of the hollow part of the sphere. Assume density of material of the sphere is 21 g/cm^3 and density of water is 1 g/cm^3.*

(a) *1 cm^3*

(b) *2 cm^3*

(c) *3 cm^3*

(d) *4 cm^3*

Problem 2. *A tuning fork A is being tested against an accurate oscillator. It is found that they produce 2 beats per second when the oscillator reads 518 Hz and 6 beats per second when it read 510 Hz. The time period of the tuning fork (in milliseconds) is (upto 4 decimals without rounding off):*

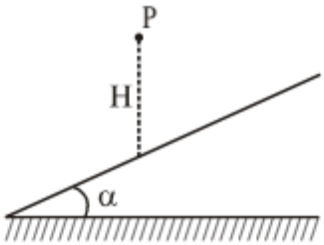
(a) *1.9531*

(b) *1.9455*

(c) *1.9379*

(d) *1.9607*

Problem 3. *Consider an inclined plane with inclination angle $\alpha \in (0, \pi/2)$. A point P is vertically above height H of the inclined plane. Beads are released in all possible directions from point P along friction-less straight wires. One of the beads reaches the inclined plane in minimum time. The minimum time is*



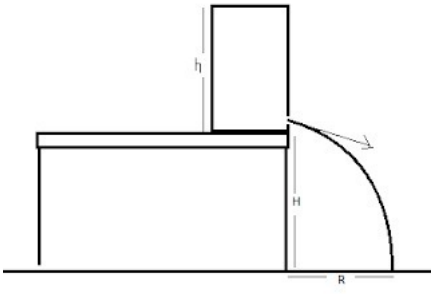
(a) $\sec\left(\frac{\alpha}{2}\right)\sqrt{\frac{2H\cos\alpha}{g}}$

(b) $\sec\left(\frac{\alpha}{2}\right)\sqrt{\frac{2H}{g}}$

(c) $\sqrt{\frac{2H\cos\alpha}{g}}$

(d) $\sqrt{\frac{2H}{g}}$

Problem 4. *A large tank filled with water to height h is placed on the top of a table of height H. It is placed on the edge of the table and is emptied through a tine tiny hole at bottom (to the side). Find the distance (R, as shown in the figure) from the table to the point where water touches the ground as a function of h and H.*
(Hint : Use Bernoulli's equation)



(a) $R(h) = \sqrt{hH}$

(b) $R(h) = 2\sqrt{h+H}$

(c) $R(h) = 2\sqrt{hH}$

(d) *None of these*

Problem 5. *A point source of light is placed at the bottom of a transparent fluid pool of refractive index μ. The height of the pool is h. Find the area of the illuminated region on the surface of the pool. It's given that atmosphere above the pool has refractive index unity.*

(a) $\pi h^2(\mu^2 - 1)$

(b) $\pi \frac{h^2}{\mu^2 - 1}$

(c) $\pi h^2 \sqrt{\mu^2 - 1}$

(d) $\pi \frac{h^2}{\sqrt{\mu^2 - 1}}$

Problem 6. *Astronomers have recently discovered a planet similar to Earth but where the density of the atmosphere is ρ is the same as that of Steel. The gravitational acceleration near the surface of this planet is g. Suppose a Steel ball near the surface of the planet is given a velocity v in any direction. What is the trajectory of the particle?*

(a) *Parabola*

(b) *Hyperbola*

(c) *Circle*

(d) *Straight Line*

Problem 7. *Three point objects of mass m are placed on three corners of a hypothetical square of side l. Another point object of mass M is placed at the center of the square. The gravitational force it experience is*

(a) $\frac{G(3m+M)M}{l^2}$

(b) $\frac{GmM}{2l^2}$

(c) $\frac{GmM}{l^2}$

(d) $\frac{2GmM}{l^2}$

Problem 8. *What speed (appx.) must be given to a* 2020 *kg block of ice at rest on a rough horizontal surface for the ice to completely melt when it comes to rest? Assume that the temperature of the ice block and the water is always* 0^oC*. The specific latent heat of ice is* $3.36 \times 10^5\ J/kg$*. Neglect all other effects.(Assume that all the Kinetic energy is converted into heat)*

(a) *410 m/s*

(b) *820 m/s*

(c) *580 m/s*

(d) *None of these*

Problem 9. *A set of point objects are placed in a straight line on a floor in the order of masses* $\langle \frac{m}{k} \frac{m}{k^2} ... \rangle$ *(k is a finite real number greater than 1) from left to right with distance,* $d = 1$ *between them. Now, another point object of mass m moving along the straight line of the point masses towards right, collides the leftmost mass(*$\frac{m}{k}$*) at a velocity v perfectly inelastic. Find the speed with which the mass system moves as time tends to infinity.*
A perfectly inelastic collision is when the colliding objects stick together and the momentum is conserved.

(a) $\frac{v}{k}$

(b) $\frac{vk}{k-1}$

(c) $\frac{v(k-1)}{k}$

(d) v

Problem 10. *When ultrasonic waves travel from air to water:*

(a) *The frequency changes*

(b) *We get sonic boom*

(c) *Speed of ultrasonic waves is greater in water than in air*

(d) *Speed of ultrasonic waves is lesser in water than in air*

Subjective Problems

Problem 1.

A Tessellation in 2-D is tiling whole of a plane using geometric shapes(called tiles) with no overlapping and no gaps. Such a Tessellation is called regular if all tiles are congruent to a regular polygon.

i. *Find all such possible regular polygons for which a regular tessellation is possible.[Let's call this set of polygons as set* ***P****]*

ii. *Compute the ratio of time periods (with ratios in ascending order) for a particle moving with constant speed on shapes belonging to set* ***P****. It's given that all the shapes in set* ***P*** *have the same side length.[Time period is defined as time required for the particle to complete one revolution around a closed shape]*

Problem 2. *Find the field of view (locus of points in space which are visible in mirror) for an observer, who is present at a perpendicular distance d, directly above the center of circular mirror of radius r. Also find the area of visibility at each distance z from the mirror. Generalise the results to scenarios where the mirror is of arbitrary planar shape and observer being at an arbitrary point in space.*
(Note: Both synthetic and coordinate presentations are accepted)

Problem 3. *Let's say we place a thin bi-convex lens of focal length f at the origin of $x-y$ plane with principal axis being the x axis. Find the image function (g_{im}) of the function g, where*

$$g(x) := ax + 2af \quad (a \in \mathbb{R}, -3f < x < -f)$$

.
By image function we mean, for each x find the coordinates of image of object placed at coordinates $(x, g(x))$. Make necessary approximations.