## Department of Physics Indian Institute of Technology Madras

## Quiz I

PH1010 Physics I

Time: 8:00 to 8:50 AM

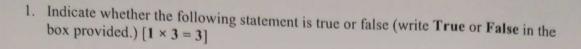
12.09.2019 Max. Marks: 20

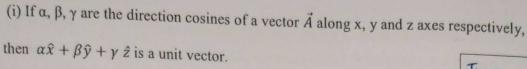
## Instructions

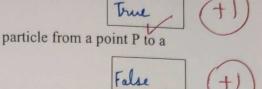
- 1. Please write your complete name, your roll number, the name of your teacher, and your batch number.
- 2. This question paper cum answer sheet booklet contains 12 pages. Please check that all the pages are present. You are expected to answer all the questions. There are no negative marks.
- 3. Write the answers only in the allotted box for Q1 and Q2. All vectors must be indicated clearly.
- 4. You can use pages 11-12 for rough work. No extra sheets will be provided.
- 5. All symbols have their usual meaning unless stated otherwise. All constants are positive and of appropriate dimensions.
- 6. You must use only black or blue ink for writing the answers.
- 7. Do not keep calculators, cell phones or any internet connectable device with you during the examination.

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

Q1	Q2	Q3	Q4	Q5	Total
					Marks







(ii) For a conservative force, the work done in bringing a particle from a point P to a point Q depends on the specific path chosen.

(iii) The equipotential curves for the force  $\vec{F}(x,y) = x\hat{x} + 2y\hat{y}$  are of the form  $x^2 + 2y\hat{y} = x\hat{y}$  $2y^2 = C$ , where C is a constant quantity. 2. Write the final answer in the box provided: Derivation is NOT required.

Suppose the temperature of this room at a point (x,y,z) is described by T(x,y,z)= (i)  $2x^2 + y^2 + 3z^2$ . The unit vector along the direction in which the temperature

increases most rapidly at the point 
$$(0,1,1)$$
 is

[1 mark]

 $\hat{U} = \hat{J} + 3\hat{k}$ 

A particle of mass m is moving on a plane. The radial distance of the particle from (ii) the origin is given by  $r(t) = r_0 \frac{\theta(t)}{\pi}$ , where  $\theta(t) = \frac{\alpha t^2}{2}$  with  $r_0$  and  $\alpha$  as constants. (a) Find the force  $\vec{F}$  on the particle as a function of time. (b) For what value (s) of  $\theta$  the radial component of the force vanishes? [1+1=2 marks]

$$(a)\vec{F} = \frac{m \Re \alpha}{\pi} \cdot \left( \left( 1 - \frac{\alpha^2 t^4}{2} \right) \hat{R} + \left( \frac{5\alpha t^2}{2} \right) \hat{\theta} \right)$$

(b) 
$$\hat{\theta} = \pm \frac{1}{\sqrt{2}}$$



(iii) A particle of unit mass moves along a circle of radius R anti-clockwise under the influence of a force given by  $\vec{F}(r,\theta) = -\frac{a}{r^2}\hat{r} + b\hat{\theta}$ , where a and b are constants. The work done by the force in moving the particle for one complete circle is



(iv) If 
$$f(r) = e^{-r}$$
, where  $r = \sqrt{x^2 + y^2 + z^2}$ , then  $\vec{\nabla} f$  at (0,0,1) is [1 mark]

(v) If  $U(x) = \frac{A}{x^{12}} - \frac{B}{x^6}$  describes the potential energy of an ideal diatomic molecule, for instance HCl, where x is the interatomic distance, and A, B are positive constants, then the equilibrium bond length of the molecule is

[1 mark]

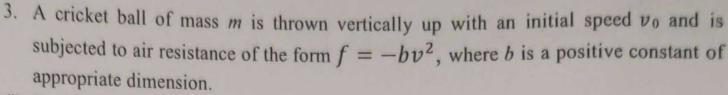
$$\alpha = \left(\frac{2A}{B}\right)^{1/6}$$

(vi) A damped driven oscillator with natural frequency  $\omega_0$  satisfies the following equation of motion

$$\ddot{x} + 2\beta \dot{x} + \omega_0^2 x = f_0 \cos \omega t$$

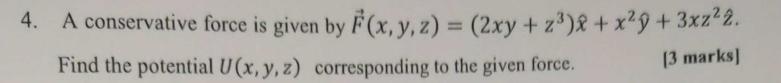
The frequency  $(\omega)$  at which the amplitude of oscillations is maximum is [1 mark]





(i) Find the terminal speed.

(ii) Determine the time taken by the ball to reach the maximum height. [1+2=3 marks]



5. An undamped driven oscillator of unit mass with natural frequency  $\omega_0$  is subjected to an external force  $f(t) = f_0 \cos \omega t$ , where  $f_0$  and  $\omega$  ( $\omega \neq \omega_0$ ) are constants. The oscillator satisfies the following equation of motion

$$\ddot{x} + \omega_0^2 x = f(t)$$

- (i) Find the particular solution  $x_p(t)$ .
- (ii) Write down the general solution  $x_h(t)$  to the corresponding homogeneous differential equation.
  - (iii) Determine the complete solution x(t) to the equation of motion using the initial conditions x(t = 0) = 0,  $\dot{x}(t = 0) = 0$ . [1+1+2=4 marks]