03 NEWTON'S LAWS

LEVEL 1

Q. 1. Let $\vec{u}$ be the initial velocity of a particle and $\vec{F}$ be the resultant force acting on it. Describe the path that the particle can take if

(a) $\vec{u} \times \vec{F} = 0$ and $\vec{F}$ = constant

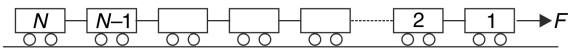
(b) $\vec{u}.\vec{F} = 0$ and $\vec{F}$ = constant

In which case can the particle retrace its path.

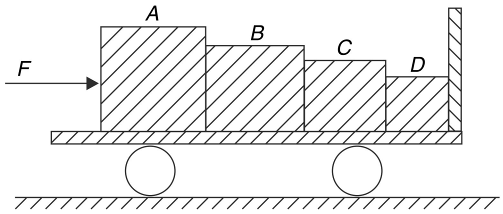
Q. 2. A ball is projected vertically up from the floor of a room. The ball experiences air resistance that is proportional to speed of the ball. Just before hitting the ceiling the speed of the ball is 10 m/s and its retardation is $2g$. The ball rebounds from the ceiling without any loss of speed and falls on the floor $2s$ after making impact with the ceiling. How high is the ceiling? Take $g = 10\ m/s^2$.

Q. 3. A small body of super dense material, whose mass is half the mass of the earth (but whose size is very small compared to the size of the earth), starts from rest at a height H above the earth's surface, and reaches the earth's surface in time t. Calculate time t assuming that H is very small compared to the radius of the earth. Acceleration due to gravity near the surface of the earth is g.

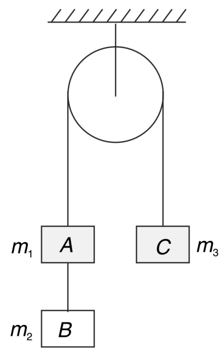
Q. 4. N identical carts are connected to each other using strings of negligible mass. A pulling force F is applied on the first cart and the system moves without friction along the horizontal ground. The tension in the string connecting 4th and 5th cart is twice the tension in the string connecting 8th and 9th cart. Find the total number of carts (N) and tension in the last string.



Q. 5. A toy cart has mass of 4 kg and is kept on a smooth horizontal surface. Four blocks A, B, C and D of masses 2 kg, 2 kg, 1 kg and 1 kg respectively have been placed on the cart. A horizontal force of F=40 N is applied to the block A (see figure). Find the contact force between block D and the front vertical wall of the cart.



Q. 6. (i) Three blocks A, B and C are placed in an ideal Atwood machine as shown in the figure. When the system is allowed to move freely it was found that tension in the string connecting A to C was more than thrice the tension in the string connecting A and B. The masses of the three blocks A, B and C are m_1, m_2 and m_3, respectively. State whether the following statements are true or false [All masses have finite non zero values and the system has a non zero acceleration].



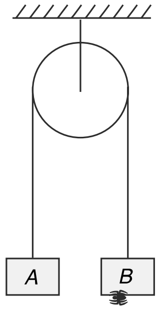
(a) m_3 can have any finite value

(b) $m_1 > 2m_2$

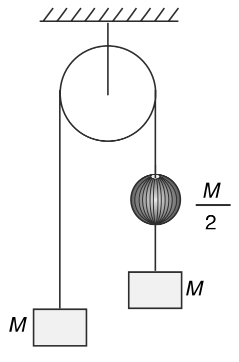
(ii) In an Atwood machine the sum of two masses is a constant. If the string can sustain a tension equal to $\left(\frac{24}{30}\right)$ of the weight of the sum of two masses, find the least acceleration of the masses. The string and pulley are light.

(iii) A load of w newton is to be raised vertically through a height h using a light rope. The greatest tension that the rope can bear is ηw ($\eta > 1$). Calculate the least time of ascent if it is required that the load starts from rest and must come to rest when it reaches a height h.

Q. 7. In the arrangement shown in the figure the system is in equilibrium. Mass of the block A is M and that of the insect clinging to block B is m. Pulley and string are light. The insect loses contact with the block B and begins to fall. After how much time the insect and the block B will have a separation L between them.



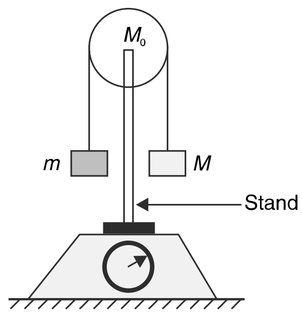
Q. 8. Two blocks of equal mass, M each, are connected to two ends of a massless string passing over a massless pulley. On one side of the string there is a bead of mass $\frac{M}{2}$.



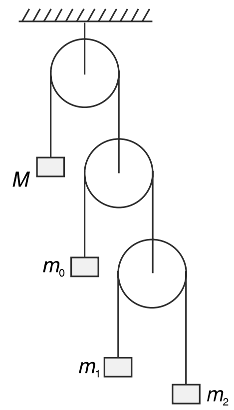
(a) When the system is released from rest the bead continues to remain at rest while the two blocks accelerate. Find the acceleration of the blocks.

(b) Find the acceleration of the two blocks if it was observed that the bead was sliding down with a constant velocity relative to the string.

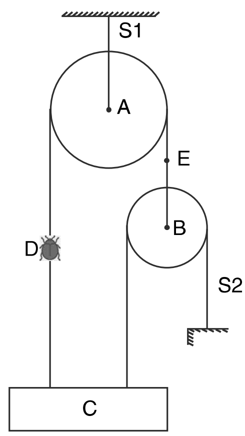
Q. 9. A pulley is mounted on a stand which is placed over a weighing scale. The combined mass of the stand and the pulley is M_0. A light string passes over the smooth pulley and two masses m and M ($> m$) are connected to its ends (see figure). Find the reading of the scale when the two masses are left free to move.



Q. 10. In the given arrangement, all strings and pulleys are light. When the system was released it was observed that M and m_0 do not move. Find the masses M and m_0 in terms of m_1 and m_2. Find the acceleration of all the masses if string is cut just above m_2.



Q.11 The system shown in the fig. is in equilibrium. Pulleys A and B have mass M each and the block C has mass $2M$. The strings are light. There is an insect (D) of mass $M/2$ sitting at the middle or the right string. Insect does not move.



(a) Just by inspection, say if the tension in the string S1 is equal to, more than or less than 9/2 Mg.

(b) Find tension in the string $S2$, and $S1$.

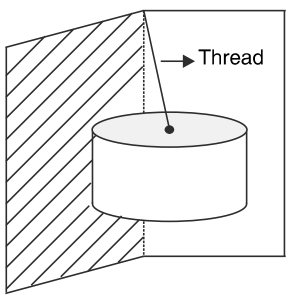
(c) Find tension in $S2$ if the insect flies and sits at point E on the string.

Q. 12. A block slides down a frictionless plane inclined at an angle θ. For what value of angle θ the horizontal component of acceleration of the block is maximum? Find this maximum horizontal acceleration.

Q. 13. A tall elevator is going up with an acceleration of $a = 4\ m/s^2$. A 4 kg snake is climbing up the vertical wall of the elevator with an acceleration of a. A 50 g insect is riding on the back of the snake and it is moving up relative to the snake at an acceleration of a. Find the friction force between the elevator wall and the snake. Assume that the snake remains straight.

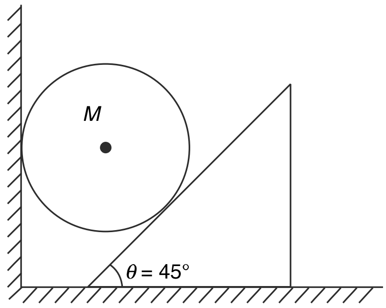
Q. 14. Due to air drag the falling bodies usually acquire a constant speed when the drag force becomes equal to weight. Two bodies, of identical shape, experience air drag force proportional to square of their speed ($F_{drag} = kv^2$, k is a constant). The mass ratio of two bodies is 1 : 4. Both are simultaneously released from a large height and very quickly acquire their terminal speeds. If the lighter body reaches the ground in 25 s, find the approximate time taken by the other body to reach the ground.

Q. 15. A cylinder of mass M and radius r is suspended at the corner of a room. Length of the thread is twice the radius of the cylinder. Find the tension in the thread and normal force applied by each wall on the cylinder assuming the walls to be smooth.



Q. 16. A rod of mass M and length L lies on an incline having inclination of $\theta = 37°$. The coefficient of friction between the rod and the incline surface is $\mu = 0.90$. Find the tension at the mid point of the rod.

Q. 17. A ball of mass M is in equilibrium between a vertical wall and the inclined surface of a wedge. The inclination of the wedge is $\theta = 45°$ and its mass is very small compared to that of the ball. The coefficient of friction between the wedge and the floor is μ and there is no friction elsewhere. Find minimum value of μ for which this equilibrium is possible.



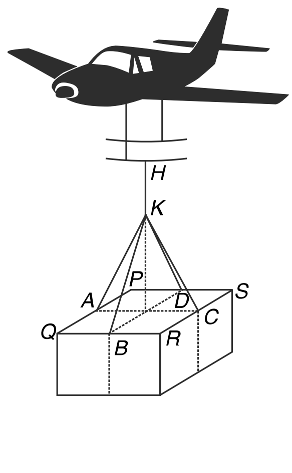
Q.18 A helicopter of mass $M = 15000\ kg$ is lifting a cubical box of mass $m = 2000\ kg$. The helicopter is going up with an acceleration of $a = 1.2\ m/s^2$. The four strings are tied at mid points of the sides of the square face $PQRS$ of the box. The strings are identical and form a knot at K. Another string KH connects the knot to the helicopter. Neglect mass of all strings and take $g = 10\ m/s^2$. Length of each string AK, BK, CK and DK is equal to side length of the cube.

(a) Find tension T in string AK.

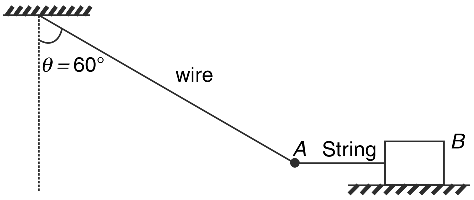
(b) Find tension T_0 in string KH.

(c) Find the force (F) applied by the atmosphere on the helicopter. Assume that the atmosphere exerts a negligible force on the box.

(d) If the four strings are tied at P, Q, R and S instead of A, B, C & D, how will the quantities T, T_0 and F change? Will they increase or decrease? Assume that length of the four identical strings remains same.



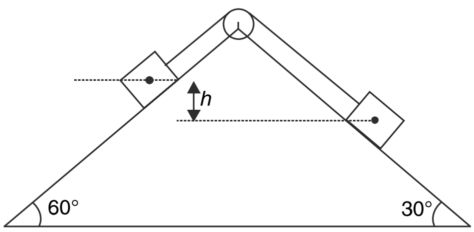
Q. 19. A pendulum has a bob connected to a light wire. Bob 'A' is in equilibrium in the position shown. The string is horizontal and is connected to a block B resting on a rough surface. The block B is on verge of sliding when $\theta = 60°$.



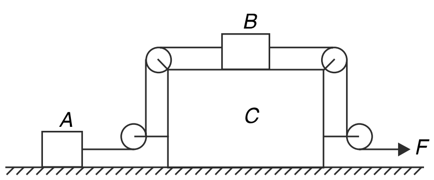
(a) Is equilibrium possible if θ were 70°?

(b) With $\theta = 60°$, calculate the ratio of tension in the pendulum wire immediately after the string is cut to the tension in the wire before the string is cut.

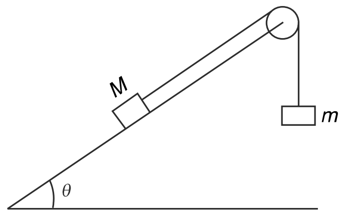
Q. 20. Two blocks of equal mass have been placed on two faces of a fixed wedge as shown in figure. The blocks are released from position where centre of one block is at a height h above the centre of the other block. Find the time after which the centre of the two blocks will be at same horizontal level. There is no friction anywhere.



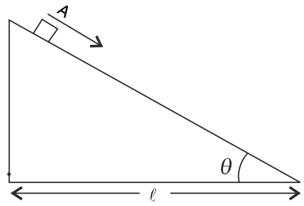
Q. 21. In the system shown in the figure, all surfaces are smooth. Block A and B have mass m each and mass of block C is 2 m. All pulleys are massless and fixed to block C. Strings are light and the force F applied at the free end of the string is horizontal. Find the acceleration of all three blocks.



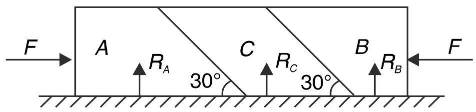
Q. 22. A particle of mass M rests on a rough inclined plane at an angle θ to the horizontal $\left(\sin\theta = \frac{4}{5}\right)$. It is connected to another mass m as shown in fig. The pulley and string are light. The largest value of m for which equilibrium is possible is M. Find the smallest value of m for which equilibrium is possible.



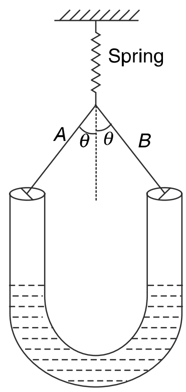
Q. 23. A small body A starts sliding down from the top of a wedge (see fig) whose base is equal to ℓ. The coefficient of friction between the body and wedge surface is $\mu = 1.0$. At what value of angle θ will the time of sliding be least?



Q. 24. Three blocks A, B and C each of mass m are placed on a smooth horizontal table. There is no friction between the contact surfaces of the blocks as well. Horizontal force F is applied on each of A and B as shown. Find the ratio of normal force applied by the table on the three blocks (i.e., $R_A : R_B : R_C$). Take $F = \frac{mg}{2\sqrt{3}}$



Q. 25. A U shaped container has uniform cross sectional area S. It is suspended vertically with the help of a spring and two strings A and B as shown in the figure. The spring and strings are light. When water (density = d) is poured slowly into the container it was observed that the level of water remained unchanged with respect to the ground. Find the force constant of the spring.

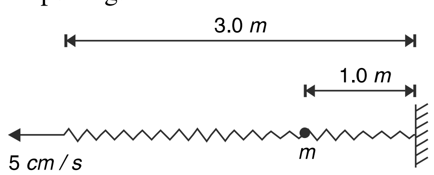


Q. 26. A uniform light spring has unstretched length of 3.0 *m*. One of its end is fixed to a wall. A particle of mass $m = 20\ g$ is glued to the spring at a point 1.0 m away from its fixed end. The free end of the spring is pulled away from the wall at a constant speed of 5 *cm/s*.

Assume that the spring remains horizontal (i.e., neglect gravity). Force constant of spring = 0.6 N/*cm*.

(a) With what speed does the particle of mass *m* move?

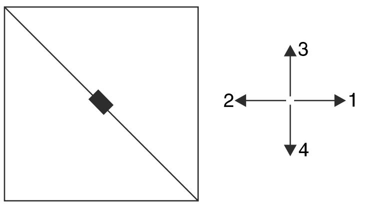
(b) Find the force applied by the external agent pulling the spring at time 2.0 s after he started pulling.



Q. 27. It was observed that a small block of mass *m* remains in equilibrium at the centre of a vertical square frame, which was accelerated. The block is held by two identical light strings as shown. [Both strings are along the diagonal]

(a) Which of 1, 2, 3 & 4 is/are possible direction/s of acceleration of the frame for block to remain in equilibrium inside it?

(b) Find the acceleration of the frame for your answers to question (a).



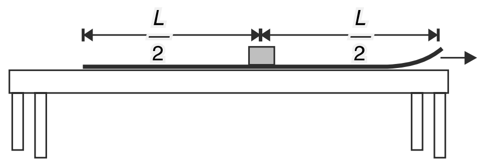
Q.28 In an emergency situation while driving one has tendency to jam the brakes, trying to stop in shortest distance. With wheels locked, the car slides and steering get useless. In ABS system the electronic sensors keep varying the brake pressure so as to keep the wheels rolling (without slipping) while ensuring that the friction remains limiting.

Your friend has an old car with good brakes. He boasts saying that all the four wheels of his car get firmly locked and stop rotation immediately after the brakes are applied. You know that your new car which has a computerized anti lock braking system (*ABS*) is much safer. How will you convince your friend?

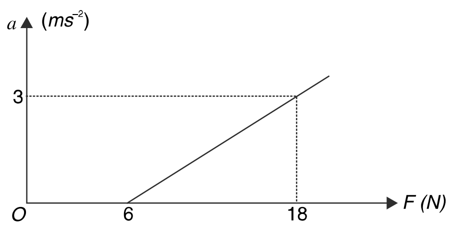
In a typical situation, car without *ABS* needs 20 *m* as minimum stopping distance. Under identical conditions, what minimum distance a car with *ABS* would need to stop? Coefficient of kinetic friction between tyre and road is 25% less than the coefficient of static friction.

Q. 29. Starting from rest a car takes at least '*t*' second to travel through a distance *s* on a flat concrete road. Find the minimum time that will be needed for it to climb through a distance '*s*' on an inclined concrete road. Assume that the car starts from rest and inclination of road is $\theta = 5°$ with horizontal. Coefficient of friction between tyres and the concrete road is $\mu = 1$.

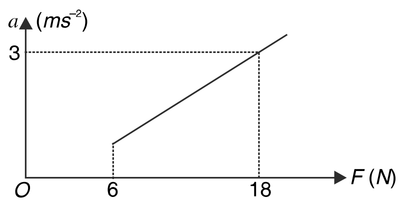
Q. 30. A table cloth of length *L* is lying on a table with one of its end at the edge of the table. A block is kept at the centre of the table cloth. A man pulls the end of the table cloth horizontally so as to take it off the table. The cloth is pulled at a constant speed V_0. What can you say about the coefficient of friction between the block and the cloth if the block remains on the table (i.e., it does not fall off the edge) as the cloth is pulled out.



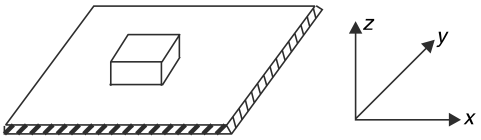
Q. 31. A block rests on a horizontal surface. A horizontal force *F* is applied to the block. The acceleration (*a*) produced in the block as a function of applied force (*F*) has been plotted in a graph (see figure). Find the mass of the block.



Q. 32. Repeat the last problem if the graph is as shown below.

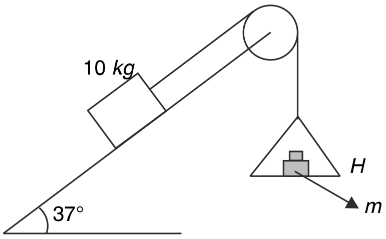


Q. 33. A solid block of mass $m = 1\ kg$ is resting on a horizontal platform as shown in figure. The z direction is vertically up. Coefficient of friction between the block and the platform is $\mu = 0.2$. The platform is moved with a time dependent velocity given by $\vec{V} = \left(2t\hat{i} + t\hat{j} + 3t\hat{k}\right)$m/s. Calculate the magnitude of the force exerted by the block on the platform. Take g = 10 m/s^2

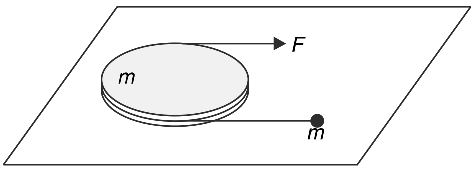


Q. 34. In the system shown in the figure, the string is light and coefficient of friction between the 10 kg block and the incline surface is $\mu = 0.5$. Mass of the hanger, H is 0.5 kg. A boy places a block of mass m on the hanger and finds that the system does not move. What could be values of mass m?

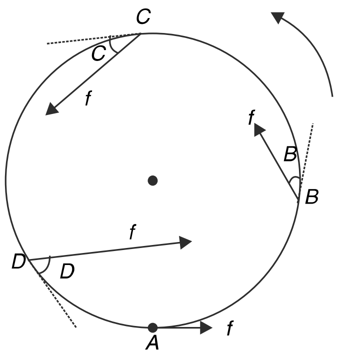
$\tan 37° = \frac{3}{4}$ *and* $g = 10$ m/s^2



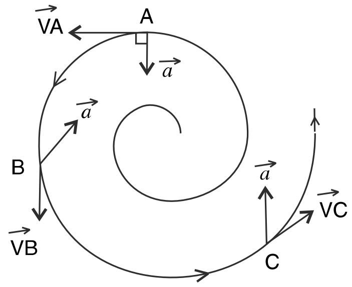
Q. 35. A disc of mass m lies flat on a smooth horizontal table. A light string runs halfway around it as shown in figure. One end of the string is attached to a particle of mass m and the other end is being pulled with a force F. There is no friction between the disc and the string. Find acceleration of the end of the string to which force is being applied.



Q. 36. (a) A car starts moving (at point A) on a horizontal circular track and moves in anticlockwise sense. The speed of the car is made to increase uniformly. The car slips just after point D. The figure shows the friction force (f) acting on the car at points A, B, C and D. The length of the arrow indicates the magnitude of the friction and it is given that $\angle D > \angle B > \angle C$. At which point ($A$, B, C or D) the friction forces represented is certainly wrong ?

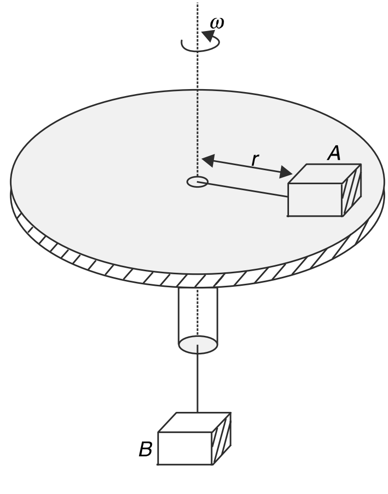


(b) A particle is moving along an expanding spiral (shown in fig) such that the normal force on the particle [i.e., component of force perpendicular to the path of the particle] remains constant in magnitude. The possible direction of acceleration $\left(\vec{a}\right)$ of the particle has been shown at three points A, B and C on its path. At which of these points the direction of acceleration has been represented correctly.



(c) A particle is moving in XY plane with a velocity. $\vec{v} = 4\hat{i} + 2t\hat{j}$ ms^{-1}. Calculate its rate of change of speed and normal acceleration at $t = 2\ s$.

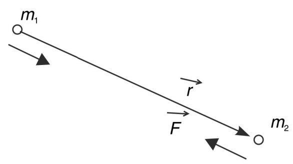
Q. 37. (i) A spinning disk has a hole at its centre. The surface of the disk is horizontal and a small block A of mass $m = 1\ kg$ is placed on it.



Block A is tied to a light inextensible string, other end of which passes through the hole and supports another block B of mass $M = 2\ kg$. The coefficient of friction between A and the disk surface is 0.5. It was observed that the disk is spinning with block A remaining at rest relative to the disk. Block B was found to be stationary. It was estimated that length of horizontal segment of the string (r) was anywhere between 1.0 m to 1.5 m. With this data what estimate can be made about the angular speed (ω) of the disk. [$g = 10\ m/s^2$]

(ii) A spring has force constant equal to $k = 100\ Nm^{-1}$. Ends of the spring are joined to give it a circular shape of radius $R = 20\ cm$. Now the spring is rotated about its symmetry axis (perpendicular to its plane) such that the circumference of the circle increases by 1%. Find the angular speed (ω). Mass of one meter length of the spring is $\lambda = 0.126\ gm^{-1}$.

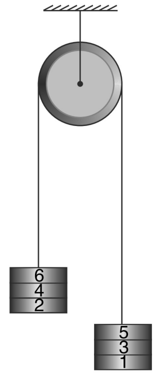
Q. 38. Two particles of mass m_1 and m_2 are in space at separation $\vec{r}$ [vector from m_1 to m_2]. The only force that the two particles experience is the mutual gravitational pull. The force applied by m_1 on m_2 is $\vec{F}$. Prove that $\mu \dfrac{d^2\vec{r}}{dt^2} = \vec{F}$ Where $\mu \dfrac{m_1 m_2}{m_1 + m_2}$ is known as reduced mass for the two particle system.



Q. 39. Six identical blocks – numbered 1 to 6 – have been glued in two groups of three each and have been suspended over a pulley as shown in fig. The pulley and string are massless and the system is in equilibrium. The block 1, 2, 3, and 4 get detached from the system in sequence starting with block 1. The time gap between separation of two consecutive block (i.e., time gap between separation of 1 and 2 or gap between separation of 2 and 3) is t_0. Finally, blocks 5 and 6 remain connected to the string.

(a) Find the final speed of blocks 5 and 6.

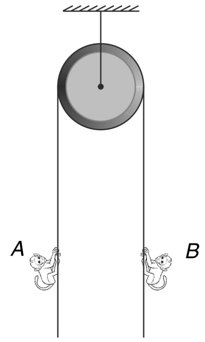
(b) Plot the graph of variation of speed of block 5 with respect to time. Take $t = 0$ when block 1 gets detached.



Q. 40. Two monkeys A and B are holding on the two sides of a light string passing over a smooth pulley. Mass of the two monkeys are $m_A = 8\ kg$ and $m_B = 10\ kg$ respectively [$g = 10\ m/s^2$]

(a) Monkey A holds the string tightly and B goes down with an acceleration $a_r = 2\ m/s^2$ relative to the string. Find the weight that A feels of his own body.

(b) What is the weight experienced by two monkeys if A holds the string tightly and B goes down with an acceleration $a_r = 4\ m/s^2$ relative to the string.



LEVEL 2

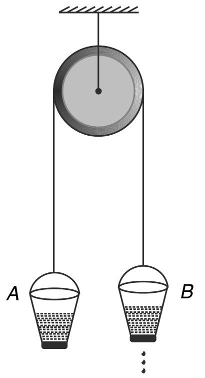
Q. 41. Two strange particles A and B in space, exert no force on each other when they are at a separation greater than $x_0 = 1.0\ m$. When they are at a distance less than x_0, they repel one another along the line joining them. The repulsion force is constant and does not depend on the distance between the particles. This repulsive force produces an acceleration of 6 ms^{-2} in A and 2 ms^{-2} in B when the particles are at separation less than x_0. In one experiment particle B is projected towards A with a velocity of 2 ms^{-1} from a large distance so as to hit A head on. The particle A is originally at rest and the system of two particles do not experience any external force.

(a) Find the ratio of mass of A to that of B.

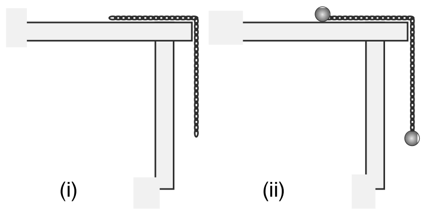
(b) Find the minimum distance between the particles during subsequent motion.

(c) Find the final velocity of the two particles.

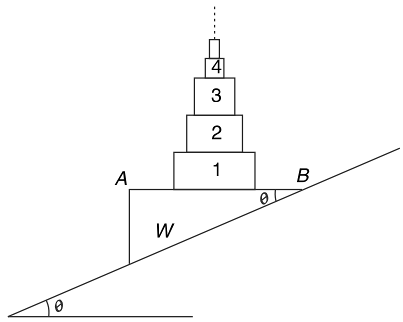
Q. 42. A light string passing over a smooth pulley holds two identical buckets at its ends. Mass of each empty bucket is M and each of them holds M mass of sand. The system was in equilibrium when a small leak developed in bucket B (take this time as $t = 0$). The sand leaves the bucket at a constant rate of μ kg/s. Assume that the leaving sand particles have no relative speed with respect to the bucket (it means that there is no impulsive force on the bucket like leaving exhaust gases exert on a rocket). Find the speed (V_0) of the two bucket when B is just empty.



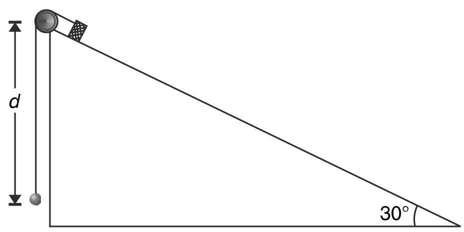
Q. 43. A chain is lying on a smooth table with half its length hanging over the edge of the table [fig(i)]. If the chain is released it slips off the table in time t_1. Now, two identical small balls are attached to the two ends of the chain and the system is released [fig(ii)]. This time the chain took t_2 time to slip off the table. Which time is larger, t_1 or t_2?



Q. 44. A triangular wedge W having mass M is placed on an incline plane with its face AB horizontal. Inclination of the incline is θ. On the flat horizontal surface of the wedge there lies an infinite tower of rectangular blocks. Blocks 1, 2, 3, 4 ………. have masses $M, \frac{M}{2}, \frac{M}{4}, \frac{M}{8}$ ....respectively. All surfaces are smooth. Find the contact force between the block 1 and 2 after the system is released from rest. Also find the acceleration of the wedge.



Q. 45. In the system shown in fig, mass of the block is $m_1 = 4$ kg and that of the hanging particle is $m_2 = 1$ kg. The incline is fixed and surface is smooth. Block is initially held at the top of the incline and the particle hangs a distance $d = 2.0$ m below it. [Assume that the block and the particle are on same vertical line in this position]. System is released from this position. After what time will the distance between the block and the particle be minimum ? Find this minimum distance. [$g = 10$ m/s^2.]



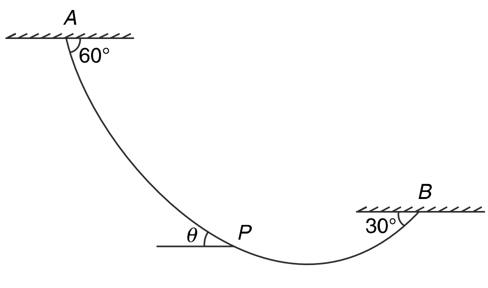
Q. 46. A uniform chain of mass $M = 4.8$ kg hangs in vertical plane as shown in the fig.

(a) Show that horizontal component of tension is same throughout the chain.

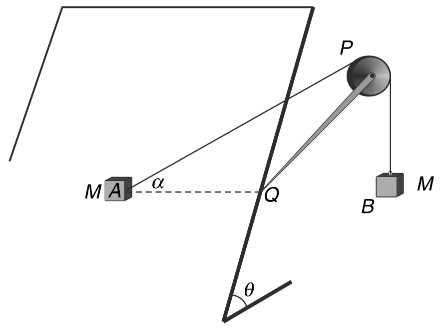
(b) Find tension in the chain at point P where the chain makes an angle $\theta = 15°$ with horizontal.

(c) Find mass of segment AP of the chain.

[Take $g = 10$ m/s^2; cos 15° = 0.96, sin 15° = 0.25]

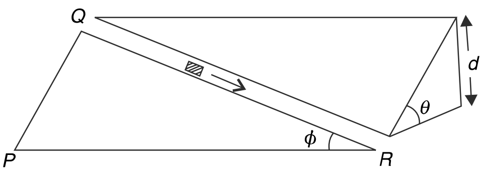


Q. 47. Block A of mass M is placed on an incline plane, connected to a string, passing over a pulley as shown in the fig. The other end of the string also carries a block B of mass M. The system is held in the position shown such that triangle APQ lies in a vertical plane with horizontal line AQ in the plane of the incline surface.

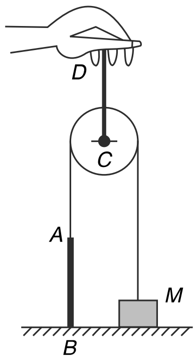


Find the minimum coefficient of friction between the incline surface and block A such that the system remains at rest after it is released. Take $\theta = \alpha = 45°$.

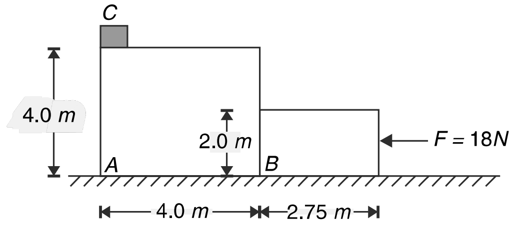
Q. 48. Figure shown a fixed surface inclined at an angle θ to the horizontal. A smooth groove is cut on the incline along QR forming an angle ϕ with PR. A small block is released at point Q and it slides down to R in time t. Find t.



Q. 49. In the system shown in the figure AB and CD are identical elastic cords having force constant K. The string connected to the block of mass M is inextensible and massless. The pulley is also massless. Initially, the cords are just taut. The end D of the cord CD is gradually moved up. Find the vertical displacement of the end D by the time the block leaves the ground.



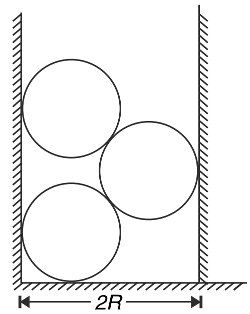
Q. 50. Blocks A and B have dimensions as shown in the fig. and their masses are 8 kg and 1 kg respectively. A small block C of mass 0.5 kg is placed on the top left corner of block A. All surfaces are smooth. A horizontal force $F = 18\ N$ is applied to the block B at time $t = 0$. At what time will the block C hit the ground surface? Take $g = 10\ m/s^2$.



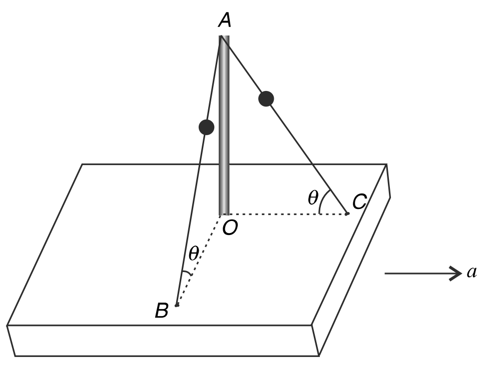
Q. 51. Three identical smooth balls are placed between two vertical walls as shown in fig. Mass of each ball is m and radius is $r = \frac{5R}{9}$ where $2R$ is separation between the walls.

(a) Force between which two contact surface is maximum? Find its value.

(b) Force between which two contact surface is minimum and what is its value?



Q. 52. A horizontal wooden block has a fixed rod OA standing on it. From top point A of the rod, two wires have been fixed to points B and C on the block. The plane of triangle OAB is perpendicular to the plane of the triangle OAC. There are two identical beads on the two wires. One of the wires

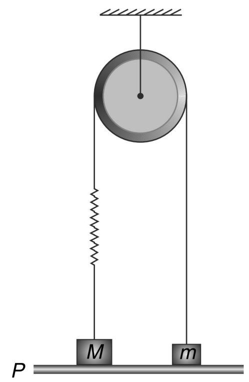


is perfectly smooth while the other is rough. The wooden block is moved with a horizontal acceleration (a) that is perpendicular to the line OB and it is observed that both the beads do not slide on the wire. Find the minimum coefficient of friction between the rough wire and the bead.

Q. 53. In the arrangement shown in the fig. the pulley, the spring and the thread are ideal. The spring is stretched and the two blocks are in contact with a horizontal platform P. When the platform is gradually moved up by 2 cm the tension in the string becomes zero. If the platform is gradually moved down by 2 cm from its original position one of the blocks lose contact with the platform. Given $M = 4\ kg$; $m = 2\ kg$.

(a) Find the force constant (k) of the spring

(b) If the platform continues to move down after one of the blocks loses contact, will the other block also lose contact? Assume that that the platform moves very slowly.

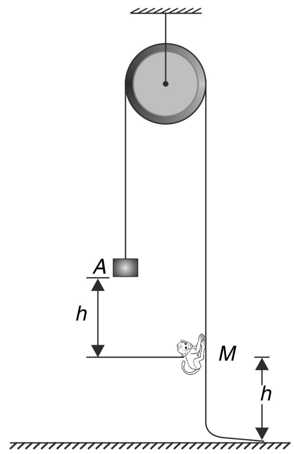


Q. 54. In the arrangement shown in the fig. a monkey of mass M keeps itself as well as block A at rest by firmly holding the rope. Rope is massless and the pulley is ideal. Height of the monkey and block A from the floor is h and $2h$ respectively [$h = 2.5\ m$]

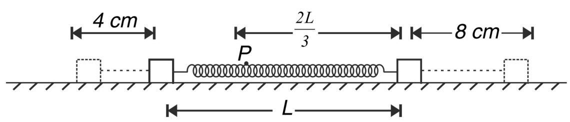
(a) The monkey loosens its grip on the rope and slides down to the floor. At what height from the ground is block A at the instant the money hits the ground?

(b) Another block of mass equal to that of A is stuck to the block A and the system is released. The monkey decides to keep itself at height h above the ground and it allows the rope to slide through its hand. With what speed will the block strike the ground?

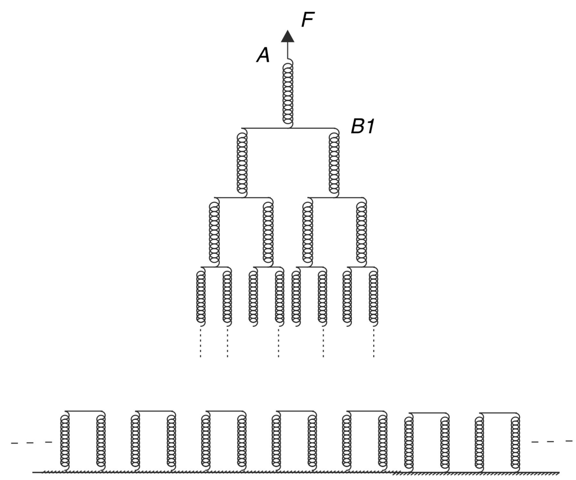
(c) In the situation described in (b), the monkey decides to prevent the block from striking the floor. The monkey remains at height h till the block crosses it. At the instant the block is crossing the monkey it begins climbing up the rope. Find the minimum acceleration of the monkey relative to the rope, so that the block is not able to hit the floor. Do you think that a monkey can climb with such an acceleration? ($g = 10\ ms^{-2}$)



Q. 55. An ideal spring is in its natural length (L) with two objects A and B connected to its ends. A point P on the unstretched spring is at a distance $\frac{2L}{3}$ from B. Now the objects A and B are moved by 4 cm to the left and 8 cm to the right respectively. Find the displacement of point P.



Q. 56. The fig. shows an infinite tower of identical springs each having force constant k. The connecting

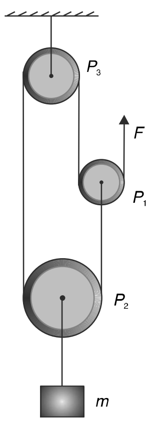


bars and all springs are massless. All springs are relaxed and the bottom row of springs is fixed to horizontal ground. The free end of the top spring is pulled up with a constant force F. In equilibrium, find

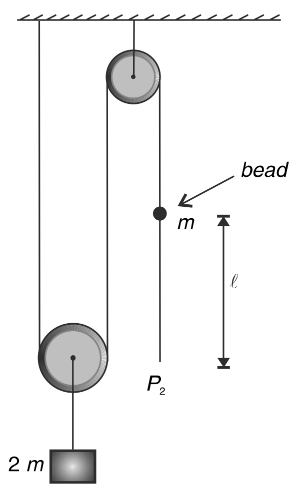
(a) The displacement of free end A of the top spring from relaxed position.

(b) The displacement of the top bar $B1$ from the initial relaxed position.

Q. 57. In the system shown in the fig. there is no friction and string is light. Mass of movable pulley P_2 is M_2. If pulley P_1 is massless, what should be value of applied force F to keep the system in equilibrium?



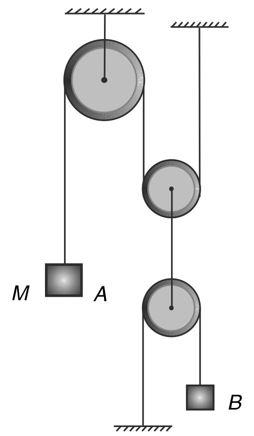
Q. 58. In the system shown in the fig., the bead of mass m can slide on the string. There is friction between the bead and the string. Block has mass equal to twice that of the bead. The system is released from rest with length l of the string hanging below the bead. Calculate the distance moved by the block before the bead slips out of the thread. Assume the string and pulley to be massless.



Q. 59. In the arrangement shown in the fig. all pulleys are mass less and the strings are inextensible and light. Block A has mass M.

(a) If the system stays at rest after it is released, find the mass of the block B.

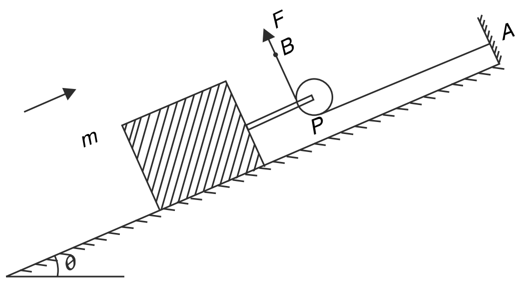
(b) If mass of the block B is twice the value found in part (a) of the problem, calculate the acceleration of block A.



Q. 60. In the fig. shown, the pulley and string are mass less and the incline is frictionless. The segment AP of the string is parallel to the incline and the segment PB is perpendicular to the incline. End of the string is pulled with a constant force F.

(a) If the block is moving up the incline with acceleration while being in contact with the incline, then angle θ must be less then θ_0. Find θ_0

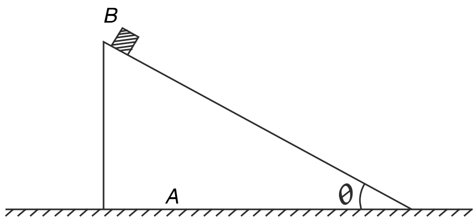
(b) If $\theta = \frac{\theta_0}{2}$ find the maximum acceleration with which the block can move up the plane without losing contact with the incline.



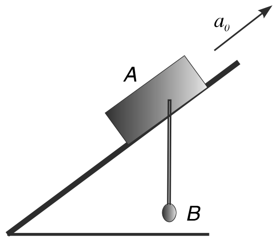
Q.61. A triangular wedge A is held fixed and a block B is released on its inclined surface, from the top. Block B reaches the horizontal ground in time t. In another experiment, the wedge A was free to slide on the horizontal surface and it took t' time for the block B to reach the ground surface after it was released from the top. Neglect friction and assume that B remains in contact with A.

(a) Which time is larger t or t'? Tell by simple observation.

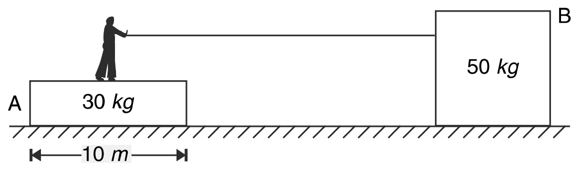
(b) When wedge A was free to move, it was observed that it moved leftward with an acceleration $\frac{g}{4}$ and one of the two measured times (t & t') was twice the other. Find the inclination θ of the inclined surface of the wedge.



Q. 62. A block A is made to move up an inclined plane of inclination θ with constant acceleration a_0 as shown in figure. Bob B, hanging from block A by a light inextensible string, is held vertical and is moving along with the block. Calculate the magnitude of acceleration of block A relative to the bob immediately after bob is released.



Q. 63. A 50 kg man is standing at the centre of a 30 kg platform A. Length of the platform is 10 m and coefficient of friction between the platform and the horizontal ground is 0.2. Man is holding one end of a light rope which is connected to a 50 kg box B. The coefficient of friction between the box and the ground is 0.5. The man pulls the rope so as to slowly move the box and ensuring that he himself does not move relative to the ground. If the shoes of the man does not slip on the platform, calculate how much time it will take for the man to fall off the platform. Assume that rope remains



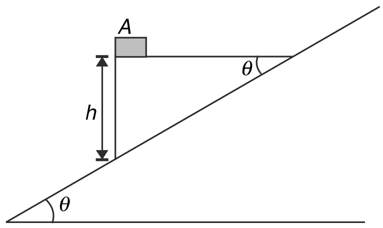
horizontal, and coefficient of friction between shoes and the platform is 0.6.

Q. 64. A wedge is placed on the smooth surface of a fixed incline having inclination θ with the horizontal. The vertical wall of the wedge has height h and there is a small block A on the edge of the horizontal surface of the wedge. Mass of the wedge and the small block are M and m respectively.

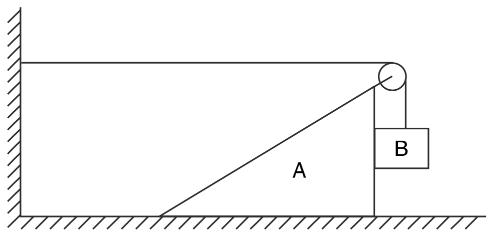
(a) Find the acceleration of the wedge if friction between block A and the wedge is large enough to prevent slipping between the two.

(b) Find friction force between the block and the wedge in the above case. Also find the normal force between the two.

(c) Assuming there is no friction between the block and the wedge, calculate the time in which the block will hit the incline.



Q. 65. In the system shown in figure, all surfaces are smooth, pulley and strings are massless. Mass of both A and B are equal. The system is released from rest.



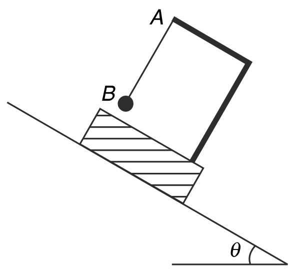
(a) Find the $\vec{a}_A \cdot \vec{a}_B$ immediately after the system is released. $\vec{a}_A$ and $\vec{a}_B$ are accelerations of block A and B respectively.

(b) Find $\vec{a}_A$ immediately after the system is released.

Q.66. A block is placed on an incline having inclination θ. There is a rigid L shaped frame fixed to the block. A plumb line (a ball connected to a thread) is attached to the end A of the frame. The system is released on the inline. Find the angle that the plumb line will make with vertical in its equilibrium position relative to the block when

(a) the incline is smooth

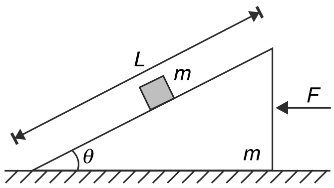
(b) there is friction and the acceleration of the block is half its value when the incline is smooth



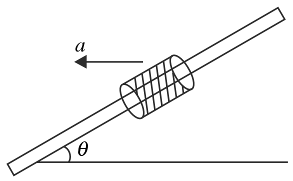
Q. 67. A wedge of mass m is placed on a horizontal smooth table. A block of mass m is placed at the mid point of the smooth inclined surface having length L along its line of greatest slope. Inclination of the inclined surface is $\theta = 45°$. The block is released and simultaneously a constant horizontal force F is applied on the wedge as shown.

(a) What is value of F if the block does not slide on the wedge?

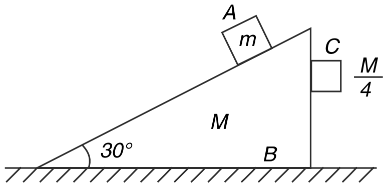
(b) In how much time the block will come out of the incline surface if applied force is 1.5 times that found in part (a)



Q. 68. A rod is kept inclined at an angle θ with the horizontal A sleeve of mass m can slide on the rod. If the coefficient of friction between the rod and the sleeve is μ, for what values of horizontal acceleration a of the rod, towards left, the sleeve will not slide over the rod?



Q. 69. In the arrangement shown in figure, a block A of mass m has been placed on a smooth wedge B of mass M. The wedge lies on a horizontal smooth surface. Another block C of mass $\frac{M}{4}$ has been placed in contact with the wedge B as shown. The coefficient of friction between the block C and the vertical wedge wall is $\mu = \frac{3}{4}$. Find the ratio $\frac{m}{M}$ for which the block C will not slide with respect to the wedge after the system is released?

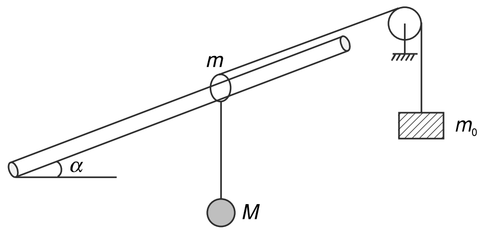


Q. 70. A smooth rod is fixed at an angle α to the horizontal. A small ring of mass m can slide along the rod. A thread carrying a small sphere of mass M is attached to the ring. To keep the system in equilibrium, another thread is attached to the ring which carries a load of mass m_0 at its end (see figure). The thread runs parallel to the rod between the ring and the pulley.

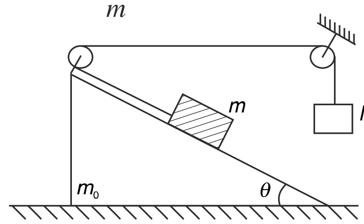
All threads and pulley are massless.

(a) Find m_0 so that system is in equilibrium.

(b) Find acceleration of the sphere M immediately after the thread supporting m_0 is cut.

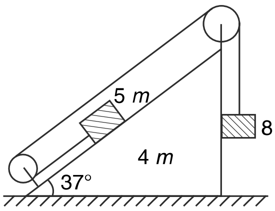


Q. 71. In the system shown in figure all surfaces are smooth and string and pulleys are light. Angle of wedge $\theta = \sin^{-1}\left(\frac{3}{5}\right)$. When released from rest it was found that the wedge of mass m_0 does not move. Find $\frac{M}{m}$.

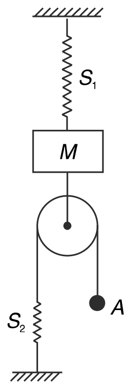


Q. 72. In the last problem take $M = m$ and $m_0 = 2\,m$ and calculate the acceleration of the wedge.

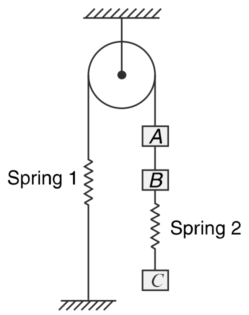
Q. 73. In the system shown in the figure all surfaces are smooth, pulley and string are massless. The string between the two pulleys and between pulley and block of mass 5 m is parallel to the incline surface of the block of mass 4 m. The system is released from rest. Find the acceleration of the block of mass 4 m. $\left[\tan 37° = \frac{3}{4}\right]$



Q. 74. In the system shown in figure, the two springs S_1 and S_2 have force constant k each. Pulley, springs and strings are all massless. Initially, the system is in equilibrium with spring S_1 stretched and S_2 relaxed. The end A of the string is pulled down slowly through a distance L. By what distance does the block of mass M move?



Q. 75. The system shown in figure is in equilibrium. Pulley, springs and the strings are massless. The three blocks A, B and C have equal masses. x_1 and x_2 are extensions in the spring 1 and spring 2 respectively.

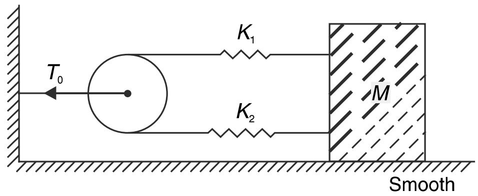


(a) Find the value of $\left|\frac{d^2x_2}{dt^2}\right|$ immediately after spring 1 is cut.

(b) Find the value of $\left|\frac{d^2x_1}{dt^2}\right|$ and $\left|\frac{d^2x_2}{dt^2}\right|$ immediately after string AB is cut.

(c) Find the value of $\left|\frac{d^2x_1}{dt^2}\right|$ and $\left|\frac{d^2x_2}{dt^2}\right|$ immediately after spring 2 is cut.

Q. 76. In the figure shown, the pulley, strings and springs are mass less. The block is moved to right by a distance x_0 from the position where the two springs are relaxed. The block is released from this position.

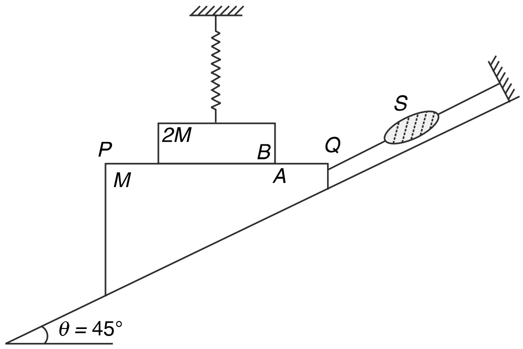


(a) Find the acceleration of the block immediately after it is released.

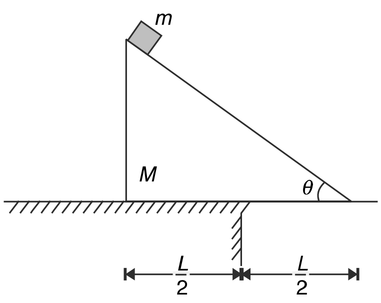
(b) Find tension (T_0) in the support holding the pulley to the wall, immediately after the block is released.

Assume no friction.

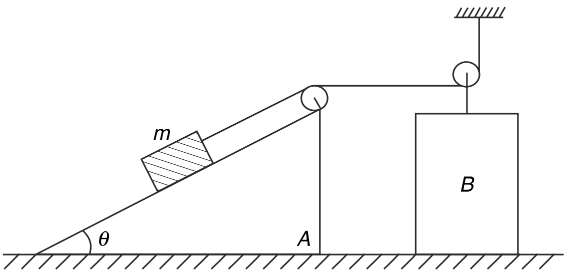
Q.77. The system shown in figure is in equilibrium. Surface PQ of wedge A, having mass M, is horizontal. Block B, having mass $2M$, rests on wedge A and is supported by a vertical spring. The spring balance S is showing a reading of $\sqrt{2}\ Mg$. There is no friction anywhere and the thread QS is parallel to the incline surface. The thread QS is cut. Find the acceleration of A and the normal contact force between A and B immediately after the thread is cut.



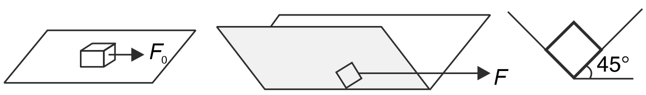
Q.78. A triangular wedge of mass M lies on a smooth horizontal table with half of its base projecting out of the edge of the table. A block of mass m is kept at the top of the smooth incline surface of the wedge and the system is let go. Find the maximum value of $\frac{M}{m}$ for which the block will land on the table. Take $\theta = 60°$.



Q.79. In the system shown in the figure all surfaces are smooth and both the pulleys are mass less. Block on the incline surface of wedge A has mass m. Mass of A and B are $M = 4\,m$ and $M_0 = 2\,m$ respectively. Find the acceleration of wedge A when the system is released from rest.

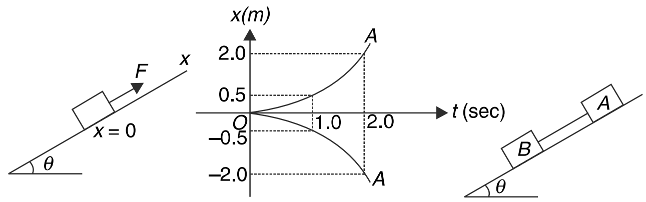


Q.80. A block of mass m requires a horizontal force F_0 to move it on a horizontal metal plate with constant velocity. The metal plate is folded to make it a right angled horizontal trough. Find the horizontal force F that is needed to move the block with constant velocity along this trough.

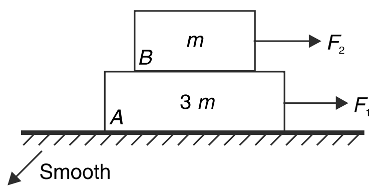


Q.81. Block A of mass $m_A = 200\,g$ is placed on an incline plane and a constant force $F = 2.2\,N$ is applied on it parallel to the incline. Taking the initial position of the block as origin and up along the incline as x direction, the position (x) time (t) graph of the block is recorded (see figure (b)). The same experiment is repeated with another block B of mass $m_B = 500\,g$. Same force F is applied to it up along the incline and its position – time graph is recorded (see figure (b)). Now the two blocks are connected by a light string and released on the same incline as shown in figure (c). Find the tension in the string.

$$\left[\tan\theta = \frac{3}{4}; g = 10\,m/s^2\right]$$



Q.82. Block B of mass m has been placed on block A of mass $3\,m$ as shown. Block A rests on a smooth horizontal table. F_1 is the maximum horizontal force that can be applied on the block A such that there is no slipping between the blocks. Similarly, F_2 is the maximum horizontal force that can be applied on the block B so that the two blocks move together without slipping on each other. When F_1 and F_2 both are applied together as shown in figure.

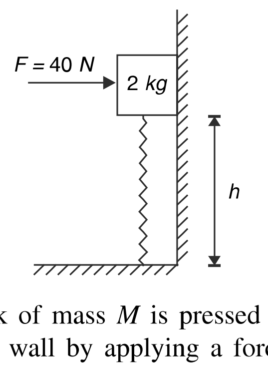


(a) Find the friction force acting between the blocks.

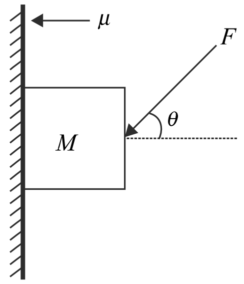
(b) Acceleration of the two blocks.

(c) If F_2 is decreased a little, what will be direction of friction acting on B.

Q. 83. (i) In the arrangement shown in the figure the coefficient of friction between the 2 kg block and the vertical wall is $\mu = 0.5$. A constant horizontal force of 40 N keeps the block pressed against the wall. The spring has a natural length of 1.0 m and its force constant is $k = 400\ Nm^{-1}$. What should be the height h of the block above the horizontal floor for it to be in equilibrium. The spring is not tied to the block.



(ii) A block of mass M is pressed against a rough vertical wall by applying a force F making an angle of θ with horizontal (as shown in figure). Coefficient of friction between the wall and the block is $\mu = 0.75$.

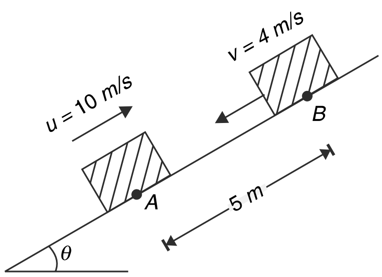


(a) If $F = 2\ Mg$, find the range of values of θ so that the block does not slide

[Take tan 37° = 0.75; sin 24° = 0.4]

(b) Find the maximum value of θ above which equilibrium is not possible for any magnitude of force F.

Q. 84. A block is projected up along a rough incline with a velocity of $\upsilon = 10\ m/s$. After 4 s the block was at point B at a distance of 5 m from the starting point A and was travelling down at a velocity of $v = 4\ m/s$.

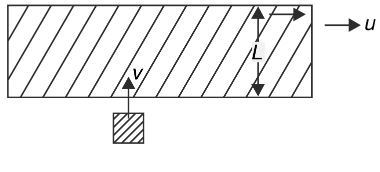


(a) Find time after projection at which the block came to rest.

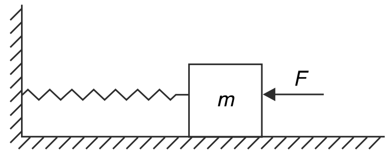
(b) Find the coefficient of friction between the block and the incline.

Take $g = 10\ m/s^2$

Q. 85. A long piece of paper is being pulled on a horizontal surface with a constant velocity υ along its length. Width of the paper is L. A small block moving horizontally, perpendicular to the direction of motion of the paper, with velocity v slides onto the paper. The coefficient of friction between the block and the paper is μ. Find maximum value of v such that the block does not cross the opposite edge of the paper.

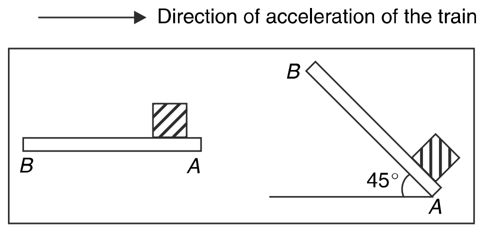


Q. 86. A block of mass $m = 1\ kg$ is kept pressed against a spring on a rough horizontal surface. The spring is compressed by 10 cm from its natural length and to keep the block at rest in this position a horizontal force (F) towards left is applied. It was found that the block can be kept at rest if $8\ N \le F \le 18\ N$. Find the spring constant (k) and the coefficient of friction (μ) between the block and the horizontal surface.

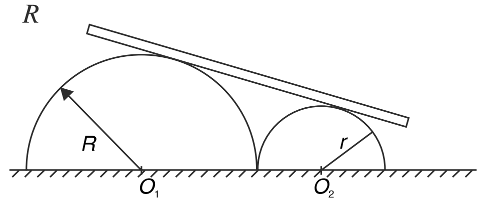


Q. 87. An experimenter is inside a uniformly accelerated train. Train is moving horizontally with constant acceleration a_0. He places a wooden plank AB in horizontal position with end A pointing towards the engine of the train. A block is released at end A of the plank and it reaches end B in time t_1. The same plank is placed at an inclination of 45° to the horizontal. When the block is released at A it now climbs to B in time t_2. It was found that $\frac{t_2}{t_1} = 2^{5/4}$.

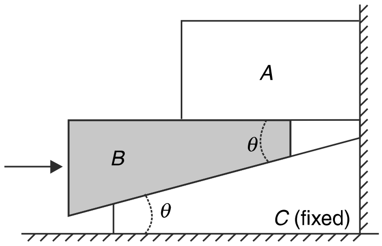
What is the coefficient of friction between the block and the plank?



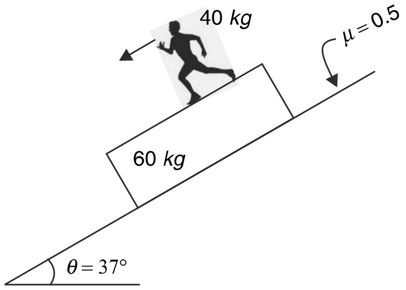
Q. 88. Two hemispheres of radii R and $r\ (< R)$ are fixed on a horizontal table touching each other (see figure). A uniform rod rests on two spheres as shown. The coefficient of friction between the rod and two spheres is μ. Find the minimum value of the ratio $\frac{r}{R}$ for which the rod will not slide.



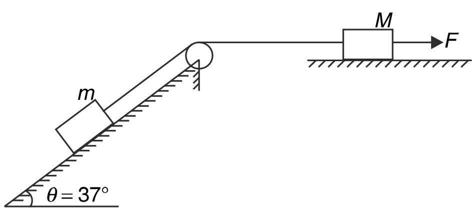
Q. 89. In order to lift a heavy block A, an engineer has designed a wedge system as shown. Wedge C is fixed. A horizontal force F is applied to B to lift block A. Wedge B itself has negligible mass and mass of A is M. The coefficient of friction at all surfaces is μ. Find the value of applied force F at which the block A just begins to rise.



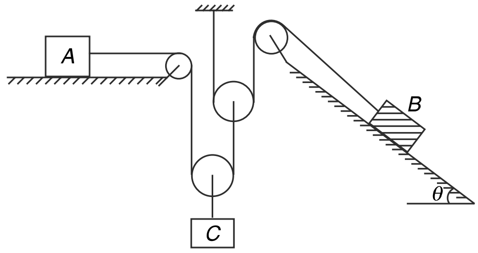
Q.90. A 60 kg platform has been placed on a rough incline having inclination $\theta = 37°$. The coefficient of friction between the platform and the incline is $\mu = 0.5$. A 40 kg man is running down on the platform so as to keep the platform stationary. What is the acceleration of the man? It is known that the man cannot manage to go beyond an acceleration of 7 m/s^2. $\left[\sin 37° = \frac{3}{5}\right]$



Q. 91. In the system show in figure, mass of the block placed on horizontal surface is M = 4 kg. A constant horizontal force of F = 40 N is applied on it as shown. The coefficient of friction between the blocks and surfaces is μ = 0.5. Calculate the values of mass m of the block on the incline for which the system does not move. $\left[\sin 37° = \frac{3}{5}; g = 10 m/s^2\right]$



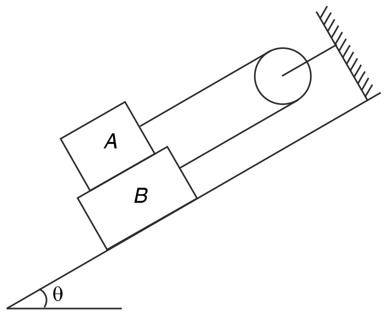
Q. 92. In the arrangement shown in the figure, block A of mass 8 kg rests on a horizontal table having coefficient of friction μ = 0.5. Block B has a mass of 6 kg and rests on a smooth incline having inclination angle $\theta = \sin^{-1}\left(\frac{2}{5}\right)$. All pulleys and strings are mass less. Mass of block C is M. [$g = 10\ m/s^2$]



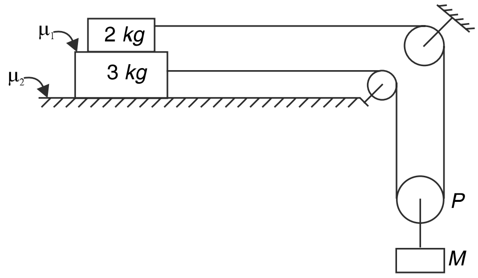
(a) Find value of M for which block B does not accelerate

(b) Find maximum value of M for which A does not accelerate.

Q.93. In the arrangement shown in figure, pulley and string are light. Friction coefficient between the two blocks is μ whereas the incline is smooth. Block A has mass m and difference in mass of the two blocks is Δm. Find minimum value of μ for which the system will not accelerate when released from rest.



Q. 94. In the arrangement shown in figure pulley P can move whereas other two pulleys are fixed. All of them are light. String is light and inextensible. The coefficient of friction between 2 kg and 3 kg block is μ_1 = 0.75 and that between 3 kg block and the table is μ_2 = 0.5. The system is released from rest



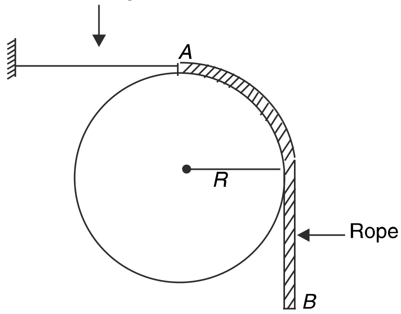
(i) Find maximum value of mass M, so that the system does not move. Find friction force between 2 kg and 3 kg blocks in this case.

(ii) If M = 4 kg, find the tension in the string attached to 2 kg block.

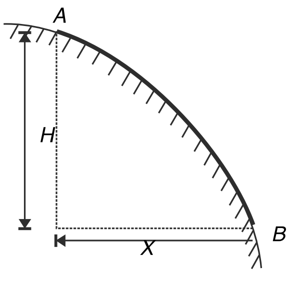
(iii) If $M = 4\ kg$ and $\mu_1 = 0.9$, find friction force between the two blocks, and acceleration of M.

(iv) Find acceleration of M if $\mu_1 = 0.75$, $\mu_2 = -0.9$ and $M = 4\ kg$.

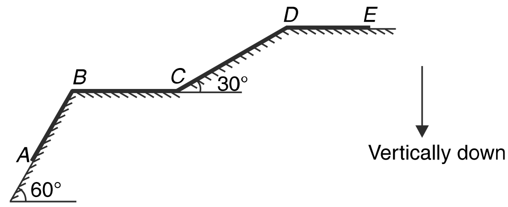
Q. 95. A rope of length $\left(\frac{\pi}{2}+1\right) R$ has been placed on a smooth sphere of radius R as shown in figure. End A of the rope is at the top of the sphere and end B is overhanging. Mass per unit length of the rope is λ. The horizontal string holding this rope in place can tolerate tension equal to weight of the rope. Find the maximum mass (M_0) of a block that can be tied to the end B of the rope so that the string does not break.



Q.96. A uniform rope has been placed on a sloping surface as shown in the figure. The vertical separation and horizontal separation between the end points of the rope are H and X respectively. The friction coefficient (μ) is just good enough to prevent the rope from sliding down. Find the value of μ.



Q.97. A uniform rope $ABCDE$ has mass M and it is laid along two incline surfaces (AB and CD) and two horizontal surfaces (BC and DE) as shown in figure. The four parts of the rope AB, BC, CD and DE are of equal lengths. The coefficient of friction (μ) is uniform along the entire surface and is just good enough to prevent the rope from sliding.

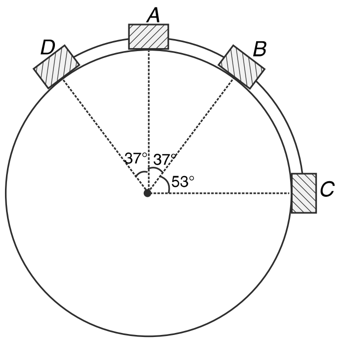


(a) Find μ

(b) x is distance measured along the length of the rope starting from point A. Plot the variation of tension in the rope (T) with distance x.

(c) Find the maximum tension in the rope.

Q. 98. (i) Four small blocks are interconnected with light strings and placed over a fixed sphere as shown. Blocks A, B and C are identical each having mass $m = 1\ kg$. Block D has a mass of $m' = 2\ kg$. The coefficient of friction between the blocks and the sphere is $\mu = 0.5$. The system is released from the position shown in figure.

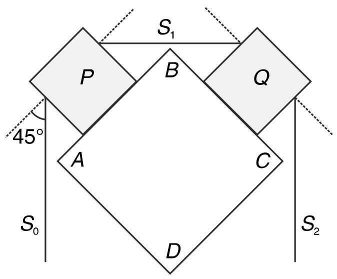


(a) Find the tension in each string. Which string has largest tension?

(b) Find the friction force acting on each block.

$$\left[\text{Take}\tan 37° = \frac{3}{4};\ g = 10\ m/s^2\right]$$

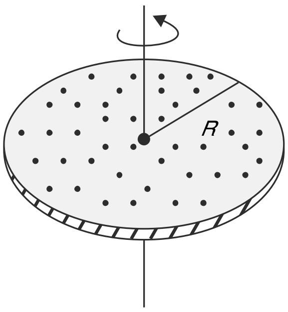
(ii) A fixed square prism $ABCD$ has its axis horizontal and perpendicular to the plane of the figure. The face AB makes 45° with the vertical. On the upper faces AB and BC of the prism there are light bodies P and Q respectively. The two bodies (P and Q) are connected using a string S_1 and strings S_0 and S_2 are hanging from P and Q respectively. All strings are mass less, and inextensible. String S_1 is horizontal and the other two strings are vertical. The coefficient of friction between the bodies and the prism is μ_0. Assume that P and Q always remain in contact with the prism.



(a) If tension in S_0 is T_0, find the minimum tension (T_1) in S_1 to keep the body P at rest.

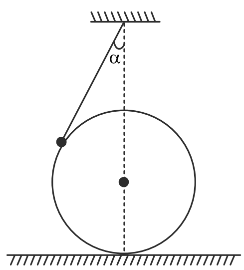
(b) A mass M_0 is tied to the lower end of string S_0 and another mass m_2 is tied to S_2. Find the minimum value of m_2 so as to keep P and Q at rest.

Q. 99. A metal disc of radius R can rotate about the vertical axis passing through its centre. The top surface of the disc is uniformly covered with dust particles. The disc is rotated with gradually increasing speed. At what value of the angular speed (ω) of the disc the 75% of the top surface will become dust free. Assume that the coefficient of friction between the dust particles and the metal disc is μ = 0.5. Assume no interaction amongst the dust particles.



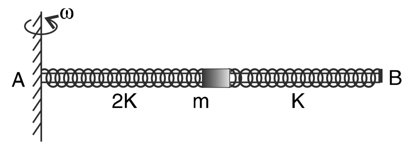
Q.100. In the last question, the axis of the disc is tilted slightly to make an angle θ with the vertical. Redo the problem for this condition and check the result by putting $\theta = 0$ in your answer.

Q. 101.

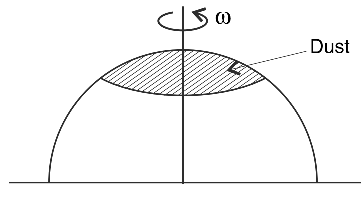


A sphere of mass M is held at rest on a horizontal floor. One end of a light string is fixed at a point that is vertically above the centre of the sphere. The other end of the string is connected to a small particle of mass m that rests on the sphere. The string makes an angle $\alpha = 30°$ with the vertical. Find the acceleration of the sphere immediately after it is released. There is no friction anywhere.

Q. 102. A light rod AB is fitted with a small sleeve of mass m which can slide smoothly over it. The sleeve is connected to the two ends of the rod using two springs of force constant $2k$ and k (see fig). The ends of the springs at A and B are fixed and the other ends (connected to sleeve) can move along with the sleeve. The natural length of spring connected to A is ℓ_0. Now the rod is rotated with angular velocity ω about an axis passing through end A that is perpendicular to the rod. Take $\frac{k}{m\omega^2} = \eta$ and express the change in length of each spring (in equilibrium position of the sleeve relative to the rod) in terms of ℓ_0 and η.



Q. 103. A metallic hemisphere is having dust on its surface. The sphere is rotated about a vertical axis passing through its centre at angular speed ω = 10 $rad\ s^{-1}$. Now the dust is visible only on top 20% area of the curved hemispherical surface. Radius of the hemisphere is R = 0.1 m. Find the coefficient of friction between the dust particle and the hemisphere [g = 10 ms^{-2}].



Q. 104. Civil engineers bank a road to help a car negotiate a curve. While designing a road they usually ignore friction. However, a young engineer decided to include friction in his calculation while designing a road. The radius of curvature of the road is R and the coefficient of friction between the tire and the road is μ.

(a) What should be the banking angle (θ_0) so that car travelling up to a maximum speed V_0 can negotiate the curve.

(b) At what speed (V_1) shall a car travel on a road banked at θ_0 so that there is no tendency to skid. (No tendency to skid means there is no static friction force action on the car).

(c) The driver of a car travelling at speed (V_1) starts retarding (by applying brakes). What angle (acute, obtuse or right angle) does the resultant friction force on the car make with the direction of motion?

Q. 105. A turn of radius 100 m is banked for a speed of 20 m/s

(a) Find the banking angle

(b) If a vehicle of mass 500 kg negotiates the curve find the force of friction on it if its speed is – (i) 30 m/s (ii) 10 m/s

Assume that friction is sufficient to prevent skidding and slipping.

[Take tan 22° = 0.4, sin 22° = 0.375, cos 22° = 0.93, $g = 10\ ms^{-2}$]

Q. 106. A horizontal circular turning has a curved length L and radius R. A car enters the turn with a speed V_0 and its speed increases at a constant rate f. If the coefficient of friction is μ,

(a) At what time t_0, after entering the curve, will the car skid? (Take it for granted that it skids somewhere on the turning)

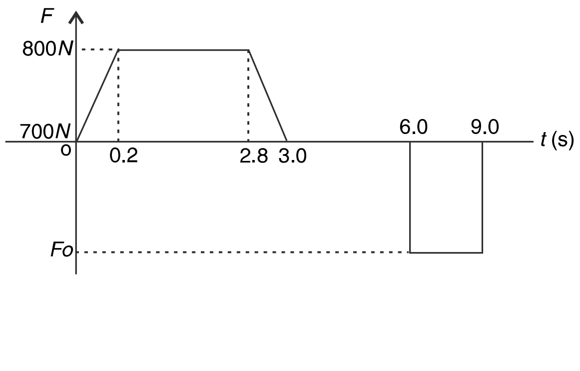
(b) At a time t ($< t_0$) what is the force of friction acting on the car?

Q. 107. A 70 kg man enters a lift and stands an a weighing scale inside it. At time t = 0, the lift starts moving up and stops at a higher floor at t = 9.0 s. During the course of this journey, the weighing scale records his weight and given a plot of his weight vs time. The plot is shown in the fig. [Take $g = 10\ m/s^2$]

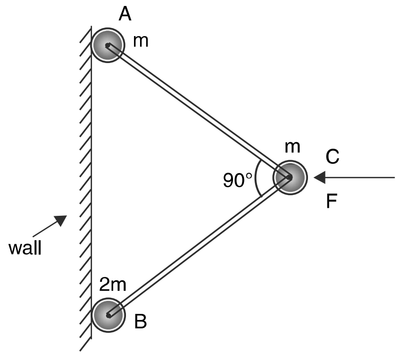
(a) Find F_0

(b) Find the magnitude of maximum acceleration of the lift.

(c) Find maximum speed acquired by the lift.

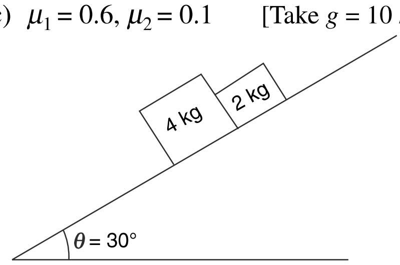


Q.108. Three small discs are connected with two identical massless rods as shown in fig. The rods are pinned to the discs such that angle between them can change freely. The system is placed on a smooth horizontal surface with discs A and B touching a smooth wall and the angle ACB being 90°. A force F is applied to the disc C in a direction perpendicular to the wall. Find acceleration of disc B immediately after the force starts to act. Masses of discs are $m_A = m$; $m_B = 2\ m$; $m_C = m$ [wall is perpendicular to the plane of the fig.]

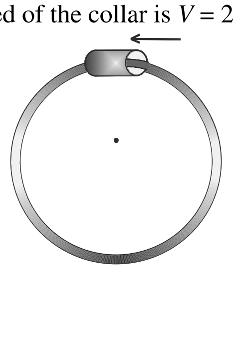


Q. 109. Figure shows two blocks in contact placed on an incline of angle $\theta = 30°$. The coefficient of friction between the block of mass 4 kg and the incline is μ_1, and that between 2 kg block and incline is μ_2. Find the acceleration of the blocks and the contact force between them if –

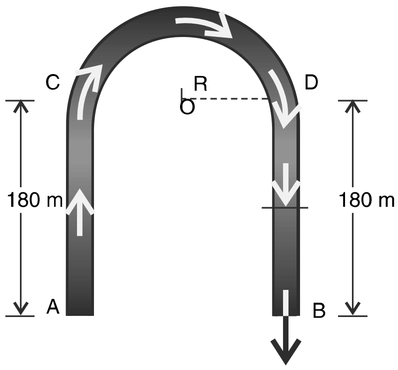
(a) $\mu_1 = 0.5, \mu_2 = 0.8$
(b) $\mu_1 = 0.8, \mu_2 = 0.5$
(c) $\mu_1 = 0.6, \mu_2 = 0.1$ [Take $g = 10\ m/s^2$]



Q. 110. A small collar of mass m = 100 g slides over the surface of a horizontal circular rod of radius R = 0.3 m. The coefficient of friction between the rod and the collar is $\mu = 0.8$. Find the angle made with vertical by the force applied by the rod on the collar when speed of the collar is $V = 2\ m/s$.



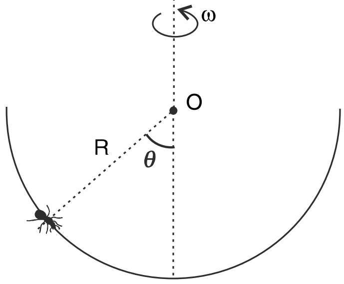
Q. 111. A flat race track consists of two straight section AC and DB each of length 180 m and one semi circular section DC of radius R = 150 m. A car starting from rest at A has to reach B in least possible time (the car may cross through point B and need not stop there). The coefficient of friction between the tyres and the road is μ = 0.6 and the top speed that the car can acquire is 180 kph. Find the minimum time needed to move from A to B under ideal conditions. Braking is not allowed in the entire journey [$g = 10\ m/s^2$]



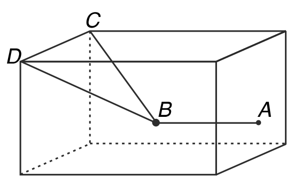
Q. 112. A small insect is climbing slowly along the inner wall of a hemispherical bowl of radius R. The insect is unable to climb beyond θ = 45°. Whenever it tries to climb beyond θ = 45°, it slips.

(a) Find the minimum angular speed ω with which the bowl shall be rotated about its vertical radius so that the insect can climb upto $\theta = 60°$.

(b) Find minimum ω for which the insect can move out of the bowl.



Q. 113.



A room is in shape of a cube. A heavy ball (B) is suspended at the centre of the room tied to three inextensible strings as shown. String BA is horizontal with A being the centre point of the wall. Find the ratio of tension in the string BA and BC.

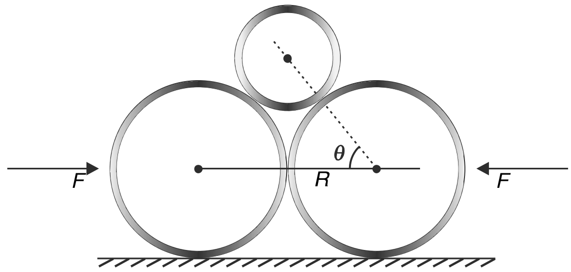
Q.114. Two identical smooth disc of radius R have been placed on a frictionless table touching each other. Another circular plate is placed between them as shown in figure. The mass per unit area of each object is σ, and the line joining the centers of the plate and the disc is θ

(a) Find the minimum horizontal force F_0 that must be applied to the two discs to keep them together.

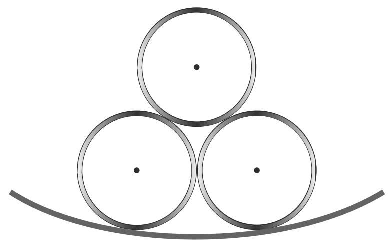
(b) Angle θ can be changed by changing the size of the circular plate. Find F_0 when $\theta \to 0$.

$$\left[\text{use } \cos\theta = 1 - \frac{\theta^2}{2} \text{ and } \sin\theta = \theta \text{ for small } \theta\right]$$

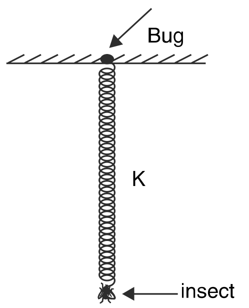
(c) Find F_0 when $\theta \to \pi/2$. Explain the result.



Q. 115. Three identical smooth cylinders, each of mass m and radius r are resting in equilibrium within a fixed smooth cylinder of radius R (only a part of this cylinder has been shown in the fig). Find the largest value of R in terms of r for the small cylinders to remain in equilibrium.



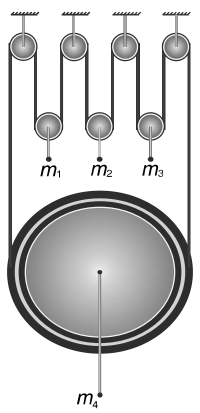
Q. 116. A massless spring of force constant K and natural length ℓ_0 is hanging from a ceiling. An insect of mass m is sitting at the lower end of the spring and the system is in equilibrium . The insect starts slowing climbing up the spring so as to eat a bug sitting on the ceiling. Assume that insect climbs without slipping on the spring and $K = \dfrac{mg}{\ell_0}$. Find the length of the spring when the insect is at $\dfrac{1}{4}$th of its original distance from the bug.



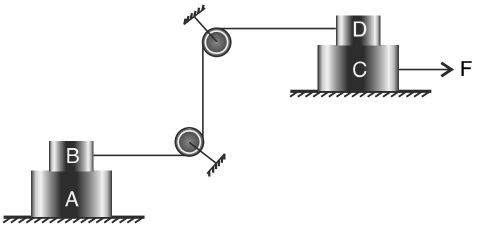
Q. 117. In the system shown in fig., all pulleys are mass less and the string is inextensible and light.

(a) After the system is released, find the acceleration of mass m_1

(b) If m_1 = 1 kg, m_2 = 2 kg and m_3 = 3 kg then what must be value of mass m_4 so that it accelerates downwards?



Q. 118. In the system shown in fig., block A and C are placed on smooth floors and both have mass equal to m_1. Blocks B and D are identical having mass m_2 each. Coefficient of friction

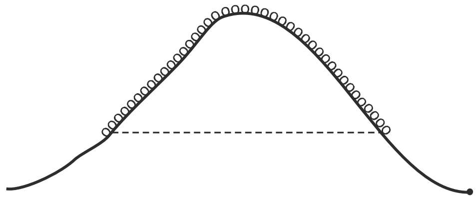


Between A and B and that between C and D are both equal to μ. String and pulleys are light. A horizontal force F is applied on block C and is gradually increased.

(a) Find the maximum value of F (call it F_0) so that all the four blocks move with same acceleration.

(b) Will the value of F_0 increase or decrease if another block (E) of mass m_2 is placed above block D and coefficient of friction between E and D is μ?

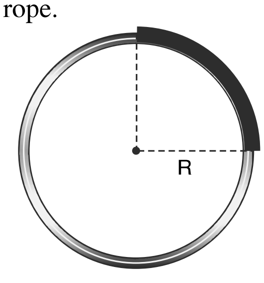
Q. 119. A chain with uniform mass per unit length lies in a vertical plane along the slope of a smooth hill. The two end of the chain are at same height. If the chain is released from this position find its acceleration.



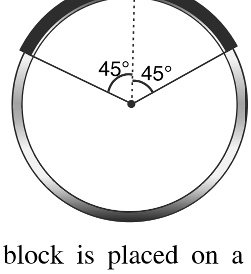
Q. 120. A uniform rope of length $\dfrac{\pi R}{2}$ has been placed on fixed cylinder of radius R as shown in the fig. One end of the rope is at the top of the cylinder. The coefficient of friction between the rope and the cylinder is just enough to prevent the rope from sliding. Mass of the rope is M.

(a) At what position, the tension in the rope is maximum?

(b) Calculate the value of maximum tension in the rope.

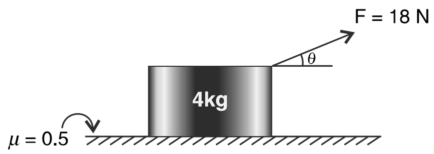


Q. 121. In the last problem, the rope is placed on the cylinder as shown. Find maximum tension in the rope.



Q. 122. A 4 kg block is placed on a rough horizontal surface. The coefficient of friction between the block and the surface is $\mu = 0.5$. A force $F = 18\ N$ is applied on the block making an angle θ with the horizontal. Find the range of values of θ for which the block can start moving.

$$\left[\begin{array}{l}\text{Take } g = 10\ \text{m/s}^2, \tan^{-1}(2) = 63^\circ \\ \qquad \sin^{-1}\left(\dfrac{10}{9\sqrt{1.25}}\right) = 84^\circ\end{array}\right]$$



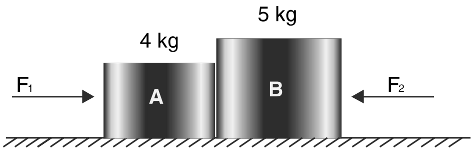
Q. 123. Two rectangular blocks A and B are placed on a horizontal surface at a very small separation. The masses of the blocks are $m_A = 4\ kg$ and $m_B = 5\ kg$. Coefficient of friction between the horizontal surface and both the blocks is $\mu = 0.4$. Horizontal forces F_1 and F_2 are applied on the blocks as shown. Both the forces vary with time as

$F_1 = 15 + 0.5\ t$

$F_2 = 2t$

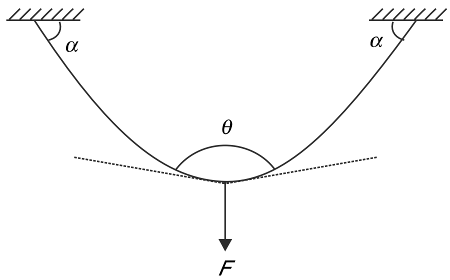
Where 't' is time in second.

Plot the variation of friction force acting on the two blocks (f_A and f_B) vs time till the motion starts. Take rightward direction to be positive for f_B and leftward direction to be positive for f_A.



LEVEL 3

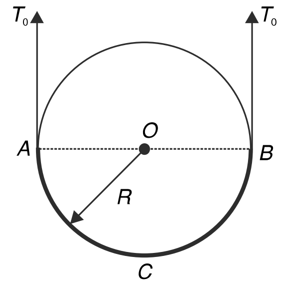
Q. 124. A rope of mass m is hung from a ceiling. The centre point is pulled down with a vertical force F. The tangent to the rope at its ends makes an angle α with horizontal ceiling. The two tangents at the lower point make an angle of θ with each other. Find θ.



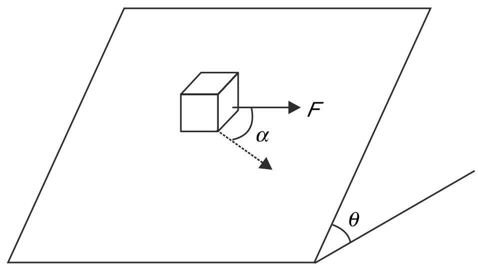
Q. 125. A smooth cylinder is fixed with its axis horizontal. Radius of the cylinder is R. A uniform rope (ACB) of linear mass density λ (kg/m) is exactly of length πR and is held in semicircular shape in vertical plane around the cylinder as shown in figure. Two massless strings are connected at the two ends of the rope and are pulled up vertically with force T_0 to keep the rope in contact with the cylinder.

(a) Find minimum value of T_0 so that the rope does not lose contact with the cylinder at any point.

(b) If T_0 is decreased slightly below the minimum value calculated in (a), where will the rope lose contact with the cylinder.

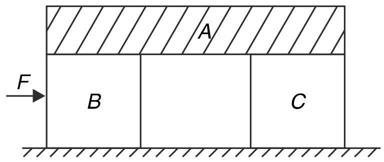


Q. 126. A block of mass m placed on an incline just begins to slide when inclination of the incline is made $\theta_0 = 45^\circ$. With inclination equal to $\theta = 30^\circ$, the block is placed on the incline. A horizontal force (F) parallel to the surface of the incline is applied to the block. The force F is gradually increased from zero. At what angle α to the force F will the block first begin to slide?



Q. 127. In the last problem if it is allowed to apply the force F in any direction, find the minimum force F_{min} needed to move the block on the incline.

Q. 128. A block A has been placed symmetrically over two identical blocks B and C. All the three blocks have equal mass, M each, and the horizontal surface on which B and C are placed is smooth. The coefficient of friction between A and either of B and C is μ. The block A exerts equal pressure on B and C. A horizontal force F is applied to the block B.

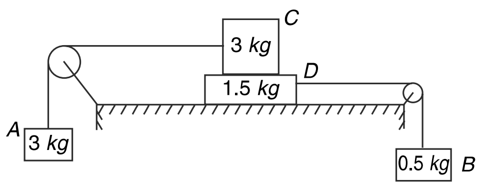


(a) Find maximum value of F so that A does not slip on B or C and the three blocks move together.

(b) If F is increased beyond the maximum found in (a) where will we see slipping first- at contact of A and B or at the contact of A and C.

(c) If F is kept half the maximum found in (a), calculate the ratio of friction force between A and B to that between A and C. Does this ratio change if F is decreased further?

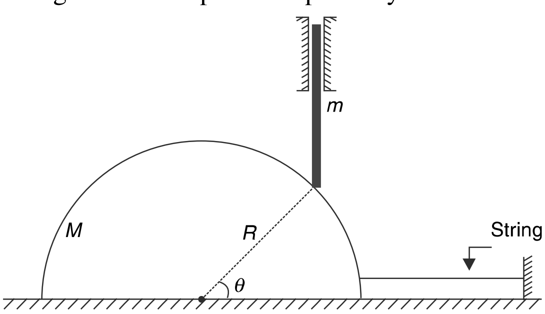
Q. 129. In the arrangement shown in the figure the coefficient of friction between the blocks C and D is $\mu_1 = 0.7$ and that between block D and the horizontal table is $\mu_2 = 0.2$. The system is released from rest. [Take g = 10 ms^{-2}] Pulleys and threads are massless.



(a) Find the acceleration of the block C.

(b) Block B is replaced with a new block. What shall be the minimum mass of this new block so that block C and D accelerate in opposite direction?

Q. 130. A hemisphere of mass M and radius R rests on a smooth horizontal table. A vertical rod of mass m is held between two smooth guide walls supported on the sphere as shown. There is no friction between the rod and the sphere. A horizontal string tied to the sphere keeps the system at rest.



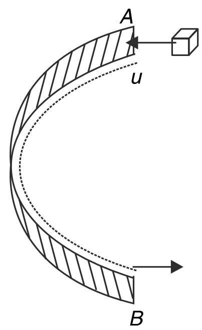
(a) Find tension in the string.

(b) Find the acceleration of the hemisphere immediately after the string is cut.

Q. 131. A semicircular ring of radius R is fixed on a smooth horizontal table. A small block is projected with speed u so as to enter the ring at end A. Initial velocity of the block is along tangent to the ring at A and it moves on the table remaining in contact with the inner wall of the ring. The coefficient of friction between the block and the ring is μ.

(a) Find the time after which the block will exit the ring at B.

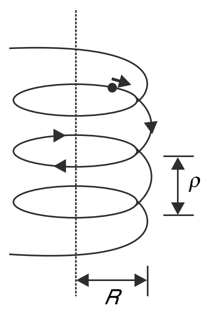
(b) With what speed will the block leave the ring at B.



Q. 132. A long helix made of thin wire is held vertical. The radius and pitch of the helix are R and ρ respectively. A bead begins to slide down the helix.

(a) Find the normal force applied by the wire on the bead when the speed of the bead is v.

(b) Eventually, the bead acquires a constant speed of v_0. Find the coefficient of friction between the wire and the bead.

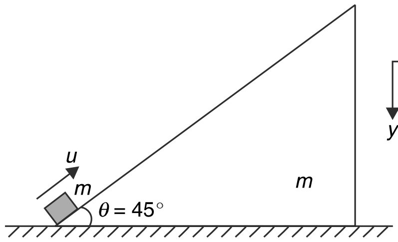


Q. 133. A wedge of mass m is kept on a smooth table and its inclined surface is also smooth. A small block of mass m is projected from the bottom along the incline surface with velocity u. Assume that the block remains on the incline and take $\theta = 45°$, $g = 10\ m/s^2$.

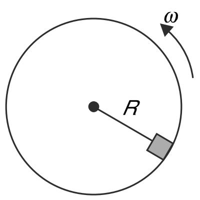
(a) Find the acceleration of the wedge and the x and y components of acceleration of the block.

(b) Draw the approximate path of the block as observed by an observer on the ground. At what angle does the block hit the table?

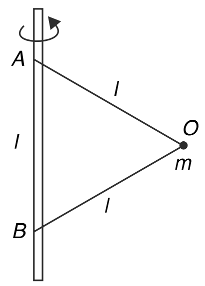
(c) Calculate the radius of curvature of the path of the block when it is at the highest point.



Q. 134. A cylinder with radius R spins about its horizontal axis with angular speed ω. There is a small block lying on the inner surface of the cylinder. The coefficient of friction between the block and the cylinder is μ. Find the value of ω for which the block does not slip, i.e., stays at rest with respect to the cylinder.



Q. 135. A particle of mass m is attached to a vertical rod with two inextensible strings AO and BO of equal lengths l. Distance between A and B is also l. The setup is rotated with angular speed ω with rod as the axis.



(a) Find the values of ω for which the particle remains at point B.

(b) Find the range of values of ω for which tension (T_1) in the string AO is greater than mg but the other string remains slack

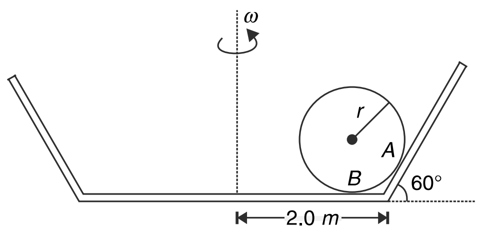
(c) Find the value of ω for which tension (T_1) in string AO is twice the tension (T_2) in string BO

(d) Assume that both strings are taut when the string AO breaks. What will be nature of path of the particle moment after AO breaks ?

Q. 136. A sphere of mass m and radius $r = \sqrt{3}m$ is placed inside a container with flat bottom and slant sidewall as shown in the figure. The sphere touches the slant wall at point A and the floor at point B. It does not touch any other surface. The container, along with the sphere, is rotated about the central vertical axis with angular speed ω. The sphere moves along with the container, i.e., it is at rest relative to the container. The normal force applied by the bottom surface and the slant surface on the sphere are N_1 and N_2 respectively. There is no friction.

(a) Find the value of ω above which N_2 becomes larger than N_1

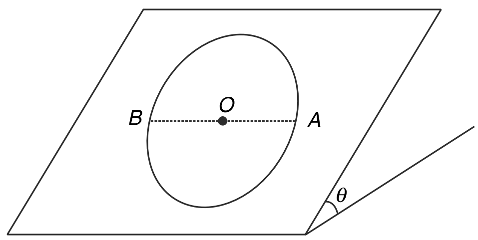
(b) Find the value of ω above which the sphere leaves contact with the floor.



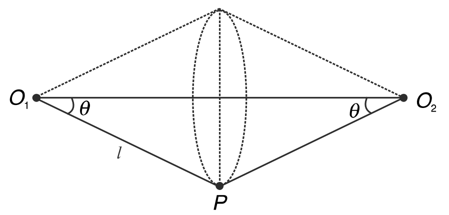
Q. 137. A car is being driven on a tilted ground. The ground makes an angle θ with the horizontal. The driven drives on a circle of radius R. The coefficient of friction between the tires and the ground is μ.

(a) What is the largest speed for which the car will not slip at point A? Assume that rate of change of speed is zero.

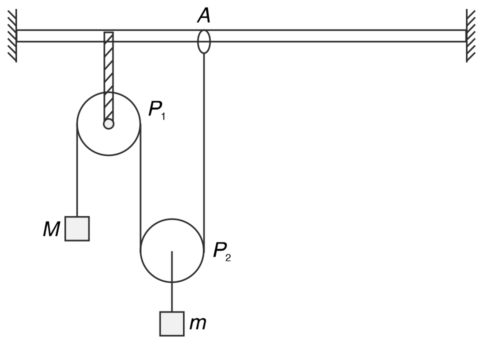
(b) What is the largest constant speed with which the car can be driven on the circle without slipping?



Q. 138. A particle P is attached to two fixed points O_1 and O_2 in a horizontal line, by means of two light inextensible strings of equal length l. It is projected with a velocity just sufficient to make it describe a circle, in a vertical plane, without the strings getting slack and with the angle $< O_2O_1P = < O_1O_2P = \theta$. When the particle is at its lowest point, the string O_2P breaks and the subsequent path of the particle was found to be a circle of radius $l \cos \theta$. Find θ.



Q. 139. The arrangement shown in figure is in equilibrium with all strings vertical. The end A of the string is tied to a ring which can be slid slowly on the horizontal rod. Pulley P_1 is rigidly fixed but P_2 can move freely. A mass m is attached to the centre of pulley P_2 through a thread. Pulleys and strings are mass less.



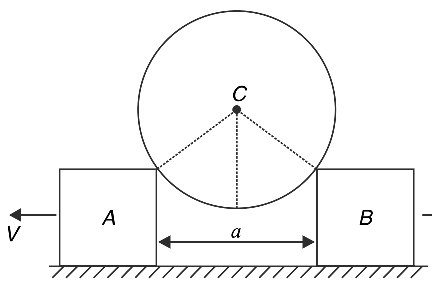
(a) Which block will move up as A is moved slowly to the right?

(b) Will the block of mass m have horizontal displacement?

(c) Is it possible, for a particular position of A, that M has no acceleration but m does have an acceleration? If this happens when string from P_2 to A makes an angle θ with vertical, find the acceleration of m at the instant.

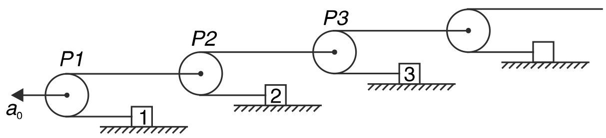
Q. 140. A smooth spherical ball of mass M = 2 kg is resting on two identical blocks A and B as shown in the figure. The blocks are moved apart with same horizontal velocity V = 1 m/s in opposite directions (see figure).

(a) Find the normal force applied by each of the blocks on the sphere at the instant separation between the blocks is $a = \sqrt{2}R$; R = 1.0 m being the radius of the ball.

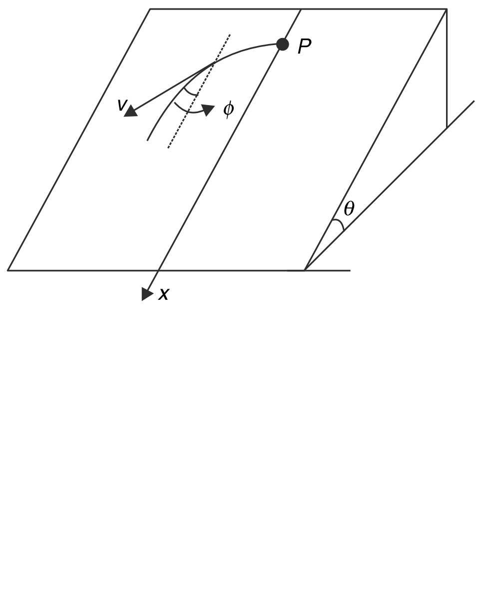


(b) How much force must be applied on each of the two blocks (when $a = \sqrt{2}R$) so that they do not have any acceleration. Assume that the he horizontal surface is smooth.

Q. 141. In the figure all pulleys ($P1$, $P2$, $P3$ …….) are massless and all the blocks (1,2,3 …..) are identical, each having mass m. The system consist of infinite number of pulleys and blocks. Strings are light and inextensible and horizontal surfaces are smooth. Pulley $P1$ is moved to left with a constant acceleration of a_0. Find the acceleration of block1. Assume the strings to remain horizontal.



Q. 142. A small disc P is placed on an inclined plane forming an angle θ with the horizontal and imparted an initial velocity v_0. Find how the velocity of disc depends on the angle ϕ which its velocity vector makes with the x axis (see figure). The coefficient of friction is $\mu = \tan \theta$ and initially $\phi_0 = \dfrac{\pi}{2}$.



ANSWERS

1. (a) straight line

(b) Parabolic

2. 20 m

3. $\sqrt{\frac{4H}{3g}}$

4. $N = 12$; Tension $= \frac{F}{N} = \frac{F}{12}$

5. 16 N

6. (i) (a) True

(b) True

(ii) $\frac{g}{5}$

(iii) $\sqrt{\frac{2\eta h}{(\eta-1)g}}$

7. $t = \sqrt{\frac{2(M-m)L}{Mg}}$

8. (a) $a = \frac{g}{4}$

(b) $a = \frac{g}{5}$

9. $\frac{4Mmg}{M+m} + M_0 g$

10. $m_0 = \frac{4m_1m_2}{m_1+m_2}$; $M = \frac{8m_1m_2}{m_1+m_2}$

All masses will fall down with acceleration g

11. (a) More than 9/2 Mg

(b) Tension in $S2 = Mg/2$, Tension in $S1 = 5\ Mg$

(c) Tension in $S2$ = Mg/6

12. $\theta = 45°$, $g/2$

13. 73.1 N

14. 12.5 s

15. $T = \sqrt{2}\,Mg$; $N = \frac{Mg}{\sqrt{2}}$

16. Zero.

17. $\mu_{min} = 1$

18. (a) 6467 N

(b) 22400 N

(c) 190400 N

(d) T_0 and F do not change. T will increase.

19. (a) No

(b) 1 : 4

20. $2\sqrt{\frac{2h}{g}}$

21. $a_A = a_B = \frac{F}{2m}$; $a_c = 0$

22. $3M/5$

23. $\theta = 62.5°$

24. $R_A : R_B : R_C = 3 : 1 : 2$

25. K = 2 Sdg

26. (a) $\frac{5}{3} cms^{-1}$

(b) 6 N

27. (a) 2, 4

(b) In both cases acceleration of the frame must be 'g'.

28. 15 m

29. $\frac{6t}{\sqrt{36-\pi}}$

30. $\mu \le \frac{v_0^2}{gL}$

31. 4 kg

32. 4.8 kg

33. $\sqrt{174}\ N$

34. $1.5\ kg \le m \le 9.5\ kg$

35. $\frac{5F}{m}$

36. (a) At C

(b) At C

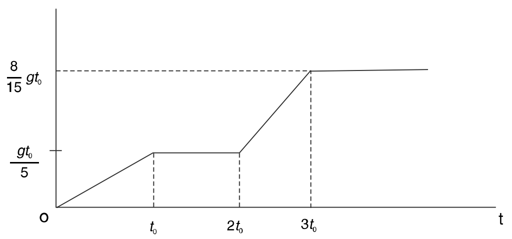
(c) $\sqrt{2}\ m/s^2$ and $\sqrt{2}\ m/s^2$

37. (i) $\sqrt{15} < \omega \sqrt{16.67}\ rad/s$

(ii) 500 $rad\ s^{-1}$

39. (a) $\dfrac{8gt_0}{15}$

(b)



40. (a) 80 N

(b) $\dfrac{640}{9}N$ for both

41. (a) $\dfrac{m_A}{m_B}=\dfrac{1}{3}$

(b) $X_{\min} = 0.75\ m$

(c) $V_A' = \left(\dfrac{3}{2}+\dfrac{3}{\sqrt{2}}\right)ms^{-1}; V_B' = \left(\dfrac{3}{2}-\dfrac{1}{\sqrt{2}}\right)ms^{-1}$

42. $V_0 = \dfrac{Mg}{\mu}\left[4\ell n\left(\dfrac{4}{3}\right)-1\right]$

43. t_2

44. $N_{12} = \dfrac{Mg\cos^2\theta}{1+2\sin^2\theta}$

$a = \dfrac{3g\sin\theta}{1+2\sin^2\theta}$

45. 1.0 s, 1.0 m

46. (b) $T_P = 21.65\ N$

(c) 3.05 kg

47. $\dfrac{\sqrt{5-2\sqrt{2}}}{\sqrt{2}-1}$

48. $t = \dfrac{1}{\sin\theta\sin\phi}\sqrt{\dfrac{2d}{g}}$

49. $\dfrac{5Mg}{2K}$

50. 2.9 s

51. (a) Force between the wall and the middle ball is maximum. It is 4 mg

(b) Force between upper ball and wall is least.

It is $\dfrac{4}{3}$ mg.

52. $\mu_{\min} = \dfrac{\sin\theta}{\sqrt{\cos^2\theta+\tan^2\theta}}$

53. (a) $K = 2.5\ N/cm$

(b) No

54. (a) The block is at height $h = 2.5\ m$

(b) $V = 5\sqrt{2}\ m/s$

(c) 25 m/s^2 (↑)

55. Zero

56. (a) $\dfrac{2F}{K}$

(b) $\dfrac{F}{K}$

57. With pulley P_1 having zero mass, equilibrium is not possible

58. $\dfrac{l}{3}$

59. (a) M

(b) $\dfrac{g}{3}$

60. (a) $\theta_0 = \dfrac{\pi}{4}$

(b) $a_{\max} = g\left[\cos\left(\dfrac{\pi}{8}\right)-\sin\left(\dfrac{\pi}{8}\right)\right]$

61. (a) $t > t^1$

(b) $\theta = \tan^{-1}\left(\dfrac{1}{12}\right)$

62. $a_0 \cos\theta$

63. $t = \sqrt{\dfrac{10}{3}}s$

64. (a) $g\sin\theta$

(b) $f = \dfrac{1}{2}mg\sin 2\theta$

$N = mg\cos^2\theta$

(c) $t = \sqrt{\dfrac{2h\left(M+m\sin^2\theta\right)}{\left(M+m\right)g\sin^2\theta}}$

65. (a) $\overrightarrow{a_A} \cdot \overrightarrow{a_B} = 0$ immediately after release

(b) $\vec{a}_A = \frac{g}{2}(\leftarrow)$

66. (a) θ

(b) $\tan^{-1}\left(\frac{\sin\theta \cdot \cos\theta}{2 - \sin^2\theta}\right)$

67. (a) $2\,mg$

(b) $t = \sqrt{\frac{3L}{\sqrt{2}g}}$

68. $\frac{g(\sin\theta - \mu\cos\theta)}{(\cos\theta + \mu\sin\theta)} \le a \le \frac{g(\sin\theta + \mu\cos\theta)}{(\cos\theta - \mu\sin\theta)}$

69. $\frac{m}{M} = \frac{20}{3\sqrt{3} - 4} = 16.7$

70. (a) $(M + m)\, g \sin\alpha$

(b) $\frac{(M+m)g\sin^2\alpha}{m + M\sin^2\alpha}$

71. $\frac{M}{m} = \frac{1}{5}$

72. $a_0 = \frac{48g}{199}$

73. $\frac{44g}{205}$

74. $\frac{2L}{5}$

75. (a) $\left|\frac{d^2x_2}{dt^2}\right| = \frac{3g}{2}$

(b) $\left|\frac{d^2x_1}{dt^2}\right| = 2g$; $\left|\frac{d^2x_2}{dt^2}\right| = 2g$

(c) $\left|\frac{d^2x_1}{dt^2}\right| = \frac{g}{2}$; $\left|\frac{d^2x_2}{dt^2}\right| = \frac{3g}{2}$

76. (a) $\frac{4k_1k_2x_0}{(k_1+k_2)M}$

(b) $\frac{4k_1k_2x_0}{k_1+k_2}$

77. $a = \frac{g}{\sqrt{2}}$; $N_{AB} = 0$

78. 3

79. $\frac{6g}{47}$

80. $\sqrt{2}\,F_0$

81. $T = 0.49\,N$

82. (a) Zero

(b) $\frac{F_1}{3m} = \frac{F_2}{m}$

(c) To right

83. (a) $\theta \le 13°$

(b) 37°

84. (a) $\frac{13}{7}s$

(b) 0.18

85. $V_{\max} = \frac{-u^2}{2} + \sqrt{\frac{u^4}{4} + (2\mu gL)^2}$

86. $k = 130\ Nm^{-1}$; $\mu = 0.5$

87. $\mu = \left(\frac{3a_0 - 4g}{4a_0 + 3g}\right)$

88. $\left(\frac{r}{R}\right)_{\min} = \frac{\sqrt{1+\mu^2} - \mu}{\sqrt{1+\mu^2} + \mu}$

89. $F = \frac{Mg}{1-\mu^2}\left[\mu + \frac{\mu\cos\theta + \sin\theta}{\cos\theta - \mu\sin\theta}\right]$

90. $5\ m/s^2 \le a \le 7\ m/s^2$

91. $2\ kg \le m \le 30\ kg$

92. (a) $\frac{960}{95}kg$

(b) $\frac{480}{61}kg$

93. $\mu_{\min} = \frac{\Delta m}{2m}\tan\theta$

94. (i) $2.5\ kg$; $12.5\ N$

(ii) $\frac{50}{3}N$

(iii) $\frac{40}{3}N, a = \frac{5}{3}\ m/s^2$

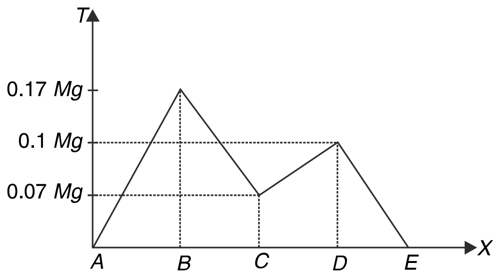
(iv) $\frac{5}{6}m/s^2$

95. $M_0 = \lambda R\left(\frac{\pi}{2} - 1\right)$

96. $\frac{H}{x}$

97. (a) $\mu = \frac{\sqrt{3}+1}{\sqrt{3}+5} = 0.4$

(b)



(c) $T_{\max} = 0.17\ Mg$

98. (i) (a) $T_{BC} = 10\ N$; $T_{AB} = 12\ N$; $T_{AD} = 7\ N$

(b) $f_C = 0$; $f_B = 4N$; $f_A = 5N$; $f_D = 5N$

(ii) (a) $T_1 = \left(\frac{1-\mu_0}{1+\mu_0}\right) T_0$

(b) $m_2 = \left(\frac{1-\mu_0}{1+\mu_0}\right)^2 M_0$

99. $\omega = \sqrt{\frac{g}{R}}$

100. $\omega = \sqrt{\frac{g}{R}(\cos\theta - 2\sin\theta)}$

101. $\frac{\sqrt{3}mg}{3m+4M}$

102. $x = \frac{l_0}{3\eta - 1}$

103. 2.45

104. (a) $\theta_0 = \tan^{-1}\left(\frac{\frac{V_0^2}{Rg} - \mu}{1 + \frac{\mu V_0^2}{Rg}}\right)$

(b) $V_1 = \sqrt{rg\tan\theta_0}$

(c) Obtuse

105. (a) 22°

(b) (i) 2315 N, 1389 N

106. (a) $t_0 = \frac{\left[R^2\left(\mu^2 g^2 - f^2\right)\right]^{1/4} - V_0}{f}$

(b) $m\sqrt{\frac{(V_0 + ft)^4}{R^2} + f^2}$

107. (a) 93.3 N

(b) $\frac{10}{7}\ m/s^2$

(c) 4 m/s

108. $\frac{F}{5m}$

109. (a) contact force = 0, acceleration of 4 kg block is 0.7 m/s^2 and that of other block is zero

(b) contact force = 1.4 N, acceleration of both = 0

(c) Contact force = 5.74 N, acceleration of both = 1.27 m/s^2

110. $\theta = \cos^{-1}\left(\frac{3}{\sqrt{41}}\right)$

111. 30.1 s

112. (a) $\sqrt{\frac{g}{R}\frac{2\left(\sqrt{3}-1\right)}{\sqrt{3}\left(\sqrt{3}+1\right)}}$

(b) $\sqrt{\frac{g}{R}}$

113. $\frac{2}{\sqrt{3}}$

114. (a) $F_0 = \frac{\sigma\pi R^2 g(1-\cos\theta)^2}{2\sin\theta.\cos\theta}$

(b) $F_0 = 0$

(c) ∞

115. $R = r(1 + 2\sqrt{7})$

116. $\frac{5l_0}{4}$

117. (a) $a_1 = g\left(1 - \frac{4M}{m_1}\right)$

(b) $m_4 > \frac{18}{11} kg$

118. $F_0 = 2\mu m_2 g \left(\frac{m_2 + m_1}{2m_2 + m_1}\right)$; increase

119. Zero

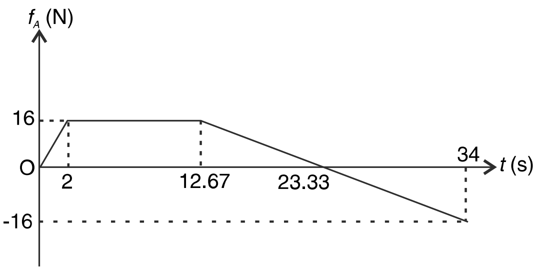
120. (a) $\theta = 45°$ from vertical diameter.

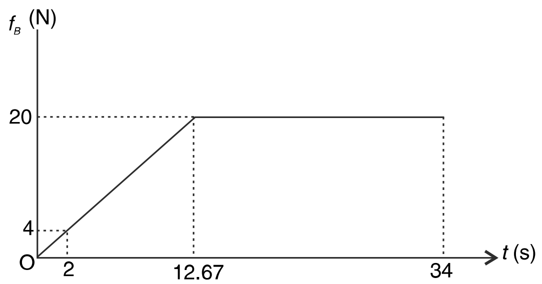
(b) $T_{max} = 2\left(\frac{\sqrt{2}-1}{\pi}\right)Mg$

121. Zero

122. $21° < \theta < 33°$

123.





124. $\theta = 2\tan^{-1}\left[\left(1 + \frac{mg}{F}\right)\cot\alpha\right]$

125. (a) $T_0 = 2\lambda Rg$

(b) At the lowest point

126. $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

127. $F_{min} = \frac{mg}{2\sqrt{2}}\left(\sqrt{3} - 1\right)$

128. (a) $F_{max} = \frac{3}{4}\mu Mg$

(b) Between A and B

(c) 2, No

129. (a) $2\ ms^{-1}$

(b) $2.1\ kg$

130. (a) $T = N\cos\theta$

(b) $\frac{mg}{M\tan\theta + m\cot\theta}$

131. (a) $t = \frac{R}{\mu u}\left[e^{\pi\mu} - 1\right]$

(b) $V = \frac{u}{e^{\pi\mu}}$

132. (a) $mg\cos\theta\sqrt{1 + \left(\frac{v^2\cos\theta}{Rg}\right)^2}$

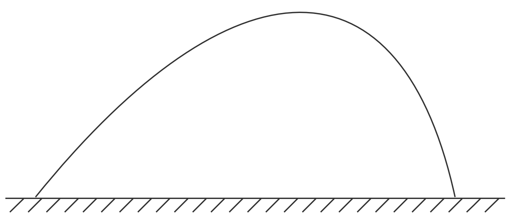
(b) $\frac{\tan\theta}{\sqrt{1 + \left(\frac{v^2\cos\theta}{Rg}\right)^2}}$ where $\tan\theta = \frac{\rho}{2\pi R}$

133. (a) $\vec{a}_{wedge} = \frac{g}{3}\hat{i}$

$a_{x\ block} = \frac{-g}{3}$

$a_{y\ block} = \frac{2g}{3}$

(b) The block hits the table normally.



(c) $\frac{3u^2}{16g}$

134. $\omega \geq \sqrt{\frac{g\sqrt{1+\mu^2}}{R\mu}}$

135. (a) $\omega > \sqrt{\frac{g}{l}}$

(b) $\sqrt{\frac{g}{l}} < \omega \le \sqrt{\frac{2g}{l}}$

(c) $\sqrt{\frac{6g}{l}}$

(d) parabolic

136. (a) $\sqrt{\frac{g}{\sqrt{3}}}$

(b) $\sqrt{\sqrt{3}g}$

137. (a) $[g^2 R^2 (\mu^2 \cos^2\theta - \sin^2\theta)]^{1/4}$

(b) $\sqrt{gR(\mu\cos\theta - \sin\theta)}$

138. $\theta = \tan^{-1}\left(\frac{1}{\sqrt{5}}\right)$

139. (a) Block with mass M will move up.

(b) yes

(c) $g(1 - \cos\theta)$

140. (a) $(10\sqrt{2} - 8)\,N$

(b) $(5 - 4\sqrt{2})N$

141. $\frac{3a_0}{2}$

142. $\frac{v_0}{1 + \cos\phi}$

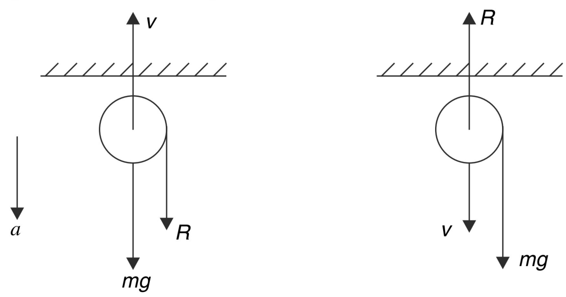
SOLUTIONS

1. (a) Initial velocity is parallel to $\vec{F}$ or anti parallel to $\vec{F}$. Hence particle moves in a straight line and speed may increase or decrease.

(b) Path is parabolic with speed increasing.

In case (a) the particle may retrace its path.

2. Just before striking the ceiling, retardation is 2 g. If air resistance force is R at this instant, then



$$ma = mg + R$$
$$m(2g) = mg + R$$
$$\Rightarrow R = mg$$

After impact, the air resistance force will be upward but its magnitude will remain mg. This is because speed has not changed.

$\therefore$ After impact net force on the ball = 0

$\therefore$ Ball will fall down with constant speed

$\therefore$ $H = (10\ m/s)(2\ s) = 20\ m$.