

4/PHY-251 Syllabus-2023

2026

(May-June)

FYUP : 4th Semester Examination

PHYSICS

**(Classical Mechanics I and Special
Theory of Relativity)**

(PHY-251)

Marks : 75

Time : 3 hours

*The figures in the margin indicate full marks
for the questions.*

Answer any **ten** questions.

1. (a) What do you understand by (i) degrees of freedom and (ii) generalized coordinates? 2+2=4
(b) What is meant by the term 'constraint'? Show that the work done by constraint forces on a rigid body is zero. 1+2½=3½
2. (a) What is virtual displacement? State and explain the principle of virtual work. 1+2½=3½
(b) Obtain an expression for the generalized force. 4

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3. (a) Obtain the Lagrangian and equation of motion of a moving particle in plane polar coordinates (r, θ) . Give the interpretation of the equation. $1+3+2=6$
- (b) Write down the Lagrangian for a simple pendulum. $1\frac{1}{2}$
4. (a) Obtain the Newton's second law of motion from Lagrange's equation of motion. $3\frac{1}{2}$
- (b) Show that the kinetic energy of a system is a homogeneous quadratic function of the generalized velocities. 4
5. (a) Obtain the Lagrange equation of motion for a particle of mass m falling freely under gravity near the surface of the earth. $3\frac{1}{2}$
- (b) What is generalized momentum? Show that the generalized momentum conjugate to a cyclic coordinate is conserved. $2+2=4$
6. (a) Define the Hamiltonian of a dynamical system. Give its physical significance. $1+1\frac{1}{2}=2\frac{1}{2}$
- (b) What is Hamilton's principle? Obtain the Lagrange's equation from it. $1+4=5$

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7. (a) Deduce Hamilton's canonical equations of motion. 4
- (b) Obtain the Hamilton's equations in cylindrical coordinates. $3\frac{1}{2}$
8. (a) Obtain Hamilton's equation of motion for a particle moving in a central force field. 4
- (b) Given the Lagrangian
- $$L = \frac{1}{2}M(\dot{r}^2 - r^2\dot{\theta}^2) - V(r)$$
- Find the Hamiltonian and hence the equations of motion. $3\frac{1}{2}$
9. (a) State the basic assumptions implied in the Galilean transformation. What are the drawbacks of the Galilean transformation? $2+1\frac{1}{2}=3\frac{1}{2}$
- (b) Write down the Galilean transformation equations and hence show that the distance between two points is invariant under this transformation. $2+2=4$
10. Give a description of the Michelson-Morley experiment. Discuss the result of the experiment. $5\frac{1}{2}+2=7\frac{1}{2}$

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11. (a) What do you understand by (i) proper length and (ii) time dilation? Show that $x^2 + y^2 + z^2 - c^2 t^2 = 0$ is invariant under Lorentz transformation. 2+3=5
- (b) The length of a rocket ship is 100 meters on the ground. When it is in flight its length appears to be 99 meters to an observer on the ground. Find its speed. 2½
12. (a) What do you understand by 'proper time'? 1½
- (b) A clock keeps correct time on the earth. It is put on a spaceship moving uniformly with a speed of $1 \times 10^8 \text{ ms}^{-1}$. How many hours does it appear to lose per day? 3
- (c) Calculate the percentage contraction in the length of a rod moving with a velocity 60% that of light in a direction at 60° to its own length. 3
13. (a) Derive the relation between relativistic energy and momentum of a free particle. Hence obtain the energy and momentum of a photon. 4+1=5
- (b) Show that $P^2 - \frac{E^2}{C^2}$ is Lorentz invariant. 2½

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14. (a) Calculate the linear momentum of a 25 GeV proton assuming the rest mass energy of the proton is approximately 1 GeV. 3
- (b) Find the velocity that an electron must be given so that its momentum is 10 times the product of its rest mass and the speed of light. What is the energy at this speed? $3+1\frac{1}{2}=4\frac{1}{2}$
15. (a) Show that the Einstein's velocity addition formula is in conformity with the principle of constancy of the speed of light c . 4½
- (b) What is relativistic Doppler effect? Explain blue shift and red shift in this effect. $1+1+1=3$
16. Obtain Einstein's mass-energy relation. Explain the physical significance of this relation. Mention an example of one nuclear phenomenon supporting this relation. $5\frac{1}{2}+2=7\frac{1}{2}$
