

NEET (UG) · JEE MAIN · JEE ADVANCED

SELECTED PROBLEMS IN PHYSICS

VOLUME 2

170 hand-picked problems with complete, step-by-step solutions

Kinematics and Laws of Motion · Energy and Momentum · Rotation · Gravitation and Oscillations · Properties of Matter · Waves · Heat · Electrostatics and Capacitors · Magnetism · Induction and AC · Optics · Modern Physics

ANANT SHUKLA & TEAM

Master Testing Agency

Selected Problems in Physics

Volume 2

NEET (UG) · JEE Main · JEE Advanced

Anant Shukla and Team

First edition, 2026 · e-book

Price: ₹ 369

Published by **Master Testing Agency**, 401, Saket, Roorkee – 247667, Uttarakhand, India

www.mastertestingagency.com · support@mastertestingagency.com

This copy is for the personal study of the buyer. Do not share, resell or upload it anywhere.

© Anant Shukla and Team. All rights reserved. No part of this book may be copied, stored or sent in any form without the written permission of the authors.

The problems in this book were chosen from the classic themes that appear again and again in competitive physics. Every problem has been rewritten in our own words, many with new data, and every solution is our own. Every numerical answer has been worked out a second time by computer from the data in the question; the book is not printed if any of these checks fails. If you still find a mistake, please write to us.

NEET (UG), JEE (Main) and JEE (Advanced) are conducted by the National Testing Agency and the Indian Institutes of Technology. This book is an independent study aid and is not connected with any of them.

Preface

Physics is learnt by solving problems. Not a thousand easy ones, but a few hundred good ones – problems that make you draw a clean figure, choose the right frame, write the right equations and check your result.

This second volume collects 170 more such problems, across the whole syllabus from kinematics to nuclear physics. None of them repeats a problem of Volume 1, so the two volumes can be used together, in either order. They range from questions a careful NEET (UG) aspirant can solve in a few minutes to problems at the top end of JEE Advanced. Each problem carries a small tag: **NEET**, **JEE Main** or **JEE Adv**. The tag shows the examination for which the problem is most useful; it is not a promise that the problem is easy or hard.

Every chapter has three parts:

- **Problems** – try every one of them yourself, on paper, before turning the page;
- **Answer Key** – the final answers in one place, so you can check quickly;
- **Worked Solutions** – complete solutions, step by step, with the physical idea stated first.

When you are stuck, read only the first line or two of the solution – the idea – and then try again. A problem you finish yourself after a hint teaches far more than a solution you read to the end.

We thank our students, whose questions over many years shaped this collection, and we wish every reader success.

Anant Shukla and Team

Values and conventions used in this book

Acceleration due to gravity	$g = 10 \text{ m s}^{-2}$ unless stated otherwise
Coulomb constant	$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Gas constant	$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
Density of water	1000 kg m^{-3}
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
Speed of light	$c = 3 \times 10^8 \text{ m s}^{-1}$
Elementary charge	$e = 1.6 \times 10^{-19} \text{ C}$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$, $hc = 1240 \text{ eV nm}$
Electron mass	$m_e = 9.1 \times 10^{-31} \text{ kg}$
Atomic mass unit	$1 \text{ u} = 931.5 \text{ MeV}/c^2$
Stefan constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Sign convention in optics	Cartesian: distances measured from the pole or the optical centre, positive in the direction of the incident light.

Contents

Preface	iii
1 Kinematics and the Laws of Motion	1
Problems	1
Answer key	2
Worked solutions	2
2 Work, Energy and Momentum	6
Problems	6
Answer key	8
Worked solutions	8
3 Rotation of Rigid Bodies	12
Problems	12
Answer key	13
Worked solutions	13
4 Gravitation and Oscillations	17
Problems	17
Answer key	19
Worked solutions	19
5 Fluids, Surface Tension, Viscosity and Elasticity	23
Problems	23
Answer key	25
Worked solutions	26
6 Waves and Sound	30
Problems	30
Answer key	31
Worked solutions	31
7 Heat and Thermodynamics	33
Problems	33
Answer key	35
Worked solutions	35
8 Electrostatics and Capacitors	38
Problems	38
Answer key	40
Worked solutions	41

9 Magnetic Field and Magnetic Forces	45
Problems	45
Answer key	47
Worked solutions	47
10 Electromagnetic Induction and Alternating Current	50
Problems	50
Answer key	52
Worked solutions	52
11 Ray Optics and Wave Optics	56
Problems	56
Answer key	58
Worked solutions	58
12 Photons, Atoms and Nuclei	61
Problems	61
Answer key	63
Worked solutions	63

CHAPTER 1

Kinematics and the Laws of Motion

Before writing a single force, decide what is fixed by geometry: a rope that folds, a rod held in guides, a block that must stay on an incline. These constraints give relations between accelerations that are as important as Newton's laws themselves.

Problems

Problem 1.1

NEET

One end of a uniform flexible rope is fixed to the ceiling. The other end is held next to it, so that the rope hangs folded in two, and is then released. At the instant when the free end is falling with speed v , how fast is the fold (the lowest point of the rope) moving?

Problem 1.2

JEE Main

A ball is thrown from a point O on level ground at 45° to the horizontal with speed u . It strikes a smooth vertical wall, rebounds elastically, and lands on the ground. Find the magnitude of its average acceleration over the whole flight.

Problem 1.3

JEE Main

A rocket starts from rest at $t = 0$ and moves vertically upwards with acceleration $a = kt^2$ until $t = t_0$, when its fuel is used up; after that only gravity acts. Find (a) its greatest speed, (b) the greatest height it reaches, (c) the total time until it falls back to the launch point.

Problem 1.4

JEE Adv

Two balls are thrown at the same instant from the top of a tall tower: the first horizontally with speed 10 m s^{-1} , the second with speed u at an angle θ above the horizontal, where $\tan \theta = 4/3$, in the same vertical plane and the same horizontal direction.

- (a) Find the least value u_0 of u for which the velocities of the two balls become perpendicular at some instant.
- (b) For $u = u_0$, when does this happen?

Problem 1.5

JEE Main

A body turning with angular velocity ω_0 is slowed down so that its angular deceleration is always proportional to the square root of its angular velocity. Find its mean angular velocity over the whole time until it stops.

Problem 1.6

JEE Main

A uniform rope of mass m hangs between two points of a horizontal ceiling. Its middle point is pulled straight down with a force F . At its ends the rope makes an angle α with the ceiling. Find the angle β between the two halves of the rope at the point where F is applied.

Problem 1.7

JEE Adv

A smooth hemisphere of mass M and radius R rests, flat face down, on a smooth horizontal table. A vertical rod of mass m , held in fixed smooth vertical guides, rests with its lower end on the curved surface at a point whose radius makes an angle θ with the vertical. A horizontal string tied to the hemisphere keeps the system at rest.

- Find the tension in the string.
- Find the acceleration of the hemisphere just after the string is cut.

Problem 1.8

JEE Adv

A wedge of mass m with a smooth face inclined at 45° stands on a smooth table. A small block, also of mass m , is projected up the face from its bottom with speed u relative to the wedge (the wedge being at rest at that moment). The block stays on the face.

- Find the acceleration of the wedge and of the block.
- Describe the path of the block seen from the ground, and find the angle at which it strikes the table on its return.
- Find the radius of curvature of the block's path at its highest point.

Problem 1.9

JEE Main

A particle of mass m is tied to two light inextensible strings, each of length ℓ , whose other ends are fixed to points A and B of a vertical rod, A being a distance ℓ above B . The rod turns about its own axis with angular velocity ω .

- For what ω does the particle stay at rest at B (string AO vertical)?
- For what ω is the tension in AO greater than mg while BO stays slack?
- For what ω is the tension in AO twice that in BO ?

Answer Key

1.1 $v/2$

1.2 $\sqrt{2}g$

1.3 (a) $kt_0^3/3$; (b) $\frac{kt_0^4}{12} + \frac{k^2t_0^6}{18g}$; (c)

$$t_0 + \frac{1}{g} \left(\frac{kt_0^3}{3} + \sqrt{\frac{k^2t_0^6}{9} + \frac{gkt_0^4}{6}} \right)$$

1.4 (a) 37.5 m s^{-1} ; (b) 1.5 s

1.5 $\omega_0/3$

1.6 $\beta = 2 \tan^{-1} [(1 + mg/F) \cot \alpha]$

1.7 (a) $mg \tan \theta$; (b) $\frac{mg \sin \theta \cos \theta}{M \cos^2 \theta + m \sin^2 \theta}$

1.8 (a) wedge $g/3$; block $g/3$ horizontally and $2g/3$ downwards; (b) a parabola; it strikes the table vertically; (c) $3u^2/16g$

1.9 (a) $\omega \leq \sqrt{g/\ell}$; (b) $\sqrt{g/\ell} < \omega < \sqrt{2g/\ell}$; (c) $\omega = \sqrt{6g/\ell}$

Worked Solutions**Solution 1.1**

Let the free end be a distance x below the ceiling and let the rope have length L . The fixed half and the falling half meet at the fold, so the length of the rope is the depth of the fold plus the distance from the fold back up to the free end: $L = y_f + (y_f - x)$, i.e. $y_f = \frac{L+x}{2}$. Differentiating, $\dot{y}_f = \dot{x}/2$: the fold descends at $v/2$.

Answer: $v/2$

Solution 1.2

An elastic rebound from a smooth vertical wall reverses the horizontal velocity and leaves the vertical velocity unchanged, so the time of flight is the same as without the wall: $T = 2u \sin 45^\circ / g = \sqrt{2}u/g$.

The ball lands with velocity $(-u \cos 45^\circ, -u \sin 45^\circ)$, exactly opposite to its initial velocity, so $|\Delta \vec{v}| = 2u$. The average acceleration is

$$\frac{|\Delta \vec{v}|}{T} = \frac{2u}{\sqrt{2}u/g} = \sqrt{2}g.$$

(It is not g : the wall gives an impulse.)

Answer: $\sqrt{2}g$

Solution 1.3

(a) While the engine works, $v = kt^3/3$ and $x = kt^4/12$. The speed is greatest at burn-out: $v_0 = \frac{kt_0^3}{3}$, at height $h_0 = \frac{kt_0^4}{12}$.

(b) It then rises a further $v_0^2/2g$:

$$H = \frac{kt_0^4}{12} + \frac{k^2 t_0^6}{18g}.$$

(c) After burn-out, $h_0 + v_0\tau - \frac{1}{2}g\tau^2 = 0$ gives $\tau = \frac{v_0 + \sqrt{v_0^2 + 2gh_0}}{g}$, so

$$T = t_0 + \frac{1}{g} \left(\frac{kt_0^3}{3} + \sqrt{\frac{k^2 t_0^6}{9} + \frac{gkt_0^4}{6}} \right).$$

Answer: (a) $kt_0^3/3$; (b) $\frac{kt_0^4}{12} + \frac{k^2 t_0^6}{18g}$; (c) $t_0 + \frac{1}{g} \left(\frac{kt_0^3}{3} + \sqrt{\frac{k^2 t_0^6}{9} + \frac{gkt_0^4}{6}} \right)$

Solution 1.4

$\vec{v}_1 = (10, -gt)$, $\vec{v}_2 = (u \cos \theta, u \sin \theta - gt)$. Perpendicular when

$$10u \cos \theta - gt(u \sin \theta - gt) = 0 \quad \Leftrightarrow \quad g^2 t^2 - gu \sin \theta t + 10u \cos \theta = 0.$$

(a) A real root needs $u^2 \sin^2 \theta \geq 40u \cos \theta$: $u_0 = \frac{40 \cos \theta}{\sin^2 \theta} = \frac{40 \times 0.6}{0.64} = 37.5 \text{ m s}^{-1}$.

(b) The double root: $t = \frac{u_0 \sin \theta}{2g} = \frac{37.5 \times 0.8}{20} = 1.5 \text{ s}$.

Answer: (a) 37.5 m s^{-1} ; (b) 1.5 s

Solution 1.5

$\frac{d\omega}{dt} = -k\sqrt{\omega}$ gives $\sqrt{\omega} = \sqrt{\omega_0} - \frac{kt}{2}$; it stops at $T = 2\sqrt{\omega_0}/k$. The angle turned is

$$\varphi = \int_0^T \left(\sqrt{\omega_0} - \frac{kt}{2} \right)^2 dt = \frac{2\omega_0^{3/2}}{3k}, \quad \bar{\omega} = \frac{\varphi}{T} = \frac{\omega_0}{3}.$$

Answer: $\omega_0/3$

Solution 1.6

Let the tension be T_1 at the ends and T_2 just beside the lowest point, where each half makes $\beta/2$ with the vertical.

At the lowest point: $2T_2 \cos(\beta/2) = F$.

For one half of the rope (weight $mg/2$): vertically $T_1 \sin \alpha = \frac{1}{2}mg + T_2 \cos(\beta/2) = \frac{1}{2}(mg + F)$; horizontally $T_1 \cos \alpha = T_2 \sin(\beta/2)$. Dividing,

$$\tan \frac{\beta}{2} = \frac{T_1 \cos \alpha}{F/2} = \left(1 + \frac{mg}{F}\right) \cot \alpha, \quad \beta = 2 \tan^{-1} \left[\left(1 + \frac{mg}{F}\right) \cot \alpha \right].$$

Answer: $\beta = 2 \tan^{-1} [(1 + mg/F) \cot \alpha]$

Solution 1.7

The surfaces are smooth, so the rod presses on the hemisphere along the radius at the contact.

(a) Rod: $N \cos \theta = mg$. Hemisphere, horizontally: $T = N \sin \theta = mg \tan \theta$.

(b) The rod can only move vertically. If the hemisphere moves away with acceleration A , the contact point slides down the surface; at the first instant (everything at rest) the rod's downward acceleration is $a = A \tan \theta$ (slope of the surface at the contact).

$$mg - N \cos \theta = mA \tan \theta, \quad N \sin \theta = MA$$

$$\Rightarrow A = \frac{mg \sin \theta \cos \theta}{M \cos^2 \theta + m \sin^2 \theta}.$$

Answer: (a) $mg \tan \theta$; (b) $\frac{mg \sin \theta \cos \theta}{M \cos^2 \theta + m \sin^2 \theta}$

Solution 1.8

(a) As usual for a block on a free smooth wedge (it does not matter whether the block moves up or down; only the forces matter):

$$A = \frac{mg \sin \theta \cos \theta}{m + m \sin^2 \theta} = \frac{g}{3}, \quad a_{\text{rel}} = \frac{2g \sin \theta}{1 + \sin^2 \theta} = \frac{2\sqrt{2}}{3}g \text{ (down the face).}$$

Let the face rise towards $+x$. The block presses on the face along its normal, which pushes the wedge towards $+x$. The block's acceleration relative to the ground is therefore $\left(-\frac{2}{3}g + \frac{1}{3}g, -\frac{2}{3}g\right) = \left(-\frac{1}{3}g, -\frac{2}{3}g\right)$ – constant.

(b) A constant acceleration means a parabola. Initially the block's ground velocity is $\frac{u}{\sqrt{2}}(1, 1)$. The relative motion is symmetric, so the block returns to the bottom of the face after $t = 2u/a_{\text{rel}} = \frac{3u}{\sqrt{2}g}$, with velocity $\left(\frac{u}{\sqrt{2}} - \frac{1}{3}gt, \frac{u}{\sqrt{2}} - \frac{2}{3}gt\right) = \left(0, -\frac{u}{\sqrt{2}}\right)$: it strikes the table vertically, at 90° . (Check with momentum: the wedge now moves at $\frac{g}{3}t = \frac{u}{\sqrt{2}}$ and carries all the horizontal momentum $mu/\sqrt{2}$.)

(c) At the highest point $v_y = 0$: $t = \frac{u/\sqrt{2}}{2g/3} = \frac{3u}{2\sqrt{2}g}$ and $v_x = \frac{u}{\sqrt{2}} - \frac{1}{3}gt = \frac{u}{2\sqrt{2}}$. The normal acceleration is the vertical component $\frac{2}{3}g$:

$$\rho = \frac{u^2/8}{2g/3} = \frac{3u^2}{16g}.$$

Answer: (a) wedge $g/3$; block $g/3$ horizontally and $2g/3$ downwards; (b) a parabola; it strikes the table vertically; (c) $3u^2/16g$

Solution 1.9

(a) With BO slack the particle is a conical pendulum hanging from A . The position on the axis is stable only if $\omega^2 \leq g/\ell$; so $\omega \leq \sqrt{g/\ell}$.

(b) As a conical pendulum at angle φ to the vertical: $T_1 = m\omega^2\ell$ and $\cos \varphi = g/\omega^2\ell$. $T_1 > mg$ needs $\omega^2 > g/\ell$. String BO becomes taut when $\triangle AOB$ is equilateral, $\varphi = 60^\circ$, i.e. $\omega^2 = 2g/\ell$. So $\sqrt{g/\ell} < \omega < \sqrt{2g/\ell}$.

(c) Both taut, each string at 60° to the vertical, radius $\ell \sin 60^\circ$:

$$T_1 \cos 60^\circ - T_2 \cos 60^\circ = mg, \quad (T_1 + T_2) \sin 60^\circ = m\omega^2\ell \sin 60^\circ.$$

With $T_1 = 2T_2$: $T_2 = 2mg$, $T_1 = 4mg$, and $\omega^2 = 6g/\ell$.

Answer: (a) $\omega \leq \sqrt{g/\ell}$; (b) $\sqrt{g/\ell} < \omega < \sqrt{2g/\ell}$; (c) $\omega = \sqrt{6g/\ell}$