Indian Institute of Science Education and Research, Tirupati

ABHIPRAJNA 2023 (Prelims)

PHYSICS QUESTION PAPER

Date: September 17, 2023 Maximum points: 30

Instructions:

- *All questions are mandatory*
- *The question paper consists of 10 questions in total, spread over 5 pages.*
- *Answers must be written in legible and readable handwriting, failing which that question shall not be considered for evaluation.*
- *The participant is free to google any facts they are unsure about.*
- *Attempt any 2 of 3 questions in Section-B.*
- *Mention clearly all assumptions you are making and all constants you are using.*
- *The question marked with $*$ is the hint question. The answer to that question is a solution for the puzzle round.*
- *The form for submitting your responses is the following https://forms.gle/mVtpDUXXQuUPC1Rt8*

SECTION-A

1. **(3 points)**

   Give a basic outline of the physics of a Banana Kick (Football). Where else do you see similar physics play out?

2. **(4 points)**

   You are buying a single slit diffraction pattern apparatus. However, the screen is a chartpaper which is rolled up. When you try to make it stand, the chartpaper is curved, such that when looking from the top, it looks like a Parabola. You perform the experiment anyways with a deformed screen, with the light source in the interior of the parabola. Describe the pattern on this parabolic screen.

3. **(3 points)**

In a recent book called the Trees of the Emerald Sea, Brandon Sanderson came up with a new world where the sea is made of magical pollen, which behaves like a normal sea under certain conditions and behaves like a desert sand under other conditions. In a collaboration with the Youtuber Mark Rober, he justified his world as plausible by relating the Emerald Sea to a Fluidized Air Bed

Assuming the planet is earth sized, what is the expected force exerted by the gas for a lake made of pollen of density 15 g/cm^3, similar to the Dead Sea, to behave like water. Make your necessary assumptions and justify them.

4. **(2 points)**

$*$ How many degrees of freedom are possible for a rigid body in d-dimensions?

5. **(2 points)**

A ball of mass 1 kg is thrown vertically upward and it faces a quadratic drag with a terminal velocity of 20 m/s. It reaches a maximum height of 30 m and falls back to the ground. Find the initial velocity by which the ball was projected.

6. **(4 points)**

A coin (disc) of variable surface density given by $\sigma(r, \theta)$= kr^{2}sin $\frac{\theta}{2}$ is tossed in a planet where the acceleration due to gravity varies more fast than that on earth and is given as g= g$_o$e$^{\frac{h}{k}}$ (k= -1m) where g_o is the acceleration due to gravity on earth and h is the vertical distance of the coin from ground. It is tossed with initial velocity 30 m/s with heads showing up. What will be the outcome of the coin toss when it strikes the ground assuming the whole planet is a mud cluster (the coin comes fully to rest when it strikes the ground).

(Radius of coin= 2 mm, Mass of coin= 300 gm, $g_o = 10\ ms^{-2}$)

7. **(4 points)**

A person is in a giant wheel and screaming in excitement with a constant frequency of f_0. Person B standing below the giant wheel measures the frequency they hear. Assume the giant wheel is rotating with a constant angular velocity. Give a function of the frequency over time as measured by Person B.

SECTION-B

8. **(4 points)**

A person of mass m, charge q falls from a building. Consider the space to have uniform magnetic field B in the x direction.

(i) What should be the height of the building such that the person lands safely on the ground?

(ii) How much time will it take to touch the ground?

(iii) How far away from the Building will the person land?

9. **(4 points)**

You have been given a gun, infinite rounds of ammunition, and a free reign to shoot as much as you need. However, your shots only count if you shoot at the board provided to you at a fixed distance. It's a square board with a circle inscribed in it. You also know that the gun has a definite inherent error such that it always misses the target aimed at by some length L, less than the diameter of the circle. You are tasked with aiming any number of shots at the center of the circle.

(i) Without a blindfold (you can see where you are shooting).

(ii) With a blindfold (you cannot see where you are shooting)

A method of estimating pi using the above setup considers the ratio of a number of shots within the circle to the number of shots within the whole square. Would the estimated value of pi in cases (a) and (b) be different? Explain your answer with sufficient detail.

10. **(4 points)**

A bead is fixed at the bottom of a wheel of radius r. The wheel begins performing pure rolling. What is the distance traveled by the bead? Sketch out the trajectory.

Click this link for submitting your solution PDF:
https://forms.gle/mVtpDUXXQuUPC1Rt8

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