NEWTON'S LAW OF MOTION

Contents

Syllabus

Newton's Law of Motion ; Inertial and uniformly accelerated frames of reference.

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KEY CONCEPT

FORCE

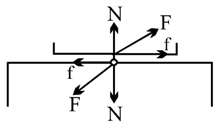
1. There are, basically, five forces, which are commonly encountered in mechanics.

(i) **Weight :** Weight of an object is the force with which earth attracts it. It is also called the force of gravity or the gravitational force.

(ii) **Contact Force :** When two bodies come in contact they exert forces on each other that is called contact forces.

(a) **Normal force (N) :** It is the component of contact force normal to the surface. It measures how strongly the surfaces in contact are pressed together.

(b) **Frictional force :** It is the component of contact force parallel to the surface. It opposes the relative motion (or attempted motion) of the two surfaces in contact.



(iii) **Tension :** The force exerted by the end of a taut string, rope or chain is called the tension. The direction of tension is to pull the body while that of normal reaction is to push the body.

(iv) **Spring force :** The force exerted by a spring is given by F = – kx, where x is the change in length and k is the stiffness constant or spring constant (units Nm^{-1}).

NEWTON'S LAWS

2. **Newton's First Law :** Every particle continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by the action of an applied force.

3. **Newton's Second Law :** $\vec{F}_{net} = m\vec{a}$

4. **Newton's Third Law :** Whenever two bodies interact they exert forces on each other which are equal in magnitude and opposite in direction. So whenever body A exerts a force F on body B, B exerts a force – F on A.

Inertial Reference Frame : A reference frame in which Newton’s first law is valid is called an inertial reference frame. An inertial frame is either at rest or moving with uniform velocity.

Non-Inertial Frame : An accelerated frame of reference is called a non-inertial frame. Objects in non-inertial frames do not obey Newton’s first law.

Pseudo Force : It is an imaginary force which is recognized only by a non-inertial observer to explain the physical situation according to Newton’s law. The magnitude of this force F_P is equal to the product of the mass m of the object and acceleration a of the frame of reference. The direction of the force is opposite to the direction of acceleration.

$$F_P = -ma$$

EXERCISE # 1

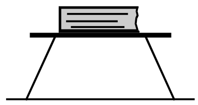
PART - I : OBJECTIVE QUESTIONS

*** Marked Questions are having more than one correct option.***

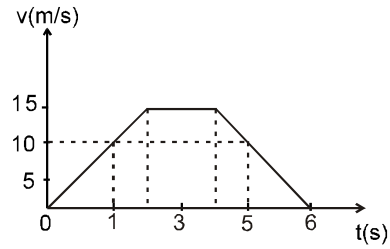
Section (A) : Force

A-1 A book is at rest on a table. What is the "reaction" force according to Newton's third law to the gravitational force by the earth on the book?

(A) the normal force exerted by the table on the book
(B) the normal force exerted by the table on the ground
(C) the normal force exerted by the ground on the table
(D) the gravitational force exerted on the earth by the book

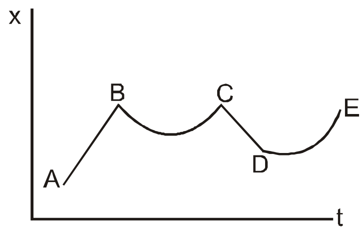


A-2 A particle of mass 100 gram moves on a straight line. The variation of speed with time is shown in figure. Find the force acting on the particle at t = 1, 3 and 5 seconds.



(A) 2 N, 0 , -1 N (B) 2 N, 0 , -2 N
(C) 1 N, 0 , -1 N (D) none of these

A-3* Figure shows the displacement of a particle going along the X-axis as a function of time. The force acting on the particle is zero in the region



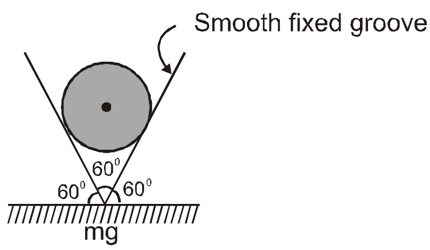
(A) AB (B) BC
(C) CD (D) DE

A-4 A 3.0 kg mass is moving in a plane, with its x and y coordinates given by $x = 5t^2 - 1$ and $y = 3t^3 + 2$, where x and y are in meters and t is in second. Find the magnitude of the net force acting on this mass at t = 2 sec.

(A) 112.08 N (B) 40N (C) 50N (D) 60N

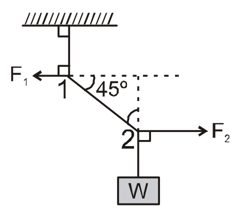
Section (B) : Equilibrium

B-1. A cylinder of weight w is resting on a fixed V-groove as shown in figure. Calculate normal reactions between the cylinder and two inclined walls.



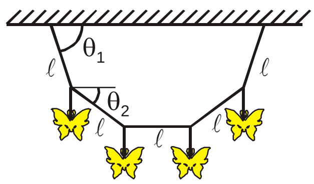
(A) w,w (B) w/2,w/2
(C) w,w/2 (D) w/2,w

B-2. In the figure the tension in the string between 1 and 2 is 60 N. Find the magnitude of the horizontal force $\vec{F}_1$ and $\vec{F}_2$ that must be applied to hold the system in the position shown.



(A) $|\vec{F}_1| = |\vec{F}_2| = 40\sqrt{2}$ N (B) $|\vec{F}_1| = |\vec{F}_2| = 30\sqrt{2}$ N
(C) $|\vec{F}_1| = |\vec{F}_2| = 10\sqrt{2}$ N (D) $|\vec{F}_1| = |\vec{F}_2| = 20\sqrt{2}$ N

B-3. Four identical metal butterflies are hanging from a light string of length 5ℓ at equally placed points as shown. The ends of the string are attached to a horizontal fixed support. The middle section of the string is horizontal. The relation between the angle θ_1 and θ_2 is given by



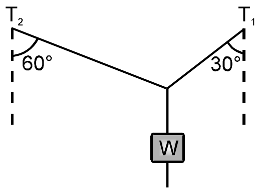
(A) $\sin\theta_1 = 2\sin\theta_2$ (B) $2\cos\theta_1 = \sin\theta_2$

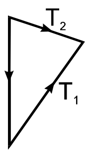
(C) $\tan\theta_1 = 2\tan\theta_2$ (D) $\theta_2 < \theta_1$ and no other conclusion can be derived.

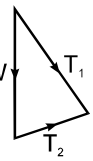
B-4. Two persons are holding a rope of negligible weight tightly at its ends so that it is horizontal. A 15 kg weight is attached to the rope at the mid point which now no longer remains horizontal. The minimum tension required to completely straighten the rope is :

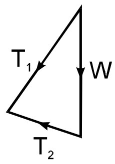
(A) 15 kg (B) $\frac{15}{2}$ kg (C) 5 kg (D) Infinitely large (or not possible)

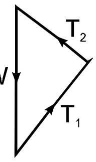
B-5. A weight W is supported by two strings inclined at 60° and 30° to the vertical. The tensions in the strings are T_1 & T_2 as shown. If these tensions are to be determined in terms of W using a triangle of forces, which of these triangles should you draw? (block is in equilibrium)



(A) 

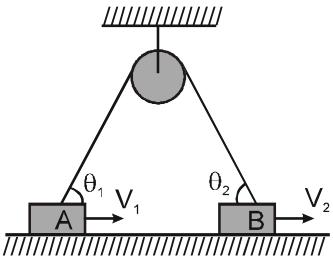
(B) 

(C) 

(D) 

Section (C) : Constrained motion

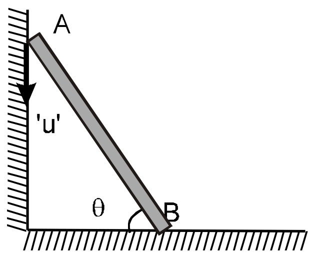
C-1. In the figure shown, blocks A and B move with velocities v_1 and v_2 along horizontal direction. Find the ratio of $\frac{v_1}{v_2}$.



(A) $\frac{\cos\theta_2}{\cos\theta_1}$ (B) $\frac{\cos\theta_1}{\cos\theta_2}$

(C) $\frac{\sin\theta_2}{\sin\theta_1}$ (D) $\frac{\tan\theta_2}{\tan\theta_1}$

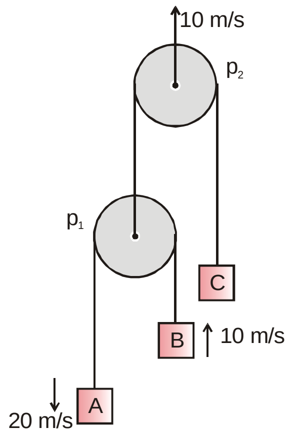
C-2. The velocity of end 'A' of rigid rod placed between two smooth vertical walls moves with velocity 'u' along vertical direction. Find out the velocity of end 'B' of that rod, rod always remains in contact with the vertical walls.



(A) u cot θ (B) u sec θ

(C) u cos θ (D) u tan θ

C-3. Velocities of blocks A, B and pulley p_2 are shown in figure. Find velocity of pulley p_1 and block C.



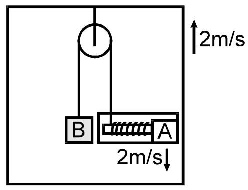
(A) $V_{P_1} = 10$ m/s ↓ , $V_C = 25$ m/s↑

(B) $V_{P_1} = 5$ m/s ↑ , $V_C = 25$ m/s↑

(C) $V_{P_1} = 5$ m/s ↓ , $V_C = 25$ m/s ↓

(D) $V_{P_1} = 5$ m/s ↓ , $V_C = 25$ m/s ↑

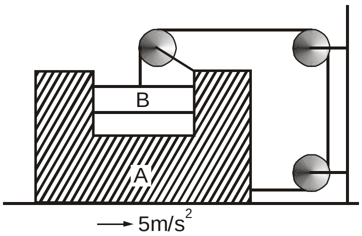
C-4. In the figure shown the velocity of lift is 2 m/s while string is winding on the motor shaft with velocity 2 m/s and block A is moving downwards with a velocity of 2 m/s, then find out the velocity of block B.



(A) 2 m/s ↑ (B) 2 m/s ↓

(C) 4 m/s ↑ (D) 8 m/s ↑

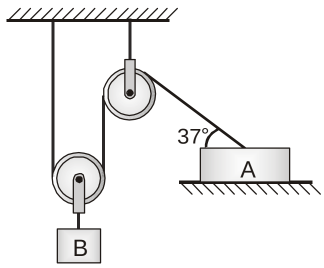
C-5. If block A is moving with an acceleration of 5 m/s^2, the acceleration of B w.r.t. ground is :



(A) 5 m/s^2 (B) $5\sqrt{2}$ m/s^2

(C) $5\sqrt{5}$ m/s^2 (D) 10 m/s^2

C-6. In the figure shown the block B moves down with a velocity 10 m/s. The velocity of A in the position shown is :



(A) 12.5 m/s

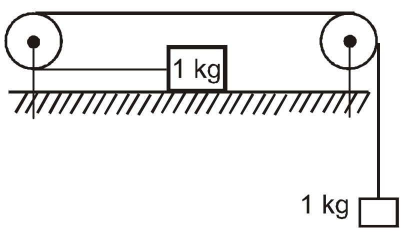
(B) 25 m/s

(C) 6.25 m/s

(D) none of these

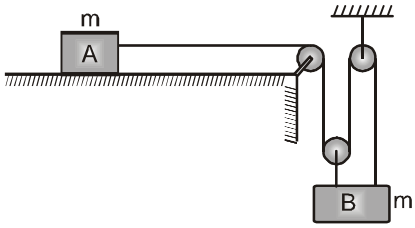
Section (D) : Calculation of Force and Acceleration

D-1. A block of mass 1 kg is connected by a light string passing over two smooth pulleys placed on a smooth horizontal surface as shown. Another bolck of 1 kg is connected to the other end of the string then acceleration of the system and tension in the string are



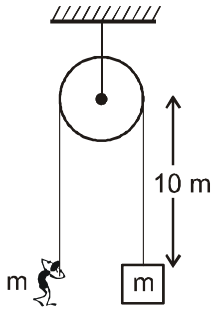
(A) 5 ms^{-2} , 5 N (B) 1 ms^{-2} , 1 N (C) 1 ms^{-2} , 5 N (D) 5 ms^{-2} , 10 N

D-2. In the figure shown all contact surfaces are smooth. Acceleration of B block will be ($g = 10\ m/s^2$) :



(A) $1\ m/s^2$ (B) $2\ m/s^2$ (C) $3\ m/s^2$ (D) none of these

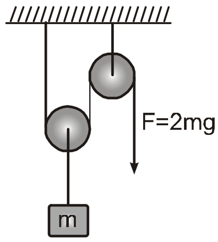
D-3. A boy and a block, both of same mass, are suspended at the same horizontal level, from each end of a light string that moves over a frictionless pulley as shown. The boy starts moving upwards with an acceleration $2.5\ m/s^2$ relative to the rope. If the block is to travel a total distance 10 m before reaching at the pulley, the time taken by the block in doing so is equal to :



(A) $\sqrt{8}$ s (B) 4s

(C) $\frac{10}{\sqrt{2}}$ s (D) 8s

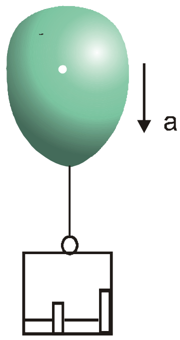
D-4. In the shown mass pulley system, string is massless. The one end of the string is pulled by the force F = 2mg. The acceleration of the block will be(mass of pulley is m)



(A) g/2 (B) 0

(C) g (D) 3g

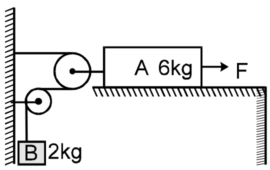
D-5. A baloon and a bucket of combined mass m starts coming down with a constant acceleration a. Determine the ballast mass to be released for the combined system to have an upward acceleration of same magnitude. Neglect air drag.



(A) $\frac{2ma}{a+g}$ (B) $\frac{ma}{a-g}$

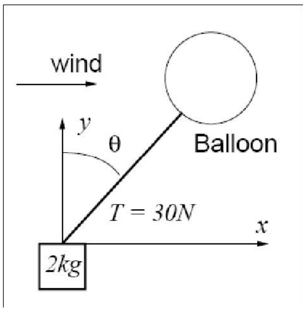
(C) $\frac{ma}{a+g}$ (D) $\frac{2ma}{g-a}$

D-6. The system starts from rest and A attains a velocity of 5 m/s after it has moved 5 m towards right. Assuming the arrangement to be frictionless every where and pulley & strings to be light, the value of the constant force F applied on A is :



(A) 50 N (B) 75 N (C) 100 N (D) 96 N

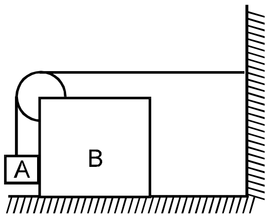
D-7. A balloon is tied to a block. The mass of the block is 2kg. The tension of the string between the balloon and the block is 30N. Due to the wind, the string has an angle θ relative to the vertical direction. $\cos\theta = 4/5$ and $\sin\theta = 3/5$. Assume the acceleration of gravity is $g = 10\ m/s^2$. Also assume the block is small so the force on the block from the wind can be ignored. Then the x-component and the y-component of the acceleration a of the block.



(A) $9\ m/s^2$, $2\ m/s^2$ (B) $9\ m/s^2$, $12\ m/s^2$

(C) $18\ m/s^2$, $2\ m/s^2$ (D) $18\ m/s^2$, $12\ m/s^2$

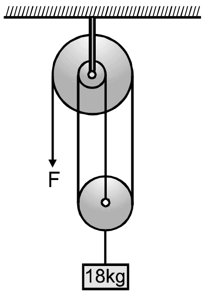
D-8. The system is released from rest from the position shown in the diagram. If A and B have mass m and M respectively and all surfaces are smooth, then the normal reaction between A and B is (string and pulley are massless)



(A) $\frac{2Mm}{(M+m)}$ (B) $\frac{Mmg}{2(M+m)}$

(C) $\frac{Mmg}{(M+m)}$ (D) zero

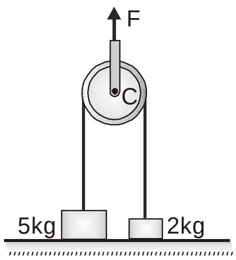
D-9. In the figure, at the free end of the light string, a force F is applied to keep the suspended mass of 18 kg at rest. Then the force exerted by the ceiling on the system (assume that the string segments are vertical and the pulleys are light and smooth) is: ($g = 10\ m/s^2$)



(A) 60 N (B) 120 N

(C) 180 N (D) 240 N

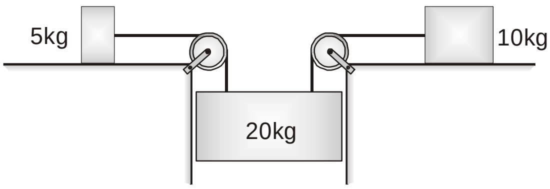
D-10. Two blocks of masses 5 kg and 2 kg (see fig.) are initially at rest on the floor. They are connected by a light string, passing over a light frictionless pulley. An upward force F is applied on the pulley and maintained constant. Calculate the acceleration a_1 and a_2 of the 5 kg and 2 kg masses, respectively, when F is 110 N ($g = 10\ ms^{-2}$).



(A) $a_1 = 1\ ms^{-2}$, $a_2 = 17.5\ ms^{-2}$ (B) $a_1 = 1\ ms^{-2}$, $a_2 = 0$

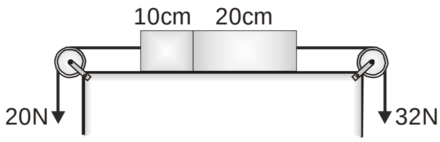
(C) $a_1 = 2\ ms^{-2}$, $a_2 = 17.5\ ms^{-2}$ (D) $a_1 = 2\ ms^{-2}$, $a_2 = 0$

D-11. In the system shown in figure all the surfaces are smooth. The 20 kg block is prevented from rotating, i.e. comes straight down. Find its acceleration



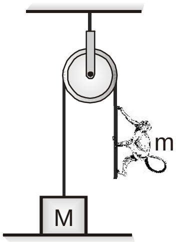
(A) $a = 5\ m/s^2$ (B) $a = 5.6\ m/s^2$ (C) $a = 6\ m/s^2$ (D) $a = 4\ m/s^2$

D-12. Figure shows a uniform block of length 30 cm having a mass of 3kg. The strings shows in figure are pulled by constant force of 20 N and 32 N. All the surface are smooth and the strings and the pulley are light. Which of the following is correct :



(A) the acceleration is 8 m/s^2
(B) the force exerted by the 20 cm part of the rod on the 10cm part is 32 N
(C) the force exerted by the 20 cm part of the rod on the 10 cm part is 20 N
(D) the force exerted by the 20 cm part of the rod on the 10 cm part is 24 N

D-13. In the figure the block of mass M is at rest on the floor. The acceleration with which a monkey of mass m should climb up along the rope of negligible mass so as to lift the block from the floor is :

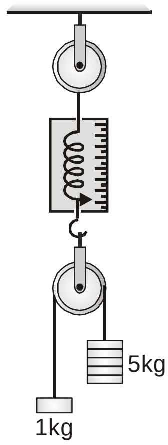


(A) $= \left(\frac{M}{m} - 1\right)g$
(B) $> \left(\frac{M}{m} - 1\right)g$
(C) $\frac{M}{m}g$
(D) $> \frac{M}{m}g$

D-14. A rod of length L and mass M is pulled by a force F_1 at its one end. Find tension at a distance y from the end where F_1 acts.
(A) F_1 (1 – y/L)
(B) F_1 (y/L)
(C) F_1 (1 + y/L)
(D) None of these

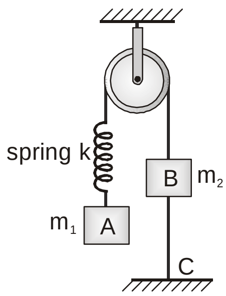
Section (E) : Weighing machine, Spring related problems and Spring balance

E-1. A frictionless pulley of negligible weight is suspended from a spring balance. Masses of 1 kg and 5 kg are tied to the two ends of a string which passes over the pulley. The masses move due to gravity. During motion, the reading of the spring balance will be :



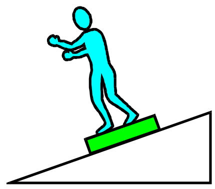
(A) $\frac{5}{3}$ kg wt
(B) $\frac{10}{3}$ kg wt
(C) 6 kg wt
(D) 3 kg wt

E-2.* In the system shown in figure, $m_1 > m_2$. System is held at rest by thread BC. Just after the thread BC is burnt :



(A) acceleration of m_2 will be upwards
(B) magnitude of acceleration of both blocks will be equal to $\left(\frac{m_1 - m_2}{m_1 + m_2}\right)g$
(C) acceleration of m_1 will be equal to zero
(D) magnitudes of acceleration of two blocks will be non-zero and unequal

E-3. A person of mass M is placed on a weighing scale at the top of the wedge as shown in the fig. The weighing scale is on a frictionless inclined plane which makes an angle θ with the horizontal. The reading in the weighing scale is:



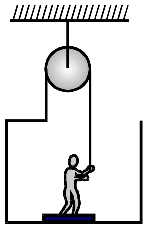
(A) Mg $\cos\theta$

(B) Mg $\cos^2\theta$

(C) Mg

(D) insufficient information

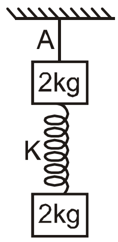
E-4. Figure shows a man of mass 50 kg standing on a light weighing machine kept in a box of mass 30 kg. The box is hanging from a pulley fixed to the ceiling through a light rope, the other end of which is held by the man himself. If the man manages to keep the box at rest, the weight shown by the machine is _______ N.



(A) 100 N (B) 150 N

(C) 200 N (D) 50 N

E-5. Two blocks of mass 2 kg are connected by a massless ideal spring of spring constant K = 10 N/m. The upper block is suspended from roof by a light string A. The system shown is in equilibrium. The string A is now cut, the acceleration of upper block just after the string A is cut will be ($g = 10\ m/s^2$)



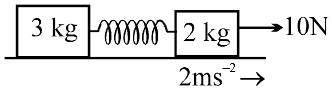
(A) $0\ m/s^2$ (B) $10\ m/s^2$

(C) $15\ m/s^2$ (D) $20\ m/s^2$

E-6. A spring of force constant k is cut into two pieces such that one piece such that one piece is double the length of the other. Then the long piece will have a force constant of

(A) (2/3) k (B) (3/2) k (C) 3k (D) 6k

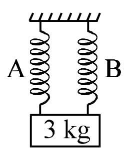
E-7. Find the acceleration of 3 kg mass when acceleration of 2 kg mass is $2\ ms^{-2}$ as shown in figure.



(A) $3\ ms^{-2}$ (B) $2\ ms^{-2}$

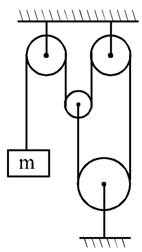
(C) $0.5\ ms^{-2}$ (D) zero

E-8. Block of 1 kg is initially in equilibrium and is hanging by two identical springs A and B as shown in figures. If spring A is cut from lower point at t=0 then, find acceleration of block in ms^{-2} at t = 0.



(A) 5 (B) 10 (C) 15 (D) 0

E-9. If the string & all the pulleys are ideal, acceleration of mass m is



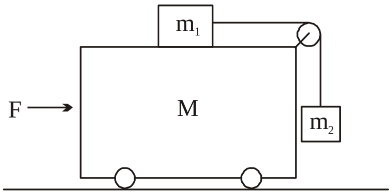
(A) $\frac{g}{2}$ (B) 0

(C) g (D) dependent on m

Section (F) : Pseudo Force

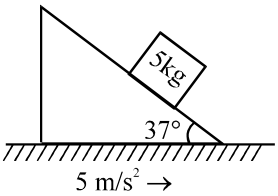
F-1.* In which of the following situations would a force of 9.8 N act on a stone of mass 1 kg : (Neglect air resistance)
(A) just after it is dropped from the window of a stationary train
(B) just after it is dropped from the window of a train running at a constant speed of 36 km/hour
(C) just after it is dropped from the window of a train accelerating at 1 ms^{-2}
(D) when it is lying at rest on the floor of a train which is accelerating at 1 ms^{-2}

F-2. What horizontal force (in Newton) must be applied to the cart shown in figure in order that the blocks remain stationary relative to the cart? Assume all surfaces, wheels, and pulley are frictionless. (M = 7kg , m_1 = 2kg , m_2 = 1kg)



(A) 50 (B) 55
(C) 60 (D) 40

F-3. Inclined plane is moved towards right with an acceleration of 5 ms^{-2} as shown in figure. Find force in newton which block of mass 5 kg exerts on the incline plane. (All surfaces are smooth)



(A) 50 (B) 55
(C) 60 (D)40

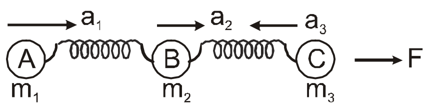
F-4. Inside a horizontally moving box, an experimenter (who is stationary relative to box) finds that when an object is placed on a smooth horizontal table and is released, it moves with an acceleration of 10 m/s^2. In this box if 1 kg body is suspended with a light string, the tension in the string in equilibrium position. (w.r.t. experimenter) will be. (Take g = 10 m/s^2)

(A) 10 N (B) $10\sqrt{2}$ N (C) 20 N (D) zero

F-5. A smooth wedge A is fitted in a chamber haging from a fixed ceiling near the earth's surface. A block B placed at the top of the wedge takes a time T to slide down the length of the wedge. If the block is placed at the top of the wedge and the cable supporting the chamber is broken at the same intant, the block will
(A) take a time longer than T to slide down the wedge.
(B) take a time shorter than T to slide down th wedge.
(C) remain at the top of the wedge.
(D) jump off the wedge.

Section (G) Newton's law for a system

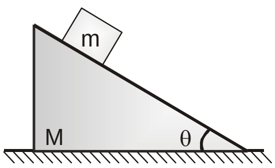
G-1. Shown in the figure is a system of three particles of mass 1 kg, 2 kg and 4 kg connected by two springs. The acceleration of A, B and C at an instant are 1 m/sec^2, 2 m/sec^2 and 1/2 m/sec^2 respectively directed as shown in the figure external force acting on the system is :



(A) 1 N (B) 7 N (C) 3 N (D) 2N

G-2. A block of mass m is released from the top of a wedge of mass M as shown in figure. All the surface are smooth. Let N be the normal reaction between the ground and the wedge, then :

(A) N = (M + m) g
(B) N > (m + M) g
(C) N < (M + m) g
(D) $N \le (M + m)g$

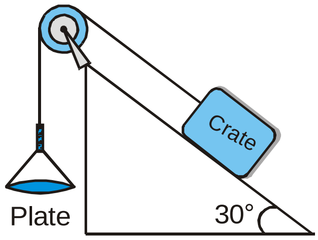


PART - II : MISCELLANEOUS OBJECTIVE QUESTIONS

COMPREHENSIONS

COMPREHENSIONS # 1

A moving company uses the pulley system in figure to lift heavy crates up a ramp. The ramp is coated with rollers that make the crate's motion essentially frictionless. A worker piles cinder blocks onto the plate until the plate moves down, pulling the crate up the ramp. Each cinder block has mass 10 kg. The plate has mass 5 kg. The rope is nearly massless, and the pulley is essentially frictionless. The ramp makes a 30° angle with the ground. the crate has mass 100 kg.



Let W_1 denote the combined weight of the plate and the cinder blocks piled on the plate. Let T denote the tension in the rope. And let W_2 denote the crate's weight.

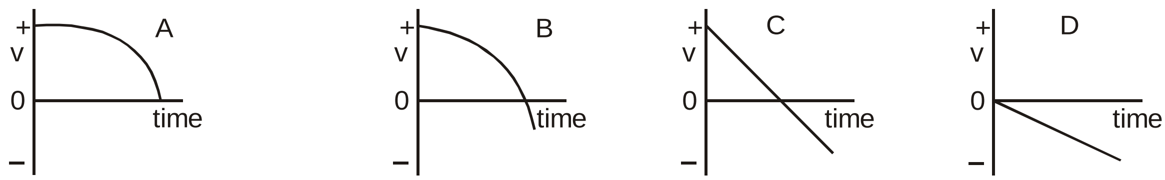
1. What is the smallest number of cinder blocks that need to be placed on the plate in order to lift the crate up the ramp?
(A) 3 (B) 5 (C) 7 (D) 10

2. Ten cinder blocks are placed on the plate. As a result, the crate accelerates up the ramp. Which of the following is true?
(A) $W_1 = T = W_2 \sin 30°$ (B) $W_1 = T > W_2 \sin 30°$
(C) $W_1 > T = W_2 \sin 30°$ (D) $W_1 > T > W_2 \sin 30°$

3. The ramp exerts a "normal" force on the crate, directed perpendicular to the ramp's surface. This normal force has magnitude:
(A) W_2 (B) $W_2 \sin 30°$ (C) $W_2 \cos 30°$ (D) $W_2 (\sin 30° + \cos 30°)$

4. The net force on the crate has magnitude:
(A) $W_1 - W_2 \sin 30°$ (B) $W_1 - W_2$ (C) $T - W_2 \sin 30°$ (D) $T - W_2$

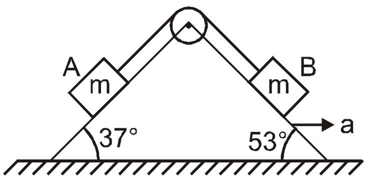
5. After the crate is already moving, the cinder blocks suddenly fall off the plate. Which of the following graphs best shows the subsequent velocity of the crate, *after* the cinder blocks have fallen off the plate? (Up the-ramp is the positive direction.)



(A) A (B) B (C) C (D) D

COMPREHENSIONS # 2

Two blocks A and B of equal masses m kg each are connected by a light thread, which passes over a massless pulley as shown. Both the blocks lie on wedge of mass m kg. Assume friction to be absent everywhere and both the blocks to be always in contact with the wedge. The wedge lying over smooth horizontal surface is pulled towards right with constant acceleration a (m/s^2).
(g is acceleration due to gravity).



6. Normal reaction (in N) acting on block B is

(A) $\frac{m}{5}(3g + 4a)$ (B) $\frac{m}{5}(3g - 4a)$ (C) $\frac{m}{5}(4g + 3a)$ (D) $\frac{m}{5}(4g - 3a)$

7. Normal reaction (in N) acting on block A.

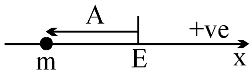
(A) $\frac{m}{5}(3g + 4a)$ (B) $\frac{m}{5}(3g - 4a)$ (C) $\frac{m}{5}(4g + 3a)$ (D) $\frac{m}{5}(4g - 3a)$

8. The maximum value of acceleration a (in m/s^2) for which normal reactions acting on the block A and block B are nonzero.

(A) $\frac{3}{4}g$ (B) $\frac{4}{3}g$ (C) $\frac{3}{5}g$ (D) $\frac{5}{3}g$

COMPREHENSIONS # 3

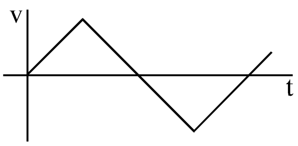
A particle of mass m is constrained to move on x-axis. A force F acts on the particle. F always points toward the position labeled E. For example, when the particle is to the left of E, F points to the right. The magnitude of F is a constant F except at point E where it is zero.
The system is horizontal. F is the net force acting on the particle. The particle is displaced a distance A towards left from the equilibrium position E and released from rest at t = 0.
Take point E at x = 0.

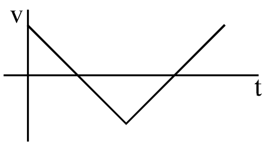


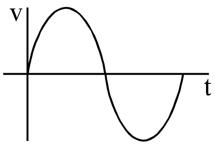
9. If the time taken by the particle to return to the initial point is considered to be the time period, what is the period of the motion?

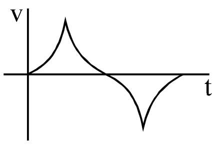
(A) $4\left(\sqrt{\frac{2Am}{F}}\right)$ (B) $2\left(\sqrt{\frac{2Am}{F}}\right)$ (C) $\left(\sqrt{\frac{2Am}{F}}\right)$ (D) None

10. Velocity – time graph of the particle is

(A)


(B)


(C)


(D)


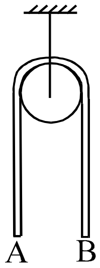
11. Find minimum time it will take to reach from $x = -\frac{A}{2}$ to 0.

(A) $\frac{3}{2}\sqrt{\frac{mA}{F}}(\sqrt{2}-1)$ (B) $\sqrt{\frac{mA}{F}}(\sqrt{2}-1)$ (C) $2\sqrt{\frac{mA}{F}}(\sqrt{2}-1)$ (D) None

COMPREHENSIONS # 4

A uniform chain of length 2L is hanging in equilibrium position, if end B is given a slightly downward displacement the imbalance causes an acceleration. Here pulley is small and smooth & string is inextensible

12. The acceleration of end B when it has been displaced by distance x, is



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

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

13. The velocity v of the string when it slips out of the pulley (height of pulley from floor > 2L)

(A) $\sqrt{\frac{gL}{2}}$ (B) $\sqrt{2gL}$ (C) $\sqrt{gL}$ (D) none of these

MATCH THE COLUMN

14. In the diagram shown in figure, match the following : (g = 10 m/s²)

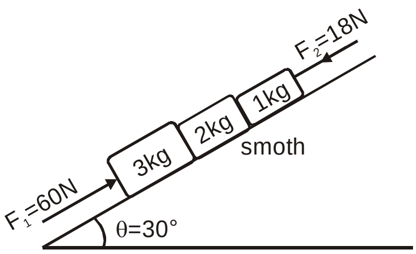


Table-1	Table-2
(A) Acceleration of 2 kg block in m/s^2	(p) 8
(B) Net force on 3 kg block in N	(q) 25
(C) Normal reaction between 2 kg and 1 kg in N	(r) 2
(D) Normal reaction between 3 kg and 2 kg in N	(s) 45
	(t) None

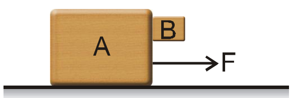
ASSERTION/REASON

Direction :

Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.
(E) Statement-1 and Statement-2 both are False.

15. **STATEMENT-1 :** Block A is moving on horizontal surface towards right under action of force F . All surfaces are smooth. At the instant shown the force exerted by block A on block B is equal to net force on block B.



STATEMENT-2 : From Newton's third law, the force exerted by block A on B is equal in magnitude to force exerted by block B on A.

16. **STATEMENT-1 :** A body in equilibrium may not be at rest.
STATEMENT-2 : When a body is at rest, it must be in equilibrium.

17. **STATEMENT-1 :** A rocket moves forward by pushing the surrounding air backwards.
STATEMENT-2 : Every action has an equal & opposite reaction.

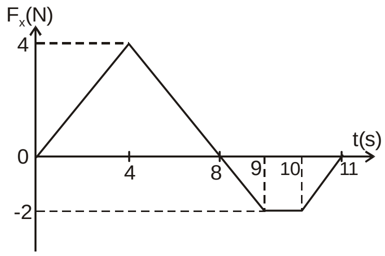
18. **STATEMENT-1 :** Non zero work has to be done on a moving particle to change its momentum.
STATEMENT-2 : To change momentum of a particle a non zero net force should act on it.

EXERCISE # 2

PART - I : OBJECTIVE QUESTIONS

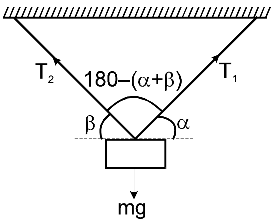
SINGLE CORRECT ANSWER TYPE

1. A 2 kg toy car can move along an x axis. Graph shows force F_x, acting on the car which begins at rest at time t = 0. The velocity of the particle at t = 10 s is :



(A) – i m/s (B) – 1.5 i m/s (C) 6.5 i m/s (D) 13 i m/s

2. A body of mass m is suspended by two strings making angle α and β with the horizontal as shown in figure. Find the tension in the strings.



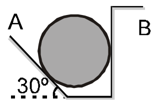
(A) $T_1 = \dfrac{mg\cos\beta}{\sin(\alpha+\beta)} = T_2$

(B) $T_1 = T_2 = \dfrac{mg\sin\beta}{\sin(\alpha+\beta)}$

(C) $T_1 = \dfrac{mg\cos\beta}{\sin(\alpha+\beta)}$, $T_2 = \dfrac{mg\cos\alpha}{\sin(\alpha+\beta)}$

(D) none of these

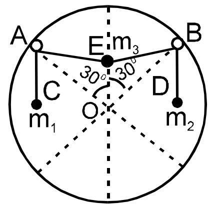
3. The 50 kg homogeneous smooth sphere rests on the 30º incline A and bears against the smooth vertical wall B. Calculate the contact forces at A and B.



(A) $N_A = \dfrac{1000}{\sqrt{3}}$ N, $N_B = \dfrac{500}{\sqrt{3}}$ N (B) $N_B = \dfrac{1000}{\sqrt{3}}$ N, $N_A = \dfrac{500}{\sqrt{3}}$ N

(C) $N_A = \dfrac{500}{\sqrt{3}}$ N, $N_B = \dfrac{500}{\sqrt{3}}$ N (D) None of these

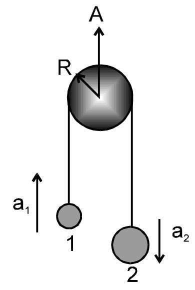
4. Two massless rings slide on a smooth circular loop of the wire whose axis lies in a horizontal plane. A smooth massless inextensible string passes through the rings, which carries masses m_1 & m_2 at the two ends and mass m_3 between the rings. If there is equilibrium when the line connnecting each ring with centre substends an angle 30^0 with vertical as shown in figure. Then the ratio of masses are:



(A) $m_1 = 2m_2 = m_3$ (B) $2m_1 = m_2 = 2m_3$

(C) $m_1 = m_2 = m_3$ (D) None of these

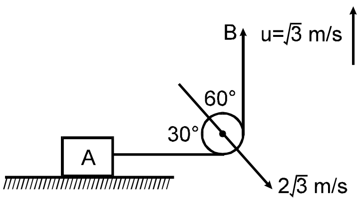
5. Two masses are connected by a string which passes over a pulley accelerating upward at a rate A as shown. If a_1 and a_2 be the acceleration of bodies 1 and 2 respectively then :



(A) $A = a_1 - a_2$ (B) $A = a_1 + a_2$

(C) $A = \frac{a_1 - a_2}{2}$ (D) $A = \frac{a_1 + a_2}{2}$.

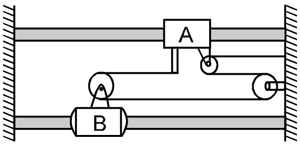
6. A system is shown in the figure. End B of string is moving upwards with $\sqrt{3}$ m/s. Pulley is moving with speed $2\sqrt{3}$ m/s in direction shown in the figure. Then velocity of the block A will be:



(A) $\sqrt{3}$ m/s (B) 3 m/s

(C) $3 + 2\sqrt{3}$ m/s (D) $3 + \sqrt{3}$ m/s

7. Collar A starts from rest & moves to the left with a constant acceleration. Knowing that after 30 s, the relative velocity of collar B w.r.t. collar A is 900 mm/s, determine the accelerations of A and B.



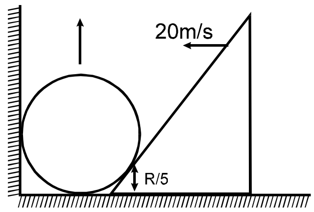
(A) a_A= 20 mm/s , a_B= 10 mm/s

(B) a_A= 10 mm/s , a_B= 10 mm/s

(C) a_A= 20 mm/s , a_B= 20 mm/s

(D) a_A= 30 mm/s , a_B= 30 mm/s

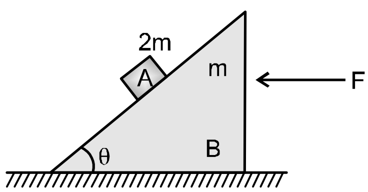
8. A sphere of radius R is in contact with a wedge. The point of contact is R/5 from the ground as shown in the figure. Wedge is moving with velocity 20 m/s, then the velocity of the sphere at this instant will be:



(A) 20 m/s (B) 15 m/s

(C) 5 m/s (D) 10 m/s

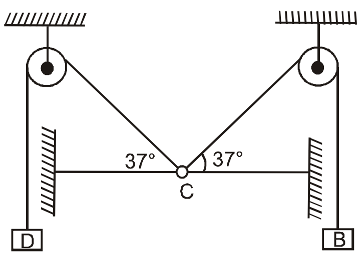
9. In the figure if block A and wedge B will move with same acceleration, then the magnitude of normal reaction between the block and the wedge will be (There is no friction between block and the wedge and the wedge moves on horizontal surface as shown.)



(A) $2 \text{ mg}/\cos\theta$ (B) $2 \text{ mg} \cos\theta$

(C) $\text{mg} \cos\theta$ (D) none of these

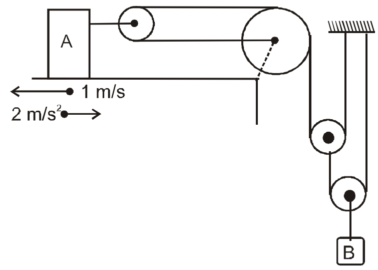
10. A bead C can move freely on a horizontal rod. The bead is connected by blocks B and D by strings as shown in the figure. If the velocity of B is v. Find the velocity of block D.



(A) v/3 (B) 4v/3

(C) v (D) 3v/4

11. In the given figure find the velocity and acceleration of B, if instantaneous velocity and acceleration of A are as shown in the figure.



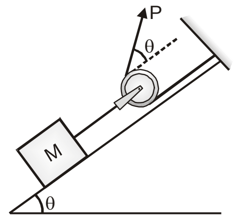
(A) v = 0.5 m/s, a = $1 m/s^2$

(B) v = 1 m/s, a = $2 m/s^2$

(C) v = 2 m/s, a = $4 m/s^2$

(D) v = 1 m/s, a = $1 m/s^2$

12. What should be the minimum force P to be applied to the string so that block of mass M just begins to move up the frictionless plane :



(A) Mg tan $\frac{\theta}{2}$ (B) Mg cot $\frac{\theta}{2}$

(C) $\frac{Mg\cos\theta}{1+\sin\theta}$ (D) none

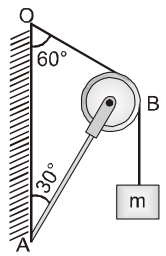
13. A 10 kg monkey is climbing a massless rope attached to a 15 kg mass over a smooth tree limb. The mass is lying on the ground. In order to raise the mass from the ground he must climb with :

(A) acceleration greater than 5 m/sec^2 (B) acceleration greater than 2.5 m/sec^2

(C) high speed (D) acceleration greater than 10 m/sec^2

14. AB is a light rod and OAB is the light string on the pulley.

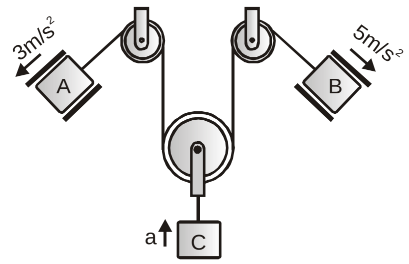
What is the force applied by the thread on the pulley :



(A) $\frac{mg}{2}$ (B) $\sqrt{3}\,mg$

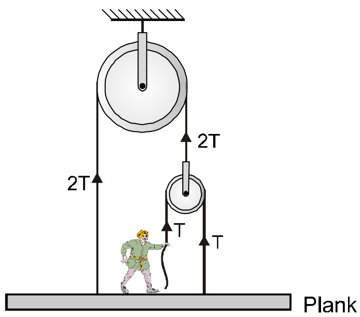
(C) $\sqrt{2}\,mg$ (D) mg

15. Assuming all the surface to be frictionless, acceleration of the block C shown in the figure is :



(A) 8 m/s^2 (B) 5 m/s^2 (C) 4 m/s^2 (D) 6 m/s^2

16. In the given diagram, with what force must the man pull the rope to hold the plank in position? Weight of the man is 60 kg. Neglect the weights of plank, rope and pulley :



(A) 15 kg

(B) 30 kg

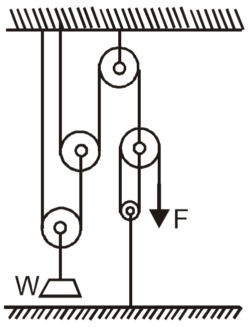
(C) 60 kg

(D) 120 kg

17. A man slides down a light rope the breaking strength of which is β times his weight ($\beta < 1$). The maximum acceleration of man so that the rope just breaks is

(A) βg (B) $(1 - \beta)\, g$ (C) $\frac{g}{1+\beta}$ (D) $\frac{g}{2+\beta}$

18. A system of pulleys is shown in the Figure . If W is 3600 kg weight, What force F is required to raise it. Neglect friction and weight of pulleys.



(A) 300 kg force

(B) 600 kg force

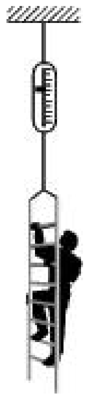
(C) 1200 kg force

(D) 450 kg force

19. Five persons A, B, C, D & E are pulling a cart of mass 100 kg on a smooth surface and cart is moving with acceleration 3 m/s^2 in east direction. When person 'A' stops pulling, it moves with acceleration 1m/s^2 in the west direction. When person 'B' stops pulling, it moves with acceleration 24 m/s^2 in the north direction. The magnitude of acceleration of the cart when only A & B pull the cart keeping their directions same as the old directions, is :

(A) 26 m/s^2 (B) $3\sqrt{71}$ m/s^2 (C) 25 m/s^2 (D) 30 m/s^2

20. Figure shows a 5 kg ladder hanging from a string that is connected with a ceiling and is having a spring balance connected in between. A boy of mass 25 kg is climbing up the ladder at acceleration 1 m/s^2. Assuming the spring balance and the string to be massless and the spring to show a constant reading, the reading of the spring balance is : (Take g = 10 m/s^2)



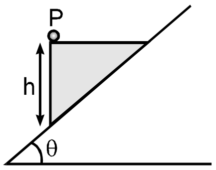
(A) 30 kg

(B) 32.5 kg

(C) 35 kg

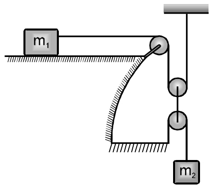
(D) 37.5 kg

21. A wedge of height 'h' is released from rest with a light particle P placed on it as shown. The wedge slides down a fixed incline which makes an angle θ with the horizontal. All the surfaces are smooth, P will reach the surface of the incline in time:



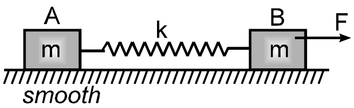
(A) $\sqrt{\frac{2h}{g\sin^2\theta}}$ (B) $\sqrt{\frac{2h}{g\sin\theta\cos\theta}}$ (C) $\sqrt{\frac{2h}{g\tan\theta}}$ (D) $\sqrt{\frac{2h}{g\cos^2\theta}}$

22. Two blocks of masses m_1 and m_2 are connected as shown in the figure. The acceleration of the block m_2 is:



(A) $\frac{m_2 g}{m_1 + m_2}$ (B) $\frac{m_1 g}{m_1 + m_2}$ (C) $\frac{4 m_2 g - m_1 g}{m_1 + m_2}$ (D) $\frac{m_2 g}{m_1 + 4 m_2}$

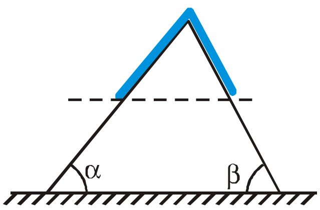
23. Initially the spring is undeformed. Now the force 'F' is applied to 'B' as shown. When the displacement of 'B' w.r.t. 'A' is 'x' towards right in some time then the relative acceleration of 'B' w.r.t. 'A' at that moment is:



(A) $\frac{F}{2m}$ (B) $\frac{F - kx}{m}$

(C) $\frac{F - 2kx}{m}$ (D) none of these

24. A uniform rope of length L and mass M is placed on a smooth fixed wedge as shown. Both ends of rope are at same horizontal level. The rope is initially released from rest, then the magnitude of initial acceleration of rope is



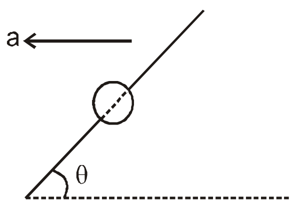
(A) Zero

(B) $M(\cos\alpha - \cos\beta)g$

(C) $M(\tan\alpha - \tan\beta)g$

(D) None of these

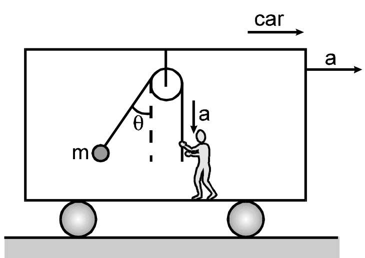
25. A pearl of mass m is in a position to slide over a smooth wire. At the initial instant the pearl is in the middle of the wire. The wire moves linearly in a horizontal plane with an acceleration a in a direction having angle θ with the wire. The acceleration of the pearl with reference to wire is



(A) $g \sin\theta - a \cos\theta$ (B) $g \sin\theta - g \cos\theta$

(C) $g \sin\theta - a \cos\theta$ (D) $g \cos\theta + a \sin\theta$

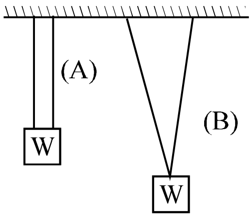
26. A bob is hanging over a pulley inside a car through a string. The second end of the string is in the hand of a person standing in the car . The car is moving with constant acceleration 'a' directed horizontally as shown in figure . Other end of the string is pulled with constant acceleration 'a' (relative to car) vertically. The tension in the string is equal to.

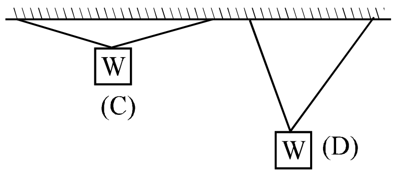


(A) $m\sqrt{g^2 + a^2}$ (B) $m\sqrt{g^2 + a^2} - ma$

(C) $m\sqrt{g^2 + a^2} + ma$ (D) $m(g + a)$

27. A weight can be hung in any of the following four ways by string of same type. In which case is the string most likely to break?



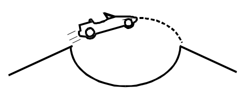


(A) A (B) B (C) C (D) D

28. A rope of mass 5 kg is moving vertically in vertical position with an upwards force of 100 N acting at the upper end and a downwards force of 70 N acting at the lower end. The tension at midpoint of the rope is

(A) 100 N (B) 85 N (C) 75 N (D) 105 N

29. A stunt man jumps his car over a crater as shown (neglect air resistance)

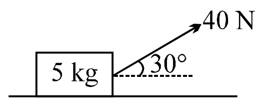


(A) during the whole flight the driver experiences weightlessness
(B) during the whole flight the driver never experiences weightlessness
(C) during the whole flight the driver experiences weightlessness only at the highest point
(D) the apparent weight increases during upward journey

30. A flexible chain of weight W hangs between two fixed points A & B which are at the same horizontal level. The inclination of the chain with the horizontal at both the points of support is θ. What is the tension of the chain at the mid point?

(A) $\frac{W}{2}$. cosec θ (B) $\frac{W}{2}$. tan θ (C) $\frac{W}{2}$ cot θ (D) none

31. Adjoining figure shows a force of 40 N acting at 30° to the horizontal on a body of mass 5 kg resting on a smooth horizontal surface. Assuming that the acceleration of free–fall is 10 ms^{-2}, which of the following statements A, B, C, D is (are) correct?

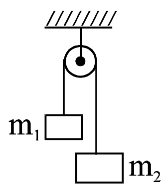


[1] The horizontal force acting on the body is 20 N
[2] The weight of the 5 kg mass acts vertically downwards
[3] The net vertical force acting on the body is 30 N

(A) 1, 2, 3 (B) 1, 2 (C) 2 only (D) 1 only

32. In a tug–of–war contest, two men pull on a horizontal rope from opposite sides. The winner will be the man who:
(A) exerts greater force on the rope
(B) exerts greater force on the ground
(C) exerts a force on the rope which is greater than the tension in the rope
(D) makes a smaller angle with the vertical

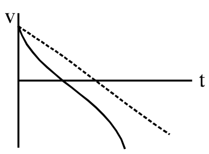
33. A student calculates the acceleration of m_1 in figure shown as

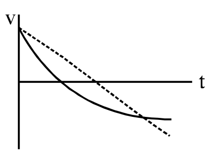


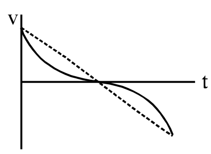
$a_1 = \frac{(m_1 - m_2)g}{m_1 + m_2}$. Which assumption is not required to do this calculation.

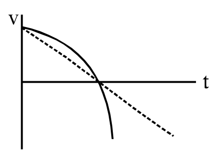
(A) rim of pulley is frictionless (B) string is massless
(C) pulley is massless (D) string is inextensible

34. Which graph shows best the velocity-time graph for an object launched vertically into the air when air resistance is given by | D | = bv? The dashed line shows the velocity graph if there were no air resistance.

(A) 

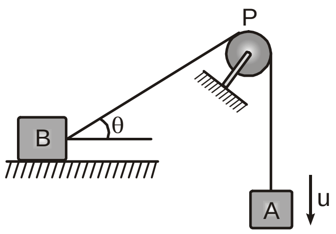
(B) 

(C) 

(D) 

Multiple Correct Answer(s) Type

35. In the Figure, the blocks are of equal mass. The pulley is fixed & massless. In the position shown, A is given a speed u and v_B= the speed of B. (θ< 90°)



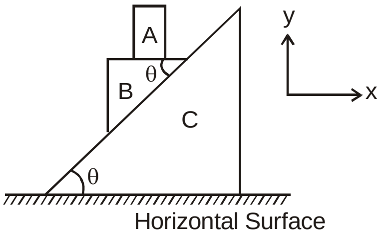
(A) B will never lose contact with the ground

(B) The downward acceleration of A is equal in magnitude to the horizontal acceleration of B.

(C) $v_B = u \cos \theta$

(D) $v_B = u/\cos \theta$

36. In the figure shown all the surface are smooth. All the blocks A, B and C are movable, x-axis is horizontal and y-axis vertical as shown. Just after the system is released from the position as shown.



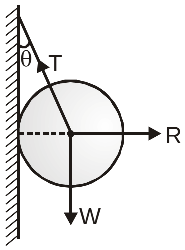
(A) Acceleration of 'A' relative to ground is in negative y-direction

(B) Acceleration of 'A' relative to B is in positive x-direction

(C) The horizontal acceleration of 'B' relative to ground is in negative x-direction.

(D) The acceleration of 'B' relative to ground directed along the inclined surface of 'C' is greater than g sin θ.

37. A metal sphere is hung by a string fixed on a wall. The forces acting on the sphere are shown in the figure. Which of the following statements are correct :



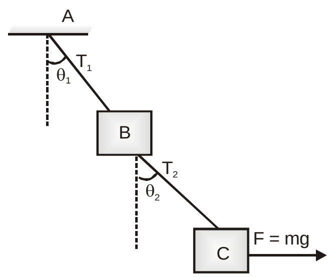
(A) $\vec{R} + \vec{T} + \vec{W} = 0$

(B) $T^2 = R^2 + W^2$

(C) T = R + W

(D) $R = W \tan \theta$

38. The blocks B and C in the figure have mass m each. The strings AB and BC are light, having tensions T_1 and T_2 respectively. The system is in equilibrium with a constant horizontal force mg acting on C :



(A) $\tan \theta_1 = \frac{1}{2}$

(B) $\tan\theta_2 = 1$

(C) $T_1 = \sqrt{5}mg$

(D) $T_2 = \sqrt{2}mg$

39. A block of weight W is suspended from a spring balance. The lower surface of the block rests on a weighing machine. The spring balance reads W_1 and the weighing machine reads W_2. (W, W_1, W_2 are in the same unit):

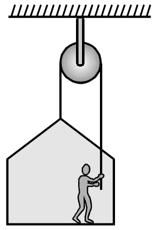
(A) $W = W_1 + W_2$ if the system is at rest

(B) $W > W_1 + W_2$ if the system moves down with some acceleration

(C) $W_1 > W_2$ if the system moves up with some acceleration

(D) no relation between W_1 and W_2 can be obtained with the given description of the system

40. A painter is applying force himself to raise him and the box with an acceleration of 5 m/s^2 by a massless rope and pulley arrangement as shown in figure. Mass of painter is 100 kg and that of box is 50 kg. If g = 10 m/s^2, then:



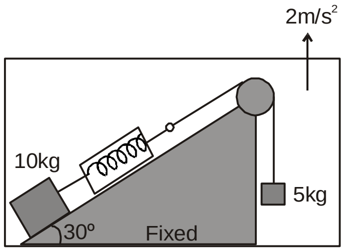
(A) tension in the rope is 1125 N

(B) tension in the rope is 2250 N

(C) force of contact between the painter and the floor is 375 N

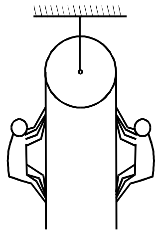
(D) none of these

41. According to figure the reading of the spring balance will be : (all contacts are smooth) [g = 10 m/s^2]



(A) 6 kg f (B) 5 kg f (C) 60 N (D) 60 kg f

42. Two men of unequal masses hold on to the two sections of a light rope passing over a smooth light pulley. Which of the following are possible?



(A) The lighter man is stationary while the heavier man slides with some acceleration

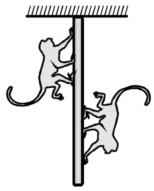
(B) The heavier man is stationary while the lighter man climbs with some acceleration

(C) The two men slide with the same acceleration in the same direction

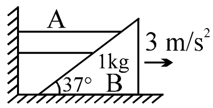
(D) The two men move with accelerations of the same magnitude in opposite directions

PART - II : SUBJECTIVE QUESTIONS

1. Two monkeys of masses 10 kg and 8 kg are moving along a vertical light rope, the former climbing up with an acceleration of 2m/s^2 while the latter coming down with a uniform velocity of 2 m/s. The tension in the rope at the fixed support is equal to 50 X(in newton).find value of X

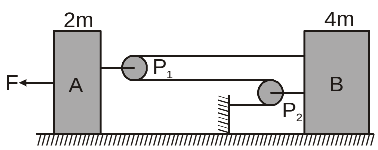


2. Find force in newton which mass A exerts on mass B if B is moving towards right with 3 ms^{-2}.(All surfaces are smooth)

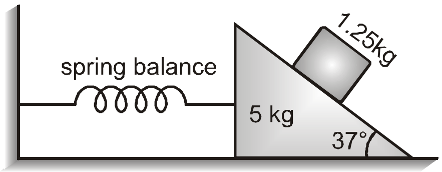


3. A monkey pulls along the ground mid point of a 10 m long light inextensible string connecting two identical objects A & B each of mass 0.3 kg continuously along the perpendicular bisector of line joining the masses. The masses are found to approach each other at a relative acceleration of 5 m/s^2 when they are 6 m apart. The constant force applied by monkey is(in newton) :

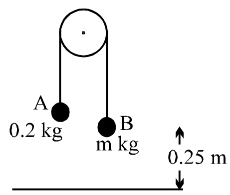
4. Calculate the acceleration of the block B in the figure, assuming the surfaces and the pulleys P_1 and P_2 are all smooth and pulleys and string are light(take F = 17 N and m = 1 kg)



5. Find the reading of spring balance as shown in figure. Assume that M is in equilibrium. (All surfaces are smooth) .



6. The diagram shows particles A and B, of masses 0.2 kg and m kg respectively, connected by a light inextensible string which passes over a fixed smooth peg. The system is released from rest, with B at a height of 0.25 m above the floor. B descends, hitting the floor 0.5 s later. All resistances to motion may be ignored.

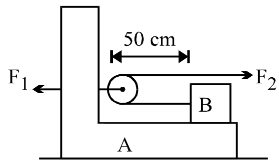


(a) Find the acceleration of B as it descends.

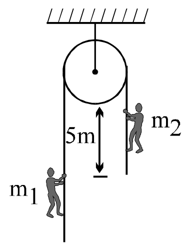
(b) Find the tension in the string while B is descending and find also the value of m.

(c) When B hits the floor it comes to rest immediately, and the string becomes slack. Find the length of time for which B remains at rest on the ground before being jerked into motion again.

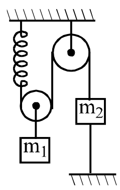
7. A 1kg block 'B' rests as shown on a bracket 'A' of same mass. Constant forces $F_1 = 20N$ and $F_2 = 8N$ start to act at time t = 0 when the distance of block B from pulley is 50cm. Time when block B reaches the pulley is _________.



8. Two men of masses m_1 and m_2 hold on the opposite ends of a rope passing over a frictionless pulley. The mass m_1 climbs up the rope with an acceleration of 1.2 m/s^2 relative to the rope. The man m_2 climbs up the rope with an acceleration of 2.0 m/s^2 relative to the rope. Find the tension in the rope if $m_1 = 40$ kg and $m_2 = 60$ kg. Also find the time after which they will be at same horizontal level if they start from rest and are initially separated by 5m.



9. In figure shown, pulleys are ideal $m_1 > 2\,m_2$. Initially the system is in equilibrium and string connecting m_2 to rigid support below is cut. Find the initial acceleration of m_2?



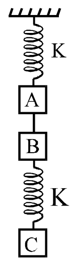
10. The system shown adjacent is in equilibrium. Find the acceleration of the blocks A, B & C all of equal masses m at the instant when

(Assume springs to be ideal)

(a) The spring between ceiling & A is cut.

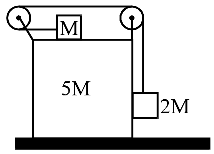
(b) The string (inextensible) between A & B is cut.

(c) The spring between B & C is cut.

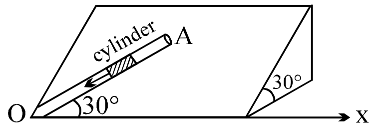


Also find the tension in the string when the system is at rest and in the above 3 cases. Solve 3 cases seperately.

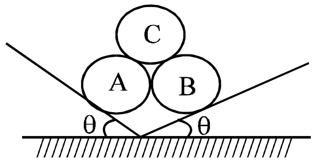
11. In the system shown. Find the initial acceleration of the wedge of mass 5M. The pulleys are ideal and the cords are inextensible. (there is no friction anywhere).



12. An inclined plane makes an angle 30° with the horizontal. A groove OA = 5 m cut in the plane makes an angle 30° with OX. A short smooth cylinder is free to slide down the influence of gravity. Find the time taken by the cylinder to reach from A to O. (g = 10 m/s^2)



13. Three identical rigid circular cylinders A, B and C are arranged on smooth inclined surfaces as shown in figure. Find the least value of θ that prevent the arrangement from collapse.



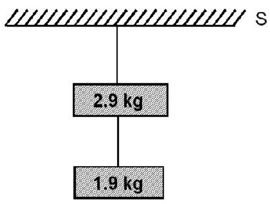
EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

***Marked Questions are having more than one correct option.**

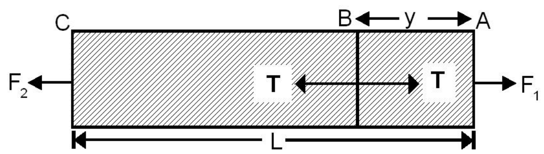
1. A ship of mass 3 × 10^7 kg initially at rest, is pulled by a force of 5 × 10^4 N through a distance of 3 m. Assuming that the resistance due to water is negligible, the speed of the ship is : **[IIT-1980, 2 marks]**
(A) 1.5 m/s (B) 60 m/s (C) 0.1 m/s (D) 5 m/s

2. Two blocks of mass 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 m. The upper wire has negligible mass and the lower wire has a uniform mass of 0.2 kg/m. The whole system of blocks, wires and support have an upward acceleration of 0.2 m/s^2. The acceleration due to gravity is 9.8 m/s^2.



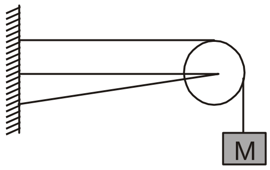
(i) Find the tension at the midpoint of the lower wire.
(ii) Find the tension at the midpoint of the upper wire. **[IIT-1989, 6 marks]**

3. What is the tension in a rod of length L and mass M at a distance y from F_1 when the rod is acted on two unequal forces F_1 and F_2 (<F_1) as shown in the figure .



4. Two blocks of masses m_1 = 3 kg and m_2 = $\frac{1}{\sqrt{3}}$ kg are connected by a light inextensible string which passes over a smooth peg. The blocks rest on the inclined smooth planes of a wedge (fixed) and the peg is fixed to the top of the wedge. The planes of the wedge supporting m_1 and m_2 are inclined at 30° and 60°, respectively, with the horizontal. Calculate the acceleration of the masses and the tension in the string. (g = 10 m/s^2) **[REE 1999, 5 marks]**

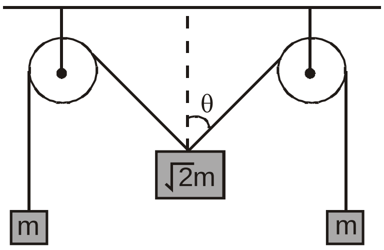
5. A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given by -



(A) $\sqrt{2}$ Mg (B) $\sqrt{2}$ mg

(C) $\left(\sqrt{(M+m)^2+m^2}\right)g$ (D) $\left(\sqrt{(M+m)^2+M^2}\right)g$ **[JEE 2001 (Scr.), 3/105]**

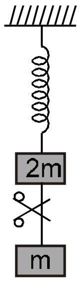
6. The pulleys and strings shown in the figure are smooth and of negligible mass for the system to remain in equilibrium, the angle θ should be



(A) 0º (B) 30º

(C) 45º (D) 60º

7. System shown in figure is in equilibrium and at rest. The spring and string are massless Now the string is cut. The acceleration of mass 2m and m just after the string is cut will be :



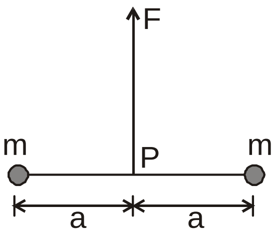
(A) g/2 upwards , g downwards

(B) g upwards, g/ 2 downwards

(C) g upwards , 2g downwards

(D) 2g upwards , g downwards **[JEE 2006, 3/184]**

8. Two particles of mass m each are tied at the ends of a light string of length 2a. The whole system is kept on a frictionless horizontal surface with the string held tight so that each mass is at a distance 'a' from the centre P (as shown in the figure). Now, the mid-point of the string is pulled vertically upwards with a small but constant force F. As a result, the particles move towards each other on the surface. The magnitude of acceleration, when the separation between them becomes 2x, is



(A) $\frac{F}{2m}\frac{a}{\sqrt{a^2-x^2}}$ (B) $\frac{F}{2m}\frac{x}{\sqrt{a^2-x^2}}$

(C) $\frac{F}{2m}\frac{x}{a}$ (D) $\frac{F}{2m}\frac{\sqrt{a^2-x^2}}{x}$ **[JEE 2007, 3/81]**

9. A piece of wire is bent in the shape of a parabola $y = kx^2$ (y-axis vertical) with a bead of mass m on it. The bead can slide on the wire without friction. It stays at the lowest point of the parabola when the wire is at rest. The wire is now accelerated parallel to the x-axis with a constant acceleration a. The distance of the new equilibrium position of the bead, where the bead can stay at rest with respect to the wire, from the y-axis is

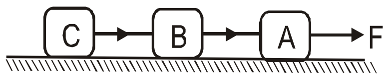
(A) $\frac{a}{gk}$ (B) $\frac{a}{2gk}$ (C) $\frac{2a}{gk}$ (D) $\frac{a}{4gk}$ **[JEE 2009, 3/160, –1]**

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

1. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is g/8, then the ratio of the masses is : **[AIEEE-2002, 4/300]**

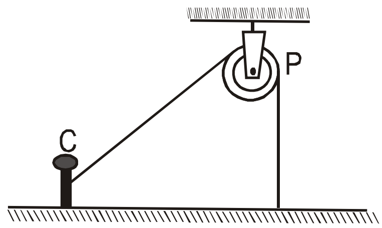
(1) 8 : 1 (2) 9 : 7 (3) 4 : 3 (4) 5 : 3

2. Three identical blocks of masses m = 2 kg are drawn by a force F = 10.2 N on a frictionless surface, then what is the tension (in N) in the string between the blocks B and C ? **[AIEEE-2002, 4/300]**



(1) 9.2 (2) 3.4 (3) 4 (5) 9.8

3. One end of massless rope, which passes over a massless and frictionless pulley P is tied to a hook C while the other end is free. Maximum tension that the rope can bear is 360 N. With what value of minimum safe acceleration (in ms^{-2}) can a man of 60 kg climb down the rope ?



(1) 16 (2) 6

(3) 4 (4) 8 **[AIEEE-2002, 4/300]**

4. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 N, When the lift is stationary. If the lift moves downward with an acceleration of 5 m/s^2, the reading of the spring balance will be : **[AIEEE-2003, 4/300]**

(1) 24 N (2) 74 N (3) 15 N (4) 49 N

5. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is : **[AIEEE-2003, 4/300]**

(1) $\frac{Pm}{M+m}$ (2) $\frac{Pm}{M-m}$ (3) P (4) $\frac{PM}{M+m}$

6. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is : **[AIEEE-2003, 4/300]**

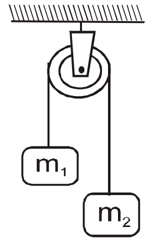
(1) Both the scale read M kg each

(2) The scale of the lower one reads M kg and of the upper one zero

(3) The reading of the two scales can be anything but the sum of the reading will be M kg

(4) Both the scales read M/2 kg

7. Two masses $m_1 = 5$ kg and $m_2 = 4.8$ kg tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses when system is free to move ? ($g = 9.8\ m/s^2$)



(1) $0.2\ m/s^2$ (2) $9.8\ m/s^2$

(3) $5\ m/s^2$ (4) $4.8\ m/s^2$ **[AIEEE-2004, 4/300]**

8. A block is kept on a frictionless inclined surface with angle of inclination α. The incline is given an acceleration a to keep the block stationary. The a is equal to **[AIEEE-2005, 4/300]**

(1) g (2) $g \tan \alpha$ (3) $g/\tan\alpha$ (4) $g\ \mathrm{cosec}\ \alpha$

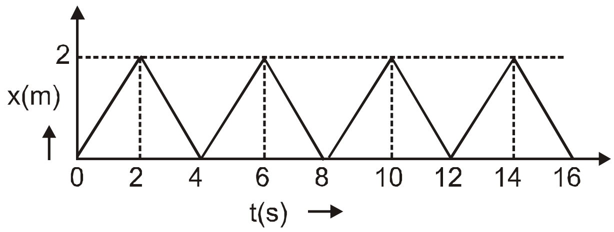
9. A ball of mass 0.2 kg is thrown vertically upwards by applying a constant force by hand. If the hand moves 0.2 m while applying the force and the ball goes upto 2m height further, find the magnitude of the force. Consider $g = 10\ m/s^2$. **[AIEEE-2006, 3/180]**

(1) 20 N (2) 22 N (3) 4 N (4) 16 N

10. A block of mass m is connected to another block of mass M by a string (massless). The blocks are kept on a smooth horizontal plane. Initially the blocks are at rest. Then a constant force F starts acting on the block of mass M to pull it. Find the force on the block of mass m **[AIEEE-2007, 3/120]**

(1) $\frac{mF}{m}$ (2) $\frac{(M+m)F}{m}$ (3) $\frac{mF}{(m+M)}$ (4) $\frac{MF}{(m+M)}$

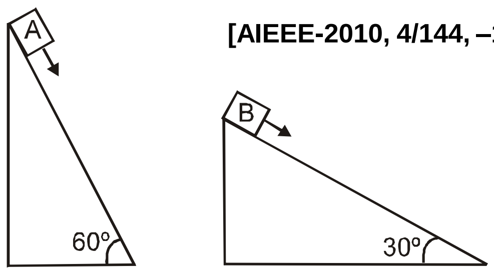
11. The figure shows the position - time (x – t) graph of one-dimensional motion of a body of mass 0.4 kg. The magnitude of each impulse is **[AIEEE-2010, 4/144, –1]**



(1) 0.4 Ns (2) 0.8 Ns (3) 1.6 Ns (4) 0.2 Ns

12. Two fixed frictionless inclined planes making an angle 30º and 60º with the vertical are shown in the figure. Two blocks A and B are placed on the two planes. What is the relative vertical acceleration of A with respect to B?

[AIEEE-2010, 4/144, –1]



(1) $4.9\ ms^{-2}$ in horizontal direction

(2) $9.8\ ms^{-2}$ in vertical direction

(3) Zero

(4) $4.9\ ms^{-2}$ in vertical direction

EXERCISE # 4

NCERT BOARD QUESTIONS

1. Give the magnitude and direction of the net force acting on
(a) a drop of rain falling down with a constant speed.
(b) a cork of mass 10 g floating on water.
(c) a kite skillfully held stationary in the sky,
(d) a car moving with a constant velocity of 30 km/h on a rough road,
(e) a high-speed electron in space far from all gravitating objects, and free of electric and magnetic fields.

2. A pebble of mass 0.05 kg is thrown vertically upwards. Give the direction and magnitude of the net force on the pebble.
(a) during its upward motion,
(b) during its downward motion,
(c) at the highest point where it is momentarily at rest. Do your answer change if the pebble was thrown at an angle of say 45° with the horizontal direction ?
Ignore air resistance.

3. Give the magnitude and direction of the net force acting on a stone of mass 0.1 kg.
(a) just after it is dropped from the window of a stationary train.
(b) just after it is dropped from the window of a train running at a constant velocity of 35 km/h.
(c) just after it is dropped from the window of a train accelerating with 1 m s^{-2},
(d) lying on the floor of a train which is accelerating with 1 m s^{-2}, the stone being at rest relative to the train. Neglect air resistance throughout.

4. A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 m s^{-1}. How long does the body take to stop ?

5. A constant force acting on a body of mass 3.0 kg changes its speed from 2.0 m s^{-1} to 3.5 s^{-1} in 25 s. The direction of the motion of the body remains unchanged. What is the magnitude and direction of the force ?

6. A body of mass 5 kg is acted upon by two perpendicular forces 8 N and 6 N. Give the magnitude and direction of the acceleration of the body.

7. The driver of a three-wheeler moving with a speed of 36 km/h sees a child standing in the middle of the road and brings his vehicle to rest in 4.0 s just in time to save the child. What is the average retarding force on the vehicle ? The mass of the three-wheeler is 400 kg and the mass of the driver is 65 kg.

8. A rocket with a lift-off mass 20,000 kg is blasted upwards with an initial acceleration of 5.0 m s^{-2}. Calculate the initial thrust (force) of the blast.

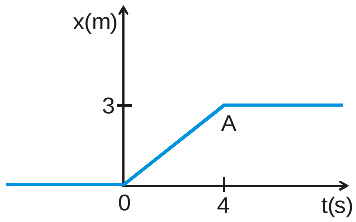
9. A particle of mass 0.40 kg moving initially with a constant speed of 10 m s^{-1} to the north is subject to a constant force of 8.0 N directed towards the south for 30 s. Take the instant the force is applied to be t = 0, the position of the particle at that time to be x = 0, and predict its position at t = – 5 s, 25 s, 100 s.

10. A truck starts from rest and accelerates uniformly with 2.0 m s^{-2}. At t = 10 s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What are the (a) velocity, and (b) acceleration of the stone at t = 11 s ? (Neglect air resistance.)

11. A bob of mass 0.1 kg hung from the ceiling of a room by a string 2 m long is set into oscillation. The speed of the bob at its mean position is 1 m s^{-1}. What is the trajectory of the bob if the string is cut when the bob is (a) at one of its extreme positions, (b) at its mean position.

12. A man of mass 70 kg stands on a weighing scale in a lift which is moving
(a) upwards with a uniform speed of 10 m s^{-1},
(b) downwards with a uniform acceleration of 5 m s^{-2},
(c) upwards with a uniform acceleration of 5 m s^{-2}
What would be the readings on the scale in each case ?
(d) What would be the reading if the lift mechanism failed and it hurtled down freely under gravity ?

13. Figure shows the position-time graph of a particle of mass 4 kg. What is the (a) force on the particle for t < 0, t > 4 s, 0 < t < 4 s ? (b) impulse at t = 0 and t = 4 s ? (Consider one-dimensional motion only).



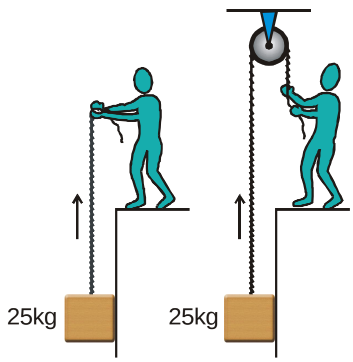
14. A horizontal force of 600 N pulls two masses 10 kg and 20 kg (lying on a frictionless table) connected by a light string. What is the tension in the string ? Does the answer depend on which mass end the pull is applied ?

15. Two masses 8 kg and 12 kg are connected at the two ends of a light inextensible string that goes over a frictionless pulley. Find the acceleration of the masses, and the tension in the string when the masses are released.

16. A helicopter of mass 1000 kg rises with a vertical acceleration of 15 m s^{-2}. The crew and the passengers weigh 300 kg. Give the magnitude and direction of the
(a) force on the floor by the crew and passengers,
(b) action of the rotor of the helicopter on the surrounding air,
(c) force on the helicopter due to the surrounding air.

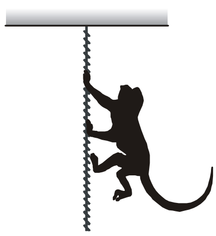
17. Ten one-rupee coins are put on top of each other on a table. Each coin has a mass m kg. Give the magnitude and direction of
(a) the force on the 7^{th} coin (counted from the bottom) due to all the coins on its top.
(b) the force on the 7^{th} coin by the eighth coin,
(c) the reaction of 6^{th} coin on the 7^{th} coin.

18. A block of mass 25 kg is raised by a 50 kg man in two different ways as shown in figure. What is the action on the floor by the man in the two cases ? If the floor yields to a normal force of 700 N, which mode should the man adopt to lift the block without the floor yielding ?

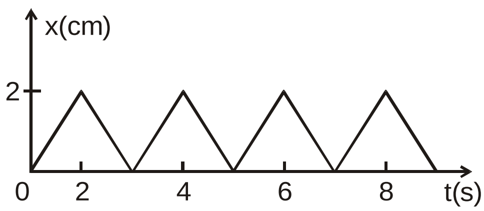


19. A monkey of mass 40 kg climbs on a rope as shown in figure which can bear a maximum tension of 600 N. In which of the following cases will the rope break : The monkey

(a) climbs up with an acceleration of 6 m s^{-2}
(b) climbs down with an acceleration of 4 m s^{-2}
(c) climbs up with a uniform speed of 5 m s^{-1}
(d) falls down the rope nearly freely under gravity ?
(Ignore the mass of the rope)



20. Figure shows the position-time graph of a particle of mass 0.04 kg. Suggest a suitable physical context for this motion. What is the time between two consecutive impulses received by the particle ? What is the magnitude of each impulse ?



ANSWERS

Exercise # 1

PART - I

A-1	(D)	**A-2**	(C)	**A-3***	(AC)	**A-4**	(A)	**B-1.**	(A)	**B-2.**	(B)	**B-3.**	(C)
B-4.	(D)	**B-5.**	(D)	**C-1.**	(A)	**C-2.**	(D)	**C-3.**	(D)	**C-4.**	(D)	**C-5.**	(C)
C-6.	(B)	**D-1.**	(A)	**D-2.**	(A)	**D-3.**	(B)	**D-4.**	(C)	**D-5.**	(A)	**D-6.**	(B)
D-7.	(A)	**D-8.**	(D)	**D-9.**	(D)	**D-10.**	(A)	**D-11.**	(B)	**D-12.**	(D)	**D-13.**	(B)
D-14.	(A)	**E-1.**	(B)	**E-2.**	(AC)	**E-3.**	(A)	**E-4.**	(A)	**E-5.**	(D)	**E-6.**	(B)
E-7.	(B)	**E-8.**	(A)	**E-9.**	(C)	**F-1.***	(ABC)	**F-2.**	(A)	**F-3.**	(B)	**F-4.**	(B)
F-5.	(C)	**G-1.**	(C)	**G-2.**	(C)								

PART-II

1.	**(B)**	**2.**	**(D)**	**3.**	**(C)**	**4.**	**(C)**	**5.**	**(C)**	**6.**	(A)	**7.**	(D)
8.	(B)	**9.**	(A)	**10.**	(A)	**11.**	(B)	**12.**	(A)	**13.**	(C)		

14. A $\rightarrow$ r ; B $\rightarrow$ t ; C $\rightarrow$ q ; D $\rightarrow$ t **15.** (D) **16.** (C) **17.** (D) **18.** (D)

Exercise # 2

PART - I

1.	(C)	**2.**	(C)	**3.**	(A)	**4.**	(C)	**5.**	(C)	**6.**	(C)	**7.**	(A)
8.	(B)	**9.**	(A)	**10.**	(C)	**11.**	(A)	**12.**	(A)	**13.**	(A)	**14.**	(D)
15.	(C)	**16.**	(A)	**17.**	(B)	**18.**	(A)	**19.**	(C)	**20.**	(B)	**21.**	(A)
22.	(A)	**23.**	(C)	**24.**	(A)	**25.**	(A)	**26.**	(C)	**27.**	(C)	**28.**	(B)
29.	(A)	**30.**	(C)	**31.**	(C)	**32.**	(B)	**33.**	(C)	**34.**	(B)	**35.**	(AD)
36.	(ABCD)	**37.**	(ABD)	**38.**	(ABCD)	**39.**	(ABD)	**40.**	(AC)	**41.**	(AC)	**42.**	(ABD)

PART-II

1. 4 **2.** 5 **3.** 2 **4.** 3 **5.** 6 N **6.** (a) 2 ms^{-2}, (b) 2.4 N, 0.3 (c) 0.2 s

7. 0.5 sec **8.** 556.8 N, 1.47 sec **9.** $\left(\frac{m_1 - 2m_2}{2m_2}\right)g$

10. **(a)** $a_A = \frac{3g\downarrow}{2} = a_B$; $a_C = 0$; T=mg/2; **(b)** a_A=2g-, a_B=2g¯, a_c=0, T=0; **(c)** $a_A = a_B$= g/2-, a_c=g¯, T=$\frac{3mg}{2}$; T=2mg

11. 2g/23 **12.** 2 sec **13.** $\tan^{-1}\left(\frac{1}{3\sqrt{3}}\right)$

Exercise # 3

PART-I

1.	(C)	**2.**	20 N, 50 N	**3.**	$F_1\left(1-\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$	**4.**	$\frac{10\sqrt{3}}{(3\sqrt{3}+1)}m/s^2$, $\frac{15(\sqrt{3}+1)}{(3\sqrt{3}+1)}N$		
5.	(D)	**6.**	(C)	**7.**	(A)	**8.**	(B)	**9.**	**(B)**

PART-II

1.	(2)	**2.**	(2)	**3.**	(3)	**4.**	(1)	**5.**	(4)	**6.**	(1)	**7.**	(1)
8.	(2)	**9.**	(2)	**10.**	(3)	**11.**	(2)	**12.**	(4)				

Exercise # 4

1. **Ans.** (a) to (d) No net force according to the First Law
(e) No force, since it is far away from all material agencies producing electromagnetic and gravitational forces.

2. **Ans.** The only force in each case is the force of gravity, (neglecting effects of air) equal to 0.5 N vertically downward. The answers do not change, even if the motiodn of the pebble is not along the vertical. The pebble is not at rest at the highest point. It has a constant horizontal component of velocity throughout its motion.

3. **Ans.** (a) 1 N vertically downwards (b) same as in (a)
(c) same as in (a); force at an instant depends on the situation at that instant, not on history.
(d) 0.1 N in the direction of motion of the train.

4. Ans. $a = -2.5\ m\ s^{-2}$. Using $v = u + at$, $0 = 15 - 2.5\ t$ i.e., $t = 6.0\ s$

5. **Ans.** $a = 1.5/25 = 0.06\ m\ s^{-2}$
$F = 3 \times 0.06 = 0.18$ N in the direction of motion.

6. **Ans.** Resultant force = 10 N at an angle of $\tan^{-1}(3/4) = 37°$ with the directionof 8 N force. Acceleration = $2\ ms^{-1}$ in the same direction as the resultant force.

7. **Ans.** $a = -2.5\ m\ s^{-2}$, Retarding force $= 465 \times 2.5 = 1.2 \times 10^3$ N

8. **Ans.** $F - 20,000 \times 10 = 20000 \times 5.0$, i.e. $F = 3.0 \times 10^5$ N

9. **Ans.** $a = -20\ m\ s^{-2}$ $0 \le t \le 30$ s
t = – 5 s : $x = ut = -10 \times 5 = -50$ m
t = 25 s : $x = ut + (½)at^2 = (10 \times 25 - 10 \times 625)m = -6$ km
t = 100 s : First consider motion up to 30 s
$x_1 = 10 \times 30 - 10 \times 900 = -8700$ m
At t = 30 s, $v = 10 - 20 \times 30 = -590\ m\ s^{-1}$
For motion from 30 s to 100 s : $x_2 = 590 \times 70 = -41300$ m
$x = x_1 + x_2 = -50$ km

10. **Ans.** (a) Velocity of car (at t = 10 s) $= 0 + 2 \times 10 = 20\ m\ s^{-1}$
By the First Law, the horizontal component of velocity is $20\ m\ s^{-1}$ throughout.
Vertical component of velocity (at t = 11 s) $= 0 + 10 \times 1 = 10\ m\ s^{-1}$
Velocity of stone (at t = 11 s) $= \sqrt{20^2+10^2} = \sqrt{500} = 22.4\ m\ s^{-1}$ at an angle of $\tan^{-1}(½)$ with the horizontal direction.
(b) $10\ m\ s^{-2}$ vertically downwards.

11. **Ans.** (a) At the extremen position, the speed ofthe bob is zero. If the string is cut, it will fall vertically downwards.
(b) At themean positionm, the bob has a horizontal velocity. Ifthe string is cut, it will fall along a parabolic path.

12. **Ans.** The reading on the scale is a mesure of the force on the floor by the man. By the Third Law, this is equal and opposite to the normal force N on the man by the floor.
(a) N = 70 × 10 = 700 N ; Reading is 70 kg
(b) 70 – 10 – N = 70 – 5 ; Reading is 35 kg
(c) N – 70 – 10 = 70 – 5 ; Reading is 105 kg
(d) 70 – 10 – N = 70 – 10 ; Reading would be zero; the scale would read zero.

13. **Ans.** (a) In all the three intervals, acceleration and, therefore, force are zero.
(b) 3 kg m s^{-1} at t = 0 ; (c) – 3 kgm s^{-1} at t = 4 s

14. **Ans.** If the 20 kg mass is pulled,
600 – T = 20a, T = 10a
a = 20 m s^{-2}, T = 200 N
If the 10 kg mass is pulled, a = 20 m s^{-2}, T = 400 N

15. **Ans.** T – 8 × 10 = 8a, 12 ×10 – T = 12 a
i.e. a = 2 ms^{-2}, T = 96 N

16. **Ans.** (a) 'Free body' : crew and passengers
Force on the system bythe floor = F
F = 7.5 × 10^3N upward
By the Third Law, force on the floor by the crew and passengers = 7.5 × 10^3 N downwards.
(b) 'Free body': helicopter plus the crew and passengers
Force by air on the system : R
R – 1300 × 10 = 1300 × 15
R = 3.25 × 10^4 N upwards
By the Third Law, force (action) on the air by the helicopter = 3.25 × 10^4 N downwards.
(c) 3.25 × 10^4 N upwards

17. **Ans.** (a) 3 mg (down) (b) 3 mg (down) (c) 4 mg (up)
Note, answer to (b) is not mg but 3 mg

18. **Ans.** Consider the forces on the man in equilibrium : his weight, force due tothe rope and normal force due to the floor.
(a) 750 N (b) 250 N; mode (b) should be adopted.

19. **(a)** T – 400 = 240, T = 640 N. **(b)** 400 – T = 160, T = 240 N
(c) T = 400 N **(d)** T = 0

20. **Ans.** A particle with a constant speed of 1 cm s^{-1} receive impulse of magnitude 0.04 kg x.02 m s^{-1} = 8 × 10^{-4} kg m s^{-1} after every 2 s from the walls at x = 0 and x = 2 cm.