Department of Physics
Indian Institute of Technology Madras

Mock quiz

From Newton's laws to simple harmonic motion

Date: September 11, 2017 Time: 08:00 – 08:50 AM

Name: **Roll No.:**

Instructor: **Batch:**

Instructions

1. Begin by completing the information requested above. Please write your complete name, your roll number, the name of your instructor, and your batch number (out of I–XII). **The answer sheet will not be evaluated unless both your name and roll number are written.**
2. This question paper cum answer sheet booklet contains **six** pages. Please check right away that all the pages are present.
3. As we had announced earlier, this quiz consists of 3 true/false questions (for 1 mark each), 3 multiple choice questions with one correct option (for 1 mark each), 4 fill in the blanks, two questions involving detailed calculations (for 3 marks each) and one question involving some plotting (for 4 marks), adding to a total of 20 marks.
4. You are expected to answer **all** the questions. There are no negative marks.
5. The answers have to be written in the boxes provided. Answers written elsewhere in the booklet will **not** be evaluated.
6. Kindly write the answers, including sketches, with a blue or black pen. Note that answers written with pencils or pens of other colors will **not** be evaluated.
7. You can use the empty reverse sides for rough work. No extra sheets will be provided.
8. You are not allowed to use a calculator or any other electronic device during the quiz. Please note that you will not be permitted to continue with the quiz if you are found with any such device.
9. Make sure that you return question paper cum answer sheet booklet before you leave the examination hall.

For use by examiners
(Do not write in this space)

Q1–Q10	Q11	Q12	Q13	Total

✦ **True or false** (1 mark each, write True (T)/False (F) in the box provided)

1. The angular momentum of a particle moving in a central force field is conserved. ☐

2. The kinetic and potential energies of an oscillator averaged over one period are equal. ☐

3. A particle moving in the potential $U(x) = \alpha\, x^2$, where $\alpha < 0$, exhibits bounded motion. ☐

✦ **Multiple choice questions** (1 mark each, write the one correct option in the box provided)

4. A particle is moving along the trajectory $\boldsymbol{r}(t) = A\, t\, \hat{\boldsymbol{x}} + B\, t^2\, \hat{\boldsymbol{y}}$. The trajectory of the particle in the x-y-plane is described by

   [**A**] $y \propto x$ [**B**] $y \propto x^2$ [**C**] $y \propto x^{1/2}$ [**D**] None of the above ☐

5. A particle is exerted upon by the force $\mathbf{F} = -\beta\, x^{-2}\, \hat{\boldsymbol{x}}$. The potential energy $U(x)$ associated with the force is

   [**A**] $U(x) = \beta/x$ [**B**] $U(x) = -\beta/x$ [**C**] $U(x) = \beta/x^2$ [**D**] $U(x) = -\beta/x^2$ ☐

6. The position of a mass exhibiting simple harmonic motion in one dimension is described by the function: $x(t) = \sqrt{3}\cos(\omega\, t) + \sin(\omega\, t)$ for $t \geq 0$. The particle crosses the origin at the times (with $n = 0, 1, 2, \ldots$)

   [**A**] $t = (3\, n + 2)\ \pi/(3\, \omega)$ [**B**] $t = (3\, n + 1)\ \pi/(6\, \omega)$
   [**C**] $t = n\, \pi/(2\, \omega)$ [**D**] $t = n\, \pi/\omega$ ☐

✦ **Fill in the blanks** (1 mark each, write the answer in the box provided)

7. A vector $\boldsymbol{a}$ that depends on time has a constant magnitude. In such a case, $\boldsymbol{a} \cdot \mathrm{d}\boldsymbol{a}/\mathrm{d}t$ equals

   ☐

8. A particle that is falling under the influence of gravity is exerted by the drag force $\boldsymbol{F} = -\beta\, v^2\, \hat{\boldsymbol{v}}$, where v is the speed of the particle and $\hat{\boldsymbol{v}}$ denotes the unit vector along the direction of velocity of the particle. In such a case, the terminal velocity v_{ter} of the particle is given by

   ☐

9. A charge q is moving in a constant electric field $\boldsymbol{E}$. If $\boldsymbol{r}$ and $\boldsymbol{v}$ denote the position and velocity of the charge, then the rate of change of work done by the electric field on the charge is given by

   ☐

10. At critical damping, the complete solution governing a damped simple harmonic oscillator is given by

    ☐

✦ Questions with detailed answers

11. *Kicking a puck up an inclined plane:* A puck is kicked up a frictionless inclined plane with an initial velocity v_0. Let the angle of incline of the inclined plane be θ. (a) Write down the Newton's equation governing the motion of the puck. (b) Solve the equation and determine the distance that the puck will travel on the inclined plane. 1+2 marks

12. *Bead on a wire:* A bead, under the influence of gravity, slides along a frictionless wire whose height is given by the function $y(x)$. (a) Express the kinetic and the potential energies of the particle in terms of $\dot{x}$, y and $\mathrm{d}y/\mathrm{d}x$. (b) Obtain the equation of motion governing the system. [1+2 marks]

13. *Motion in one dimension:* A particle moves in the one-dimensional potential $U(x) = \alpha \left(x^2 - x_0^2\right)^2$, where $\alpha > 0$. (a) Plot the potential. (b) Identify the range of energies for which the particle has four turning points. (c) Determine the frequency of small oscillations near the minima. 2+1+1 marks