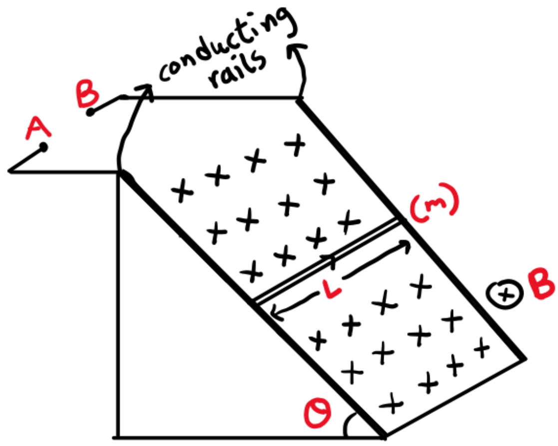
1. There is a magnetic field B directed into the plane of a smooth inclined plane. There is a smooth conducting rod of length L and mass m on the inclined plane. It is left to freely slide down the inclined plane with the help of two conducting rails at the ends of the rod. (See Figure).

Analyse the motion of the rod when A & B are connected with:



A. A resistor of resistance **R**
B. An Uncharged Capacitor of Capacitance **C**
C. An Inductor of Inductance **L**

2. A cylindrical pipe of radius r is rolling towards a frog sitting on the horizontal ground. Centre of the pipe is moving with a constant velocity v. To save itself, the frog jumps up and passes over the pipe touching it only at the top. Denoting air time of the frog by T, horizontal range of the jump as R, and acceleration due to gravity as g, which of the following conclusions can you make.

A. $T = 4\sqrt{\frac{r}{g}}$

B. $T \geq 4\sqrt{\frac{r}{g}}$

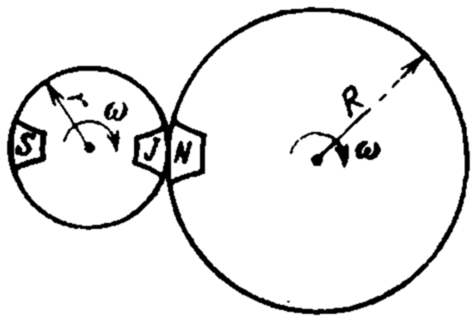
C. $R = 4(\sqrt{gr} - v)\sqrt{\frac{r}{g}}$

D. $R \geq 4(\sqrt{gr} - v)\sqrt{\frac{r}{g}}$

3. An hour glass is placed on a weighing scale. Initially all the sand of mass. m_0 kg in the glass is held in the upper reservoir (ABC) and the mass of the glass alone is M kg. At t = 0, the sand is released. It exits the upper reservoir at constant rate $\frac{dm}{dt} = \lambda$ kg/s dt where m is the mass of the sand in the upper reservoir at time t sec. Assume that the speed of the falling sand is zero at the neck of the glass and after it falls through a constant height h it instantaneously comes to rest on the floor (DE) of the hour glass. Obtain the reading on the scale for all times t > 0. Make a detailed plot of the reading vs time.

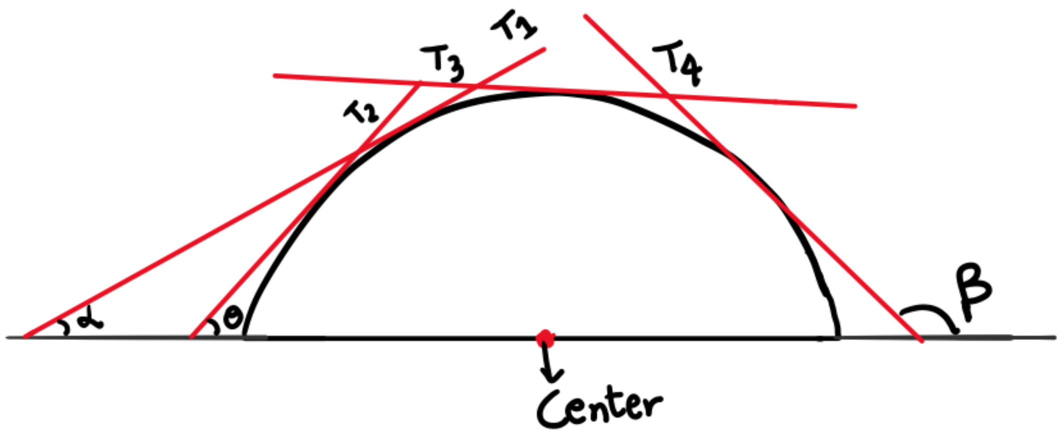
Be careful while attempting this question, make sure to cover all possible time intervals.

4. Three schoolboys, Sam, John and Nick are on a merry-go-round. Sam and John occupy diametrically opposite points on a merry-go-around of radius r. Nick is on another merry-go-around of radius R. The positions of the boys at the initial instant are shown in the figure.



Considering that the merry-go-arounds touch each other and rotate in the same direction with an angular velocity ω, determine the nature of motion of Nick from John's point of view and of Sam from Nick's point of view.

5. You are provided with 4 objects: A half ring, a half disc, a hollow hemisphere and a solid hemisphere. A tangential axis is drawn to the object and makes an angle θ with the horizontal (see figure). Call the moment of inertia of this axis I_0. Now we start to draw other tangents to the object each with its own horizontal angle. Your job is to plot the moment of inertia's dependence on the horizontal angle for each of the 4 shapes.



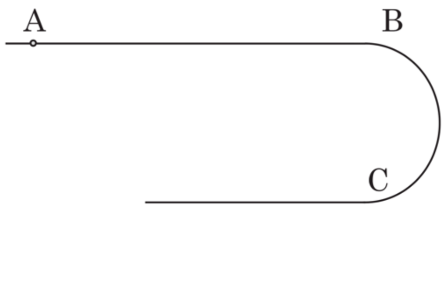
6. A man is standing on a rotating table rotating with an angular velocity ω_0. Initially the man has his hands close to body and is moving along with the table with an angular velocity ω_0. Now, he spreads his hands out and his angular velocity becomes ω_1 ($\omega_0 > \omega_1$).

A. What happens to the Kinetic Energy of the system? If it is changing, what agent is causing the change?

B. The angular velocity of the system has decreased, what agent is producing the torque necessary for this change?

7. Point A moves uniformly with a velocity v so that the vector v is continually "aimed" at point B which in turn moves rectilineарly and uniformly with velocity u < v. At the initial moment of time v ⊥ u and the points are separated by a distance l. How soon will the points converge?

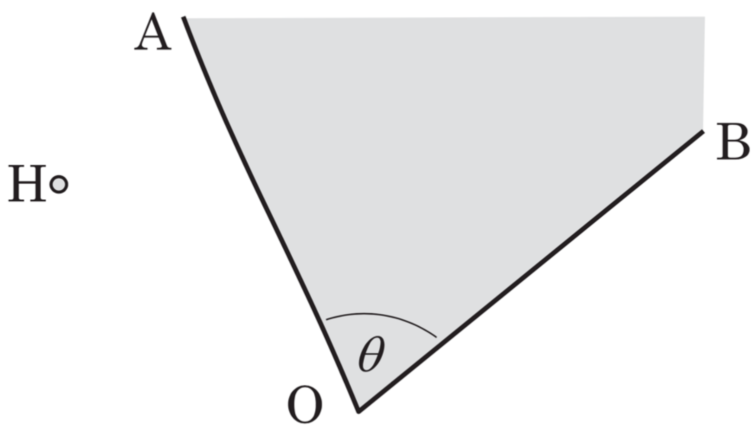
8. A boy starts from point A and passes point C of a track ABC shown in the figure. Portion AB of length l is straight and portion BC is a semicircle of radius r (r<l). Anywhere on the track, the modulus of the maximum acceleration of the boy is a. Find minimum transit time of the boy from A to C.



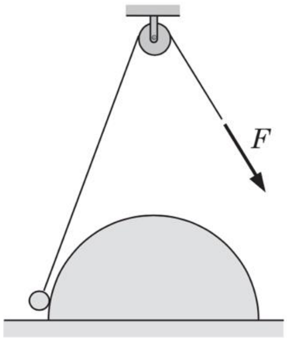
9. An aeroplane is flying along the horizontal at velocity v_0 starts to ascend, describing a circle in the vertical plane. The velocity of the plane changes with height h above the initial level of motion according to the law $v^2 = v_0^2 - 2a_0h$. The velocity of the plane at the upper point of the trajectory is $v_1=\frac{v_0}{2}$.

Determine the acceleration a of the pale at the moment its velocity is directed vertically upwards.

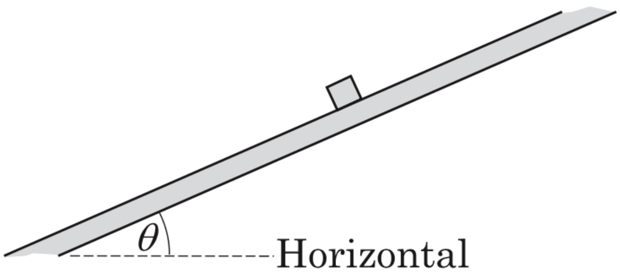
10. House H of an angler is at a distance d from bank OA of a bay AOB and at a distance l from the corner O. The angler can walk on the ground with a constant speed v and swim in the bay with a constant speed u (u<v) relative to the water. One day he decides at his house to fish somewhere on the bank OB. Find the minimum time in which he can reach the desired fishing spot.



11. A small metal ball is being pulled gradually on a fixed frictionless hemisphere as shown in the figure. Radii of the ball and that of the pulley are much smaller than that of the hemisphere. As the ball slides from the bottom to a position close to the top of the hemisphere, how do the magnitudes of pulling force f and contact force R between the ball and the hemisphere change?

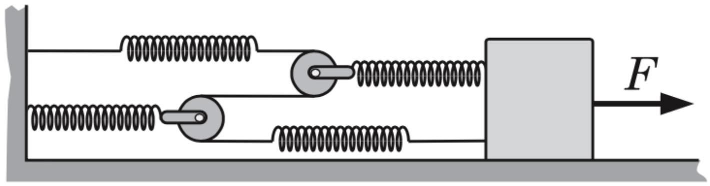


12. A small block is sliding on a frictionless inclined plane that is moving upward with a constant angular acceleration. If the block remains at a level height, what is the acceleration of the inclined plane? Acceleration due to gravity is g.



13. Why is it more difficult to turn the steering wheel of a stationary motorcar than that of a moving car.

14. In the setup shown, a block is placed on a frictionless floor, the cords and pulleys are ideal and each spring has stiffness k. The block is pulled away from the wall. How far will the block shift, while the pulling force is increased gradually from zero to a value F?



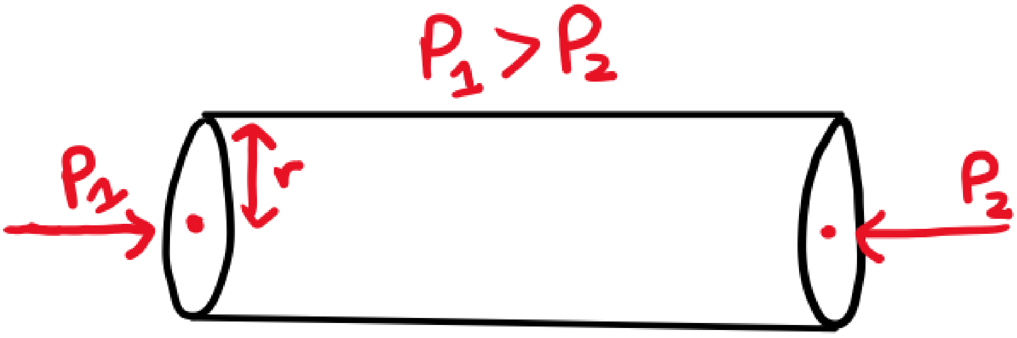
15. A fluid of viscosity η fills the space between two long co-axial cylinders of radii R_1 and R_2 with $R_2 > R_1$. The inner cylinder is stationary while the outer one is rotated with a constant angular velocity ω_2. The fluid flow is laminar. Taking into account the friction force acting on a unit area of a cylindrical surface of radius r is defined by the formula $\sigma = \eta r \bullet \frac{\partial \omega}{\partial r}$ find:

a. The angular velocity of the rotating fluid as a function of radius r

b. The moment of the frictional forces acting on a unit length of the outer cylinder.

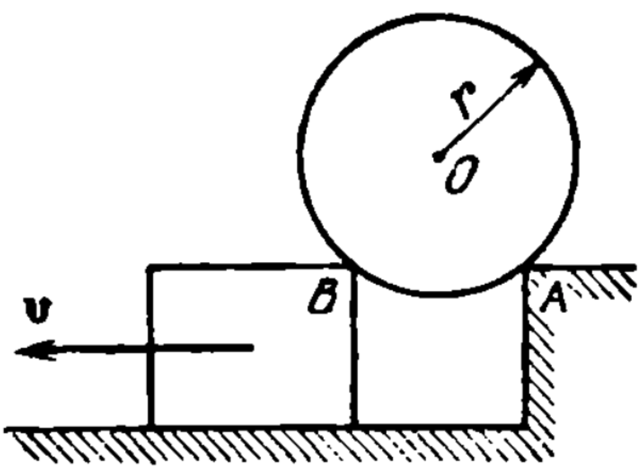
16. A disc of radius R is floating on a viscous fluid of viscosity η and it is also rotating with an angular velocity ω_0 with the help of an external agent. The liquid is filled up to a depth h, where h<<R for ease of calculation. How much torque must the external agent exert on the disc to keep the disc's angular velocity ω_0 constant.

17. A hollow cylinder of radius r is filled with a viscous gas of viscosity η. Two external agents are applying P_1 and P_2 ($P_1 > P_2$) find how much gas flows inside the cylinder in any suitable unit.

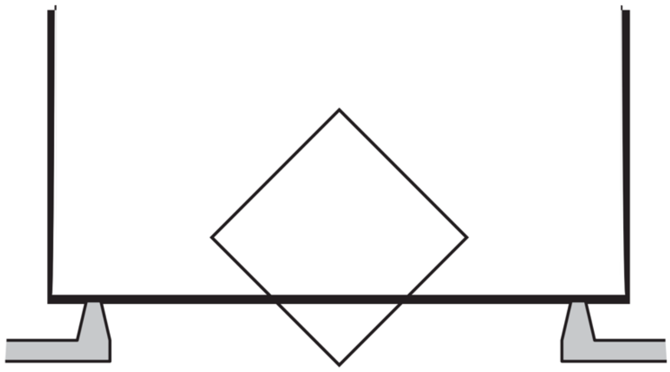


18. A cylinder of mass m and radius r rests on two supports of the same height (See Figure). One support is stationary, while the other slides from under the cylinder at a velocity v.

Determine the force of normal pressure N exerted by the cylinder on the stationary support at the moment when the distances between points A and B of the supports is AB $= r\sqrt{2}$, assume that the supports were very close to each other at the initial instant. The friction between the cylinder and the supports should be neglected.



19. A rectangular hole of dimensions a x b is cut in the horizontal bottom
Of a large vessel. To close the hole, a cuboidal block of dimensions b x c x c is put on it in such a way that the square faces and a diagonal plane remain vertical as shown in the figure. Now a liquid of density ρ is slowly poured into the vessel. What should the mass m of the block be so that the hole always remains closed irrespective of the level of liquid in the vessel?



20. A heavy ball of mass m is tied to a weightless thread of length l. The friction of the ball against air is proportional to its velocity relative to the air: f = μv. A strong horizontal wind is blowing at a constant velocity v.

Determine T, the period of small oscillations, assume that the oscillations of the ball attenuate in a time much longer than the period of oscillations.

Problem Set 1- Answers (Non-Descriptive Questions)

1. **Descriptive, Solution will be updated in website**

2. A, D

3. **Descriptive, Solution will be updated in website**

4. **Descriptive, Solution will be updated in website**

5. **Descriptive, Solution will be updated in website**

6. **A.** K.E. changes (Negative work done by man decreases kinetic energy)

   B. Hint: Coriolis Force

7. $\frac{\eta b}{(\eta^2-1)}$

8. $(\pi - 1)\sqrt{\frac{r}{a}} + 2\sqrt{\frac{2l+r}{2a}}$

9. $\frac{a_0\sqrt{109}}{3}$

10. $\frac{d(u^2-v^2 sin^2\theta)}{uv\sqrt{u^2-v^2 sin^2\theta}} + \frac{sin\theta}{u}\sqrt{l^2 - d^2}$

11. F decreases and R remains unchanged

12. $g\ tan^2\theta$

13. **Descriptive, Solution will be updated in website**

14. $\frac{10F}{9k}$

15. A. $\omega = \omega_2 \frac{R_1^2 \bullet R_2^2}{R_2^2-R_1^2}[\frac{1}{R_1^2} - \frac{1}{r^2}]$ B. $4\pi\eta\omega_2 \frac{R_1^2 \bullet R_2^2}{R_2^2-R_1^2}$

16. $\frac{\pi\eta\omega_0 R^4}{2h}$

17. $\frac{\pi r^4}{18\eta l}[P_1^2 - P_2^2]$

18. N $= \frac{mg}{\sqrt{2}} - \frac{mv^2}{r}$

19. m $> \rho b \bullet (c - \frac{a}{2})^2$

20. $\frac{2\pi}{\sqrt{(g/l)\sqrt{1+(\mu v/mg)^2 - \mu^2/4m^2}}}$