QH-5322

# M. Sc. (Sem.-I) Examination, December, 2023

## PHYSICS

## PAPER - PHY - 1002

## Classical Mechanics

Time allowed : **Three Hours**

Max. Marks : **70**
Min. Pass Marks : **28**

*Note : This question paper contains two sections as under :*



***Section-A*** ***Max. Marks-20***

*This section will have 10 questions, having 02 questions from each unit with no internal choice. Answer in about 20 words. All questions will have equal marks.* ***(10×02=20)***

***Section-B*** ***Max. Marks-50***

*This section will have 10 questions, having 02 questions from each unit, one question to be attempted from each unit. Words limit approximately 400-500. Questions may have sub divisions. All questions will have equal marks.* ***(10×05=50)***

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### SECTION - A

1 Under what circumtances, the Hamiltonian function is the total energy of the system?

2 What do you mean by Lagrangian and what type of potential can you call it?

3 Define normal modes of vibration.

4 Define the equilibrium when a small oscillation causes the system in unbounded motion.

5 Give statement of Hamilton's variational principle.

6 Why do we use Lagrange's method of undetermined Multipliers?



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7 What do you mean by Hamilton's principal function?

8 Estimate the degree of freedom of a rigid body.

9 Explain that for a plane monochromatic wave, four propagation vector $K^{\mu}$ satisfies

$K_{\mu} K^{\mu} = 0$

10 Explain that photon cannot exist in the state of rest.

## SECTION - B

### UNIT - I

1 (A) Define the following terms. **[1+1+1+1+1=5]**

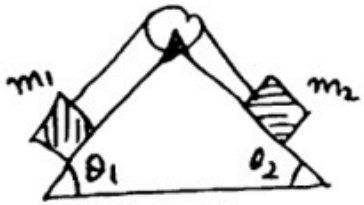
(i) Scleronomic constraints
(ii) Rheonomic constraints
(iii) Degrees of freedom
(iv) Generalized co-ordinates
(v) Virtual displacement

(B) (i) Five particles constrained on vertices of a pentagon are moving free in space, determine degrees of freedom. **2**



(ii) Two particles of masses $m_1$ and $m_2$ are located on a frictionless double inclined planes and connected by an inextensible massless string passing over a smooth pulley of negligible mass. Using principle of virtual work prove that in case of equilibrium we should have

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{m_2}{m_1}$$




**3**

**OR**

(i) Explain principle of virtual work and D'Alembert's principle. **[1$\frac{1}{2}$+1$\frac{1}{2}$=3]**

(ii) What do you understand by reversed effective force? **1**

(iii) A solid homogeneous cylinder of radius '$r$', rolls without slipping inside a big stationary cylinder of Radius '$R$'. Find the equation of motion using Lagrange's equations and show that the frequency of oscillations of small amplitude about stable equilibruium will be -

$$\nu = \frac{1}{2\pi}\sqrt{\frac{2g}{3(R-r)}}$$ **6**

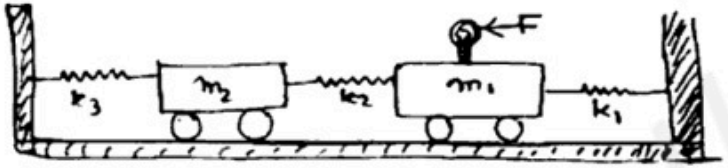


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## UNIT - II

2 (A) The system shown below consists of two masses $m_1$ and $m_2$ coupled by elastic springs of stiffness $k_1$, $k_2$ and $k_3$. The harmonic force $F = F_0 \sin \omega t$ is applied externally to $m_1$. The smooth surfaces allow no damping at all. Show that the critical frequencies of small oscillations will be

$$\omega^2 = \frac{k_1 + k_2}{2m_1} + \frac{k_2 + k_3}{2m_2} \pm \sqrt{\left(\frac{k_1 + k_2}{2m_1} + \frac{k_2 + k_3}{2m_2}\right)^2 - \left(\frac{k_1 k_2 + k_2 k_3 + k_3 k_2}{m_1 m_2}\right)}$$




7

(B) In the special case $m_1 = m_2 = m$, $k_1 = k_2 = k$, $k_3 = 0$, the two frequencies will be -

$\omega_{\pm}^2 = \frac{3 \pm \sqrt{5}}{2} \cdot \frac{k}{m}$ and for tower frequency, the two motions are in phase, while for upper frequency it is out of phase.

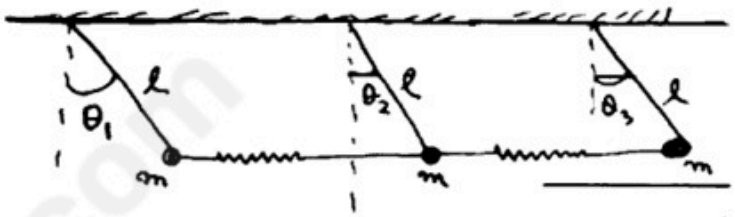
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OR



Show that the normal mode frequencies of a triple pendulum are given by

$\omega_1 = \omega_2 = \sqrt{\frac{g}{\ell} + \frac{2k}{m}}$ and $\omega_3 = \sqrt{\frac{g}{\ell} - \frac{k}{m}}$




4

Further show that the generalized coordinates $\theta_i$ are related to normal coordinates $Q_i$ as

$$\begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} C & B & A \\ -2C & C & A \\ C & -B & A \end{bmatrix} \begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix},$$

Where $3A^2 = 2B^2 = 6C^2 = \frac{1}{m\ell^2}$

6

3 (A) Deduce Hamilton's canonical equations from Hamilton's modified/variational principle.

5

(B) Write the Hamiltonian function and the equations of motion for a two dimensional isotropic harmonic oscillator, using cartesian and polar co-ordinates.

5

OR



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(A) (i) Define Legendre Transformations. $1\frac{1}{2}$

(ii) What is generating function? $1\frac{1}{2}$

(iii) Give condition for canonical transformations. 1

(iv) What do you mean by Bilinear invariant? 1

(v) Given the generating function.

$$F_1(q,Q,t)=\frac{1}{2}m\omega\left[q=\frac{f(t)}{m\omega^2}\right]^2\cot Q\ ,$$

find the transformation equations and thus obtain the equations of motion of a simple harmonic oscillator acted upon by a force $F(t)$ interms of $Q$ and $R$. 5

## UNIT - III

4 (A) Obtain Hamilton - Jacobi equation of motion. 5

(B) Obtain Hamilton's characteristic function for simple Harmonic oscillator. 5

**OR**



(A) Describe nutation angle, precession angle and body angle. 5

(B) Calculate the inertia tensor for the system of four point masses 1 gm, 2 gm and 4 gm, located at the points (1, 0, 0), (1, 1, 0), (1, 1, 1) and (1, 1, −1) cm. 5

5 (A) If a Lorentz transformation is given by

$$(x^\nu)^1=a^\nu{}_\mu x^\mu$$

then show that $a_\mu{}^\nu\ a^\mu{}_\sigma=\delta^\nu_\sigma$. 5

(B) Show that a photon cannot give rise to an electron-positron pair in free space in the absence of an external field. 5

**OR**

(A) Show that the relation $v=\frac{dE}{dp}$ holds good in non-relativistic as well as non-relativistic dynamics. 5

(B) Obtain relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field. 5



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