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PHY 101: Introduction to Physics-1

Monsoon 2024, Midterm

Time: 2 hr 15 min **Marks:35**

Answer all the questions.

(**Note:** All parameters in the questions are in SI units unless stated otherwise. Ensure that all answers are also expressed in SI units.)

Q1. The motion of a body undergoing simple harmonic motion can be represented as:

$$x(t) = A\sin(\omega t + \varphi_0)\,,$$

where the symbols bear their usual meaning. Now consider a particle executing such a motion about $x = 0$ with a period of 2 seconds and an amplitude of 4 cm. At time $t = 0$ it is located at $x = 2$ cm.
Find its **(1+1+1+1=4)**

(a) displacement $x(t)$,
(b) velocity $\dot{x}(t)$,
(c) acceleration $\ddot{x}(t)$,
(d) and phase φ_o .

Q2. A light rope fixed at one end of a wooden clamp on the ground passes over a tree branch and hangs on the other side. It makes an angle of 30° with the ground. A man weighing (50 kg) wants to climb up the rope. The wooden clamp can come out of the ground if an upward force greater than 300 N is applied to it.

(a) Draw the free body diagram for this problem indicating all the force components.
(b) Find the maximum tension that will not detach the clamp.
(c) Find the maximum acceleration in the upward direction with which the man can climb safely. Neglect friction at the tree branch. Take g = 10 m/s^2. **(1+1+1=3)**

Q3. A particle of mass m is constrained to move along the positive x axis under the influence of a single force whose potential energy function is

$$U(x) = -axe^{-\left(\frac{x^2}{b^2}\right)}\,,$$

where a and b are positive constants. Find the stable and unstable equilibrium points. **(2+2=4)**

Q4. A damped harmonic oscillator of mass 2 kg has the equation of motion

$$2\ddot{x} + 12\dot{x} + 50x = 0\,,$$

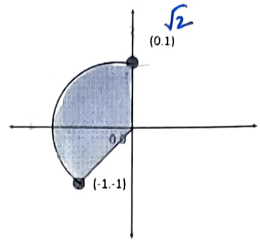
where x is the displacement from equilibrium measured in meters.

(a)What are the damping constant and the natural angular frequency for this oscillator?
(b) What type of damping is this? Is the motion oscillatory and periodic? If so, what is the oscillation period?

(c) For what value of the damping constant would this system, if displaced, return as quickly as possible to equilibrium? What would the equation of motion then be? **(1+2+2=5)**

Q5. (a) Convert points (0,1) and (-1, -1) into polar coordinates.

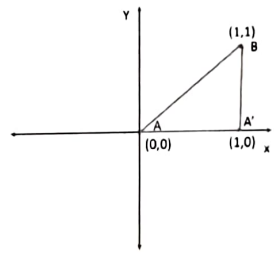
(b) Find the area of the circular sector confined between the two points with respect to the origin (0,0). (shown in the figure) **(2+3=5)**



Q6. A small body of mass m was launched up an inclined plane set at an angle $\theta = 30^0$ against the horizontal.

(a) Write the force equation during ascent and the expression for the time t_1 of ascent in terms of the distance travelled along the inclined plane S and the acceleration a_1
(b) Write the force equation during descent and expression for the time t_2 of descent in terms of the distance travelled along the inclined plane S and the acceleration a_2.
(c) Find the coefficient of friction if the ratio time of the ascent of the body is β which is twice the time of descent. **(2+2+3=7)**

Q7. Let $\vec{F} = F_0(e^{xy}\hat{\imath} + y^3\hat{\jmath})$ be the force acting on a body when it moves from A to B through two paths AA'B and AB diagonally as shown in the figure.



(a) Find the work done through path AA'B.
(b) What is the work done through path AB ?
(c) Explain whether the force is conservative or not.

(3+3+1=7)