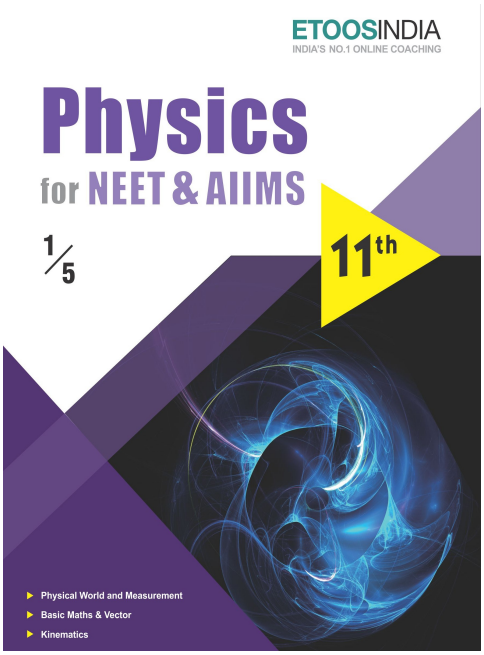
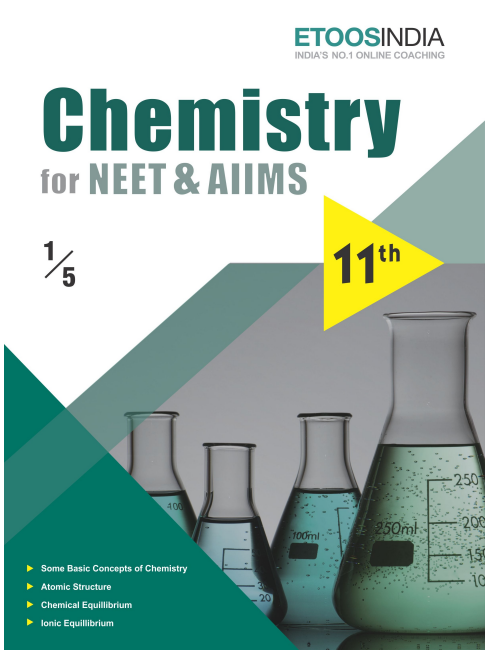
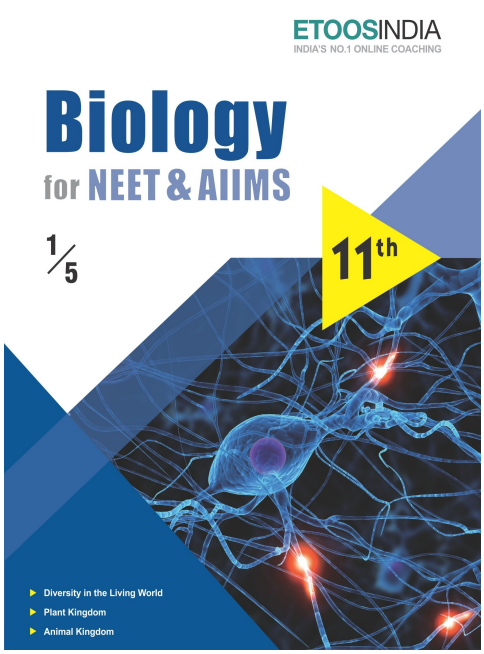
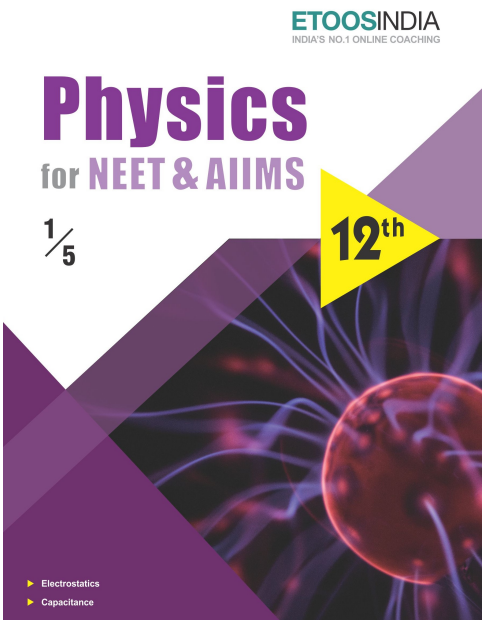
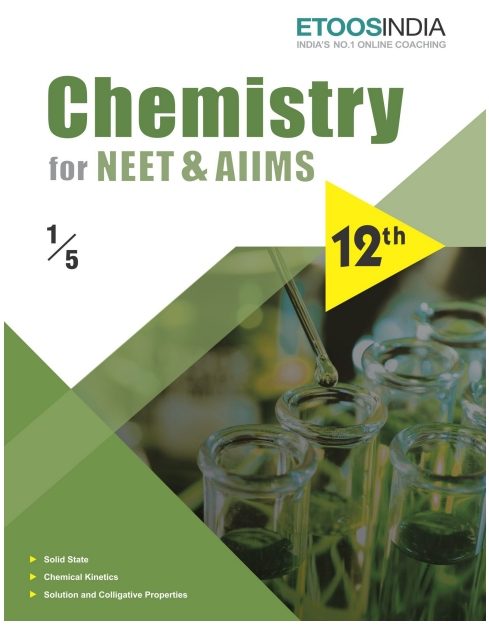
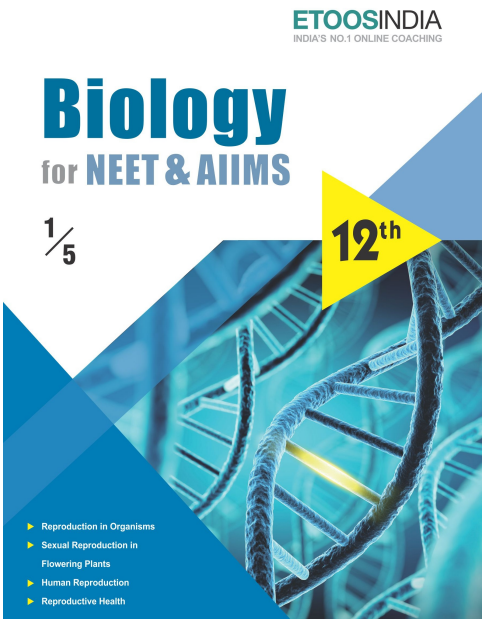












CHAPTER 04

LAW OF MOTION & FRICTION

All that science can achieve is a perfect knowledge and a perfect understanding of the action of natural and moral forces.

"HERMANN VON HELMHOLTZ"

INTRODUCTION

Then we look around us, we find the planets moving around the sun in orderly manner, movement of machinery parts in a factory, phases of the moon-all of them are following certain laws. They all are acted upon by certain forces. In the preceding two chapters, we described motion in terms of displacement, velocity and acceleration, *i.e.*, we used kinematic quantities for describing motion without considering what might cause that motion. In order to understant this beauty, let us take a step forward by understanging "Force and laws of motion". In this chapter, we shall study about force and its effects on the objects and various alws related to motion of the objects.

Inertial frame of Reference

The first law requires a frame of reference in which only the forces acting on a body can be responsible for any acceleration produced in the body and not the acceleration of the frame of reference. These frames of reference are known as inertial frames

2. The Second Law of motion

The rate of change in momentum of a body is equal to, and occurs in the direction of the net applied force. A body of mass m in translational motion with velocity $\vec{v}$, if acted upon with a net external force $\vec{F}$, the second law suggests:

$$\vec{F} = \frac{d}{dt}(m\vec{v})$$

If mass of the body is constant, the above equation relates the acceleration $\vec{a}$ of the body with the net force $\vec{F}$ acting on it

$$\vec{F} = \frac{d}{dt}(m\vec{v}) = m\vec{a}$$

The first law provides concept of force and the second law provides the quantitative definition of force, therefore the second law is also valid only in inertial frames.

SI unit of force in newton. It is abbreviated as N. One newton equals to one kilogram-meter per second square

$$1\ N = 1\ kg\text{-}m/s^2$$

Dimension of force are $[MLT^{-2}]$

ETOOS KEY POINTS

(i) The second law is obviously consistent with the first law as F = 0 Implies a = 0

(ii) The second law of motion is a vector law it is actually a combination of three equations

$$F_x = \frac{dp_x}{dt} = ma_x, F_y = \frac{dp_y}{dt} = ma_y$$

$$F_z = \frac{dp_z}{dt} = ma_z$$

This means that if a force is not parallel to the velocity of the body, but makes some angles with it, it changes only the component of velocity along the direction of force. The component of velocity normal to the force remains unchanged.

(iii) The second law of motion given above is strictly applicable to a single point mass the force F in the law stand for the net external force on the particle and a stands for the acceleration of the particle. Any internal forces in the system are not to be include in F.

(iv) The second law of motion is a local relation what this means is that the force F at a point in space (location of the particle) at a certain instant of time is related to a at the same point at the same instant that is acceleration here and now is determined by the force here and now not by any history of the motion of the particle.

3. Newton Third Law of motion

Force is always a two-body interaction. The first law describes qualitatively and the second law describes quantitatively what happens to a body if a force acts on it, but do not reveal anything about what happens to the other body participating in the interaction responsible for the force.

The third law accounts for this aspect of the force and states the every action on a body has equal and opposite reaction on the other body participating in the interaction.

Etoos Tips & Formulas

NEWTON'S LAW OF MOTION

I. Impulse - Momentum theorem

Impulse of a force is equal to the change of momentum $\vec{F}\Delta t = \Delta p$

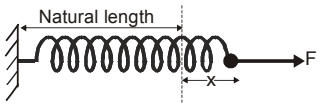
1. Newton`s third law of motion :

Whenever a particle A exerts a force on another particle B, B simultaneously exerts a force on A with the same magnitude in the opposite direction.

2. Spring Force (According to Hooke`s law) :

In equilibrium F = kx (k is spring constant)

Note : Spring force is non impulsive in nature.



3. Motion of bodies in contact

When two bodies of masses m_1 and m_2 are kept on the frictionless surface and a force F is applied on one body, then the force with which one body presses the other at the point of contact is called force of contact. These two bodies will move with same acceleration a.

(a) When the force F acts on the body with mass m_1 as shown in fig (i)

$F = (m_1 + m_2)a$

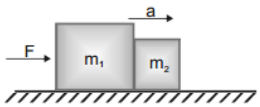


Fig. (1) : When the force F acts on mass m_1

(b) If the force exerted by m_2 on m_1 is f_1 (force of contact) then for body m_1 : $(F - f_1) = m_1 a$

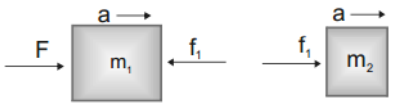


Fig. 1(a) : F.B.D. representation of action and reaction forces

For body m_2 : $f_1 = m_2 a \Rightarrow$ action of m_1 on m_2 : $\dfrac{m_2 F}{m_1 + m_2}$

4. Pulley system

A single fixed pulley changes the direction of force only and in general, assumed to be massless and frictionless.

5. SOME CASES OF PULLEY

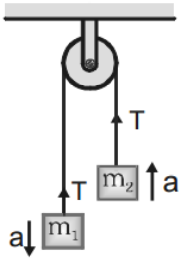
Case I

Let $m_1 > m_2$

now for mass m_1, $m_1 g - T = m_1 a$

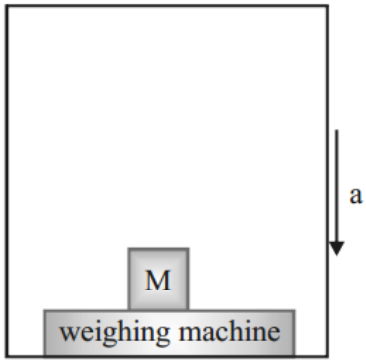
for mass m_2, $T - m_2 g = m_2 a$

$$\text{Acceleration} = a = \frac{(m_1 - m_2)}{(m_1 + m_2)}\, g = \frac{\text{net pulling force}}{\text{total mass to be pulled}}$$



SOLVED EXAMPLE

Ex.1 With what acceleration 'a' shown the elevator descends so that the block of mass M exerts a force of $\frac{Mg}{10}$ on the weighing machine ? [g = acceleration due to gravity]

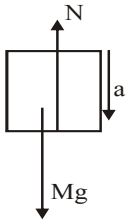


(A) 0.3 g **(B)** 0.1 g
(C) 0.9g **(D)** 0.6 g

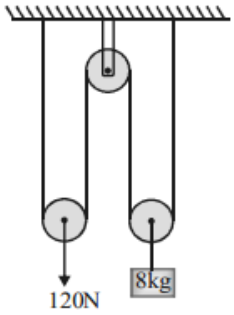
Sol. FBD of block :

$Mg - N = Ma$; Now according to question $N = \frac{Mg}{10}$

So $a = \frac{Mg - \frac{Mg}{10}}{M} = 0.9g$

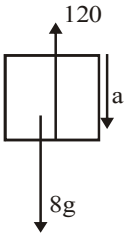


Ex.2 If the string is pulled down with a force of 120 N as shown in the figure, then the acceleration of 8 kg block would

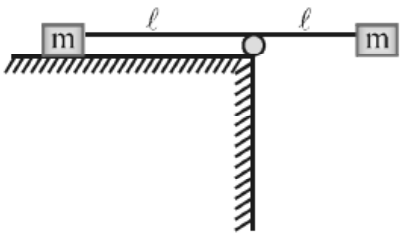


(A) 10 m/s² **(B)** 5 m/s²
(C) 0 m/s² **(D)** 4 m/s²

Sol. FBD of 8 kg block $a = \frac{120 - 80}{8} = 5 m/s^2$



Ex.3 As shown in figure, the left block rests on a table at distance ℓ from the edge while the right block is kept at the same level so that thread is unstretched and does not sag and then released. What will happen first ?



(A) Left block reach the edge of the table
(B) Right block hit the table
(C) Both (A) and (B) happens at the same time
(D) Can't say anything

Sol. Net force in horizontal direction is more for left block so it will reach the edge of the table first.

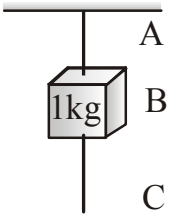
Ex.4 The force exerted by the floor of an elevator on the foot of a person standing there is less than the weight of the person if the elevator is
(A) going up and slowing down
(B) going up and speeding up
(C) going down and slowing down
(D) going down and speeding up

Ans **(A, D)**

Sol. If N < mg then N = m(g-a) $\Rightarrow$ elevator is going down with acceleration or elevator is going up with retardation.

Exercise # 1 SINGLE OBJECTIVE NEET LEVEL

1. A mass of 1 kg is suspended by a string A. Another string C is connected to its lower end (see figure). If a sudden jerk is given to C, then



(A) The porition AB of the string will break
(B) The porition BC of the string will break
(C) None of the strings will break
(D) The mass will start rotating

2. In the above question, if the string C is stretched slowly then
(A) The portion AB of the string will break
(B) The porition BC of the string will break
(C) None of the strings will break
(D) None of the above

3. A particle is moving with a constant speed along a staright line path. A force is not required to
(A) Increase its speed
(B) Decrease the momentum
(C) Change the direction
(D) Keep it moving with uniform velocity

4. A man getting down a running bus falls forward because
(A) Due to inertia of rest, road is left behind and man reaches forward
(B) Due to inertia of motion upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road.
(C) He leans forward as a matter of habbit.
(D) Of the combined effect of all the three factors stated in (A), (B) and (C)

5. When a bus suddenly takes a turn, the passangers are thrown outwards because of
(A) Inertia of direction
(B) Acceleration of motion
(C) Speed of motion
(D) Both (B) and (C)

6. If a bullet of mass 5 gm moving with velocity 100 m / sec. penetrates the wooden block upto 6 cm. Then the average force imposed by the bullet on the block is
(A) 8300 N (B) 417 N
(C) 830 N (D) Zero

7. A body of mass 0.4 kg straight at origin at t = 0 with a speed of 10m/s in the positive x-axis direction is subjected to a constant force F = 8N towards negative x-axis. Calculate the position of the particle after 25 seconds.
(A) –6000 m (B) –8000 m
(C) +4000 m (D) +7000 m

8. The velocity of a body of mass 20 kg decreases from 20 m/s to 5 m/s in a distance of 100 m. Force on the body is
(A) –27.5 N (B) –47.5 N
(C) –37.5 N (D) –67.5 N

9. The mass of a lift is 2000 kg. When the tension in the supporting cable is 28000 N, then its acceleration is
(A) 30 ms^{-2} downwards (B) 4 ms^{-2} upwards
(C) 4 ms^{-2} downwards (D) 14 ms^{-2} upwards

10. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m while applying the force and the ball goes upto 2m height further, find the magnitude of the force. Consider g = 10 m/s^2
(A) 16 N (B) 20 N
(C) 22 N (D) 4 N

11. Formula for true force is
(A) F = ma (B) $F = \frac{mdv}{dt}$
(C) $F = \frac{dmv}{dt}$ (D) $F = \frac{md^2x}{dt^2}$

12. A body of mass 4 kg is accelerated upon by a constant force, travels a distance of 5 m in the first second and a distance of 2 m in the third second. The force acting on the body is
(A) 6 N (B) 8 N
(C) 2 N (D) 4 N

Exercise # 2 SINGLE OBJECTIVE AIIMS LEVEL

1. A monkey is descending from the branch of a tree with constant acceleration. If the breaking strength of branch is 75% of the weight of the monkey, the minimum acceleration with which the monkey can slide down without breaking the branch is

(A) g (B) $\frac{3g}{4}$

(C) $\frac{g}{4}$ (D) $\frac{g}{2}$

2. A body of mass m_1 exerts a force on another body of mass m_2. If the magnitude of acceleration of m_2 is a_2, then the magnitude of the acceleration of m_1 is (considering only two bodies in space)

(A) Zero (B) $\frac{m_2 a_2}{m_1}$

(C) $\frac{m_1 a_2}{m_2}$ (D) a_2

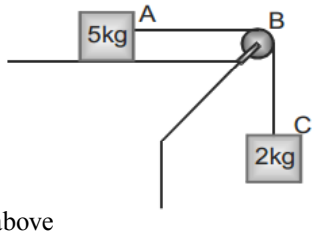
3. A trolley of mass 5 kg on a horizontal smooth surface is pulled by a load of mass 2 kg by means of uniform rope ABC of length 2 m and mass 1 kg. As the load falls from BC = 0 to BC = 2m. its acceleration in m/s^2 changes–

(A) $\frac{20}{6}$ to $\frac{20}{5}$

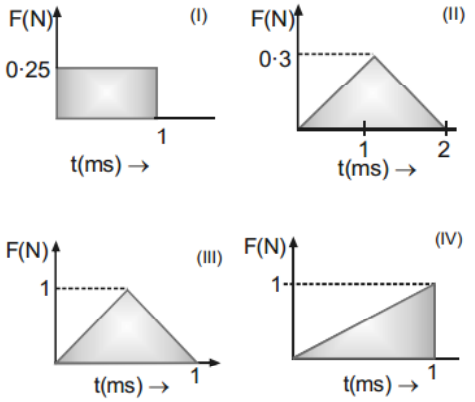
(B) $\frac{20}{8}$ to $\frac{30}{8}$

(C) $\frac{20}{5}$ to $\frac{30}{6}$

(D) None of the above



4. Figures I, II, III and IV depicts variation of force with time



In which situation impulse will be maximum

(A) I & II (B) III & I

(C) III & IV (D) Only IV

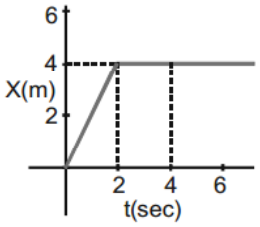
5. In the figure, the position–time graph of a particle of mass 0·1 kg is shown. The impulse at t=2 second is

(A) 0·2 $kgms^{-1}$

(B) –0·2 $kgms^{-1}$

(C) 0·1 $kgms^{-1}$

(D) –0·4 $kgms^{-1}$



6. A pulley is attached to the ceiling of a lift moving upwards. Two particles are attached to the two ends of a string passing over the pulley. The masses of the particles are in the ratio 2 : 1. If the acceleration of the particles is g/2, then the acceleration of the lift will be

(A) g (B) $\frac{g}{2}$

(C) $\frac{g}{3}$ (D) $\frac{g}{4}$

7. A monkey is sitting on the pan of a spring balance which is placed on an elevator. The maximum reading of the spring balance will be when :

(A) the elevator is stationary

(B) the string of the elevator breaks and it drops freely towards the earth

(C) the elevator is accelerated downwards

(D) the elevator is accelerated upwards.

8. A body kept on a smooth inclined plane inclination 1 in x will remain stationary relative to the inclined plane if the plane is given a horizontal acceleration equal to :–

(A) $\sqrt{x^2-1}\,g$ (B) $\frac{\sqrt{x^2-1}}{x}g$

(C) $\frac{gx}{\sqrt{x^2-1}}$ (D) $\frac{g}{\sqrt{x^2-1}}$

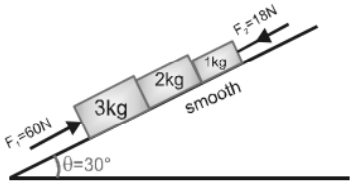
Exercise # 3 PART - 1 MATRIX MATCH COLUMN

Following question contains statements given in two columns, which have to be matched. The statements in **Column-I** are labelled as A, B, C and D while the statements in **Column-II** are labelled as p, q, r and s. Any given statement in **Column-I** can have correct matching with **one or more** statement(s) in **Column-II**.

1. Velocity of three particles A, B and C varies with time t as, $\vec{v}_A = (2t\hat{i} + 6\hat{j})$ m/s $\vec{v}_B = (3\hat{i} + 4\hat{j})$ m/s and $\vec{v}_C = (6\hat{i} - 4t\hat{j})$ m/s. Regarding the pseudo force match the following table :–

	Column I		Column II
(A)	On A as observed by B	(p)	Along positive x–direction
(B)	On B as observed by C	(q)	Along negative x–direction
(C)	On A as observed by C	(r)	Along positive y–direction
(D)	On C as observed by A	(s)	Along negative y–direction
		(t)	Zero

2. In the diagram shown in figure ($g = 10$ m/s^2)



	Column I		Column II
(A)	Acceleration of 2kg block	(p)	8 SI unit
(B)	Net force on 3kg block	(q)	25 SI unit
(C)	Normal reaction between 2kg and 1kg	(r)	2 SI unit
(D)	Normal reaction between 3kg and 2kg	(s)	45 N
		(t)	None

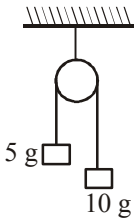
3. Match the following

	Column I		Column II
(A)	Friction is a	(P)	0 AND $\mu_k R$ where R is reaction force
(B)	Friction force is independent of	(Q)	Area of surface in contact
(C)	The value of static friction force lies between	(R)	Non-conservation force
(D)	Magnitude of static friction is always greater than	(S)	Kinetic friction
		(T)	$\mu_s R$ and $\mu_k R$
		(U)	Conservative force
		(V)	Rolling friction

Exercise # 4

PART - 1 | PREVIOUS YEAR (NEET/AIPMT)

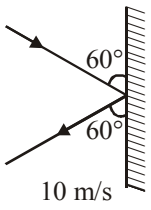
1. Two masses as shown in the figure are suspended from a massless pulley. The acceleration of the system when masses are left free is [2000]



(A) $\frac{2g}{3}$ (B) $\frac{g}{3}$

(C) $\frac{g}{9}$ (D) $\frac{g}{7}$

2. A body of mass 3 kg hits a wall at an angle of 60° and returns at the same angle. The impact time was 0.2 sec. The force exerted on the wall [2000]



(A) $150\sqrt{3}$ N

(B) $50\sqrt{3}$ N

(C) 100 N

(D) $75\sqrt{3}$ N

3. A 1 kg stationary bomb is exploded in three parts having mass 1 : 1 : 3 respectively. Parts having same mass move in perpendicular direction with velocity 30 m/s, then the velocity of bigger part will be

(A) $10\sqrt{2}$ m/sec (B) $\frac{10}{\sqrt{2}}$ m/sec [2001]

(C) $15\sqrt{2}$ m/sec (D) $\frac{15}{\sqrt{2}}$ m/sec

4. A cricketer catches a ball of mass 150 gm in 0.1 sec moving with speed 20 m/s, then he experiences force of [2001]

(A) 300 N (B) 30 N

(C) 3 N (D) 0.3 N

5. On the horizontal surface of a truck a block of mass 1 kg is placed (μ = 0.6) and truck is moving with acceleration 5 m/sec^2 then the frictional force on the block will be [2001]

(A) 5 N (B) 6 N

(C) 5.88 N (D) 8 N

6. 250 N force is required to raise 75 kg mass from a pulley. If rope is pulled 12 m then the load is lifted to 3 m, the efficiency of pulley system will be [2001]

(A) 25% (B) 33.3 %

(C) 75% (D) 90%

7. A block of mass 10 kg placed on rough horizontal surface having coefficient of friction μ = 0.5, if a horizontal force of 100 N acting on it then acceleration of the block will be [2002]

(A) 10 m/s^2 (B) 5 m/s^2

(C) 15 m/s^2 (D) 0.5 m/s^2

8. A lift of mass 1000 kg which is moving with acceleration of 1 m/s^2 in upward direction, then the tension developed in string which is connected to lift is [2002]

(A) 9800 N (B) 10,800 N

(C) 11,000 N (D) 10,000 N

9. A monkey of mass 20 kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope ? (g = 10 m/s^2) [2003]

(A) 5 m/s^2 (B) 10 m/s^2

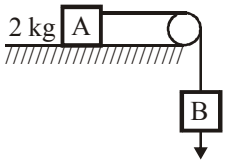
(C) 25 m/s^2 (D) 2.5 m/s^2

10. A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 m/s^2. What would be the reading on the scale ? (g = 10 m/s^2) [2003]

(A) zero (B) 400 N

(C) 800 N (D) 1200 N

11. The coefficient of static friction, μ_s, between block A of mass 2 kg and the table as shown in the figure is 0.2. What would be the two blocks do not move? The string and the pulley are assumed to be smooth and massless. (g = 10 m/s^2) [2004]



(A) 2.0 kg

(B) 4.0 kg

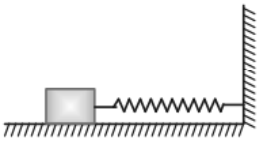
(C) 0.2 kg

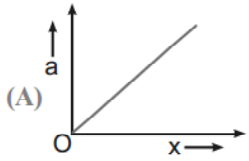
(D) 0.4 kg

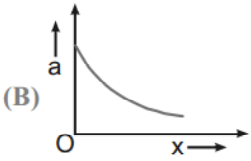
MOCK TEST

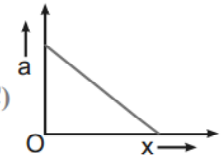
STRAIGHT OBJECTIVE TYPE

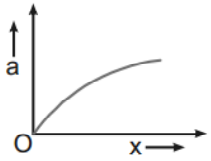
1. A light spring is compressed and placed horizontally between a vertical fixed wall and a block free to slide over a smooth horizontal table top as shown in the figure. The system is released from rest. The graph which represents the relation between the magnitude of acceleration ' a ' of the block and the distance ' x ' travelled by it (as long as the spring is compressed) is:



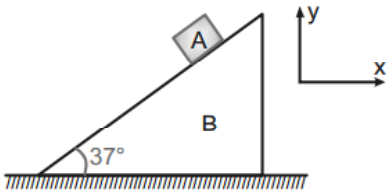
(A) 

(B) 

(C) 

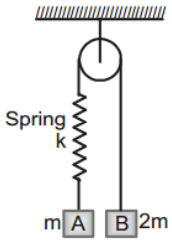
(D) 

2. In the figure shown the acceleration of A is, $\vec{a}_A = 15\hat{i}+15\hat{j}$ then the acceleration of B is: (A remains in contact with B)



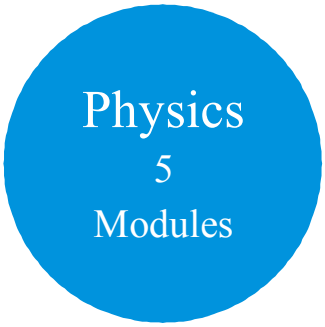
(A) $6\hat{i}$ (B) $-15\hat{i}$ (C) $-10\hat{i}$ (D) $-5\hat{i}$

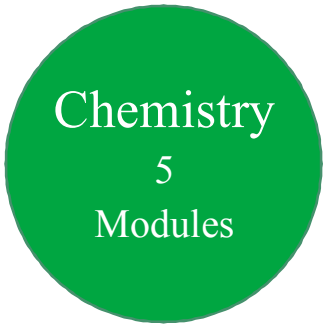
3. Two blocks A and B of masses m & 2m respectively are held at rest such that the spring is in natural length. Find out the accelerations of both the blocks just after release:

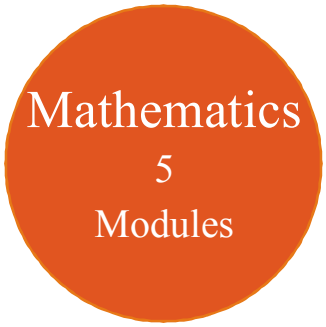


(A) $g\downarrow, g\downarrow$ (B) $\frac{g}{3}\downarrow, \frac{g}{3}\uparrow$ (C) $0, 0$ (D) $g\downarrow, 0$

11th Class Modules Chapter Details

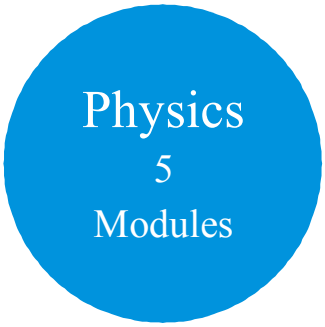


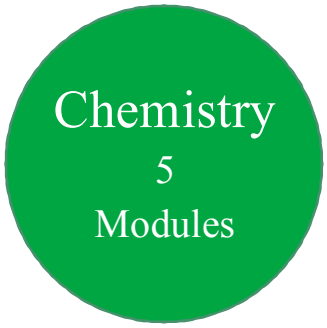


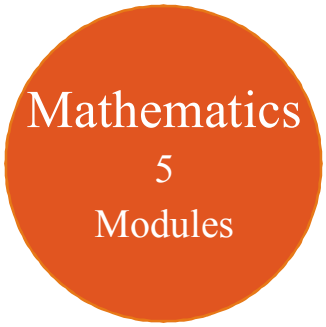


PHYSICS	CHEMISTRY	BIOLOGY
Module-1 1. Physical World & Measurements 2. Basic Maths & Vector 3. Kinematics **Module-2** 1. Law of Motion & Friction 2. Work, Energy & Power **Module-3** 1. Motion of system of particles & Rigid Body 2. Gravitation **Module-4** 1. Mechanical Properties of Matter 2. Thermal Properties of Matter **Module-5** 1. Oscillations 2. Waves	**Module-1(PC)** 1. Some Basic Conceps of Chemistry 2. Atomic Structure 3. Chemical Equilibrium 4. Ionic Equilibrium **Module-2(PC)** 1. Thermodynamics & Thermochemistry 2. Redox Reaction 3. States Of Matter (Gaseous & Liquid) **Module-3(IC)** 1. Periodic Table 2. Chemical Bonding 3. Hydrogen & Its Compounds 4. S-Block **Module-4(OC)** 1. Nomenclature of Organic Compounds 2. Isomerism 3. General Organic Chemistry **Module-5(OC)** 1. Reaction Mechanism 2. Hydrocarbon 3. Aromatic Hydrocarbon 4. Environmental Chemistry & Analysis Of Organic Compounds	**Module-1** 1. Diversity in the Living World 2. Plant Kingdom 3. Animal Kingdom **Module-2** 1. Morphology in Flowering Plants 2. Anatomy of Flowering Plants 3. Structural Organization in Animals **Module-3** 1. Cell: The Unit of Life 2. Biomolecules 3. Cell Cycle & Cell Division 4. Transport in Plants 5. Mineral Nutrition **Module-4** 1. Photosynthesis in Higher Plants 2. Respiration in Plants 3. Plant Growth and Development 4. Digestion & Absorption 5. Breathing & Exchange of Gases **Module-5** 1. Body Fluids & Its Circulation 2. Excretory Products & Their Elimination 3. Locomotion & Its Movement 4. Neural Control & Coordination 5. Chemical Coordination and Integration

12th Class Modules Chapter Details







PHYSICS

Module-1

1. Electrostatics
2. Capacitance

Module-2

1. Current Electricity
2. Magnetic Effect of Current and Magnetism

Module-3

1. Electromagnetic Induction
2. Alternating Current

Module-4

1. Geometrical Optics
2. Wave Optics

Module-5

1. Modern Physics
2. Nuclear Physics
3. Solids & Semiconductor Devices
4. Electromagnetic Waves

CHEMISTRY

Module-1(PC)

1. Solid State
2. Chemical Kinetics
3. Solutions and Colligative Properties

Module-2(PC)

1. Electrochemistry
2. Surface Chemistry

Module-3(IC)

1. P-Block Elements
2. Transition Elements (d & f block)
3. Co-ordination Compound
4. Metallurgy

Module-4(OC)

1. HaloAlkanes & HaloArenes
2. Alcohol, Phenol & Ether
3. Aldehyde, Ketone & Carboxylic Acid

Module-5(OC)

1. Nitrogen & Its Derivatives
2. Biomolecules & Polymers
3. Chemistry in Everyday Life

BIOLOGY

Module-1

1. Reproduction in Organisms
2. Sexual Reproduction in Flowering Plants
3. Human Reproduction
4. Reproductive Health

Module-2

1. Principles of Inheritance and Variation
2. Molecular Basis of Inheritance
3. Evolution

Module-3

1. Human Health and Disease
2. Strategies for Enhancement in Food Production
3. Microbes in Human Welfare

Module-4

1. Biotechnology: Principles and Processes
2. Biotechnology and Its Applications
3. Organisms and Populations

Module-5

1. Ecosystem
2. Biodiversity and Conservation
3. Environmental Issues