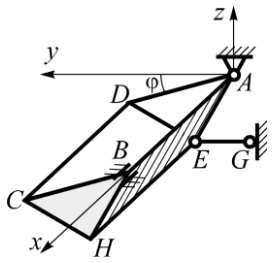
2023 INTERNATIONAL ENGINEERING MECHANICS CONTEST (ASIAN REGION)

The Theoretical Contest

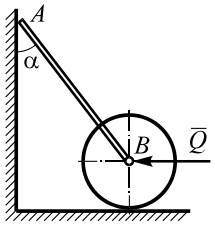
Problem S-1



A weightless symmetrical triangular box *ABCDEH* of length $AB = CD = 4l$ with sides $AE = DE = l$ and angle $\angle AED = \pi/2$ is kept in the equilibrium state by spherical and cylindrical hinges at points *A* and *B*, respectively, and by a weightless rod *EG*. The axis of hinges *A* and *B* is horizontal, and the rod *EG* is located horizontally in a plane perpendicular to this axis. The box edge *AD* makes an angle $\varphi = 15°$ with the horizon. The maximum possible amount of liquid with mass density ρ is poured into the box.

Determine the value of the hinge *A* reaction.

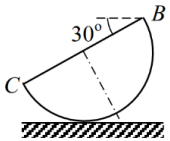
Problem S-2

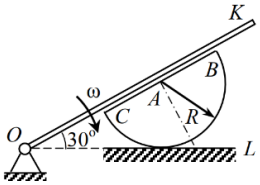


The handle *AB* of the roller, pivotally connected to its axis in the point *B*, rests with its end *A* on a vertical smooth wall. The handle weight is equal to *P*, its length is *l*, the roller weight is also equal to *P*, its radius is *r*. At point *B*, a horizontal force $Q = 2P$ is applied to the roller. The sliding friction coefficient between the roller and the horizontal plane is *f*, the rolling friction coefficient is δ.

At what angles α is the system equilibrium possible?

Problem K-1

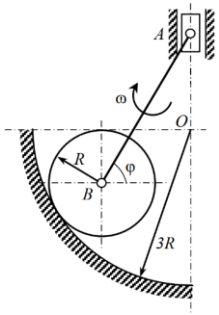




Part 1. The half-disk rolls along the plane without slipping. At the moment when its edge *BC* (the half-disk diameter) is inclined to this plane at an angle of 30°, the point *B* velocity is equal to *v*. Define the point *C* velocity. (3 points)

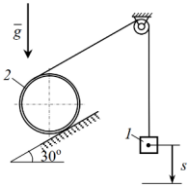
Part 2. The rod *OK* rotates around the hinge *O* with an angular velocity ω and pushes a half-disk of radius *R* along the plane *OL*. The half-disk has a constant contact with the rod along the disc edge *BC*. Determine the velocities of point *A* (the middle of *BC*) and point *B* of the half-disk for the moment when the inclination angle of the rod to the plane is 30°. (7 points)

Problem K-2



A disk of radius *R* rolls without slipping along a stationary surface with an internal rounding of radius 3*R*. A rod *AB* of length $2\sqrt{3}R$ is pivotally connected to the slider *A* and the center of the disk *B*. The continuation of the slider *A* movement line passes through the center of the internal rounding *O*. At a given angle $\varphi = 60°$, the rod *AB* rotates with a constant angular velocity ω. What are the values of the angular velocity and angular acceleration of the disk?

Problem D-1

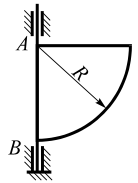


A material point 1 of mass *m* and a homogeneous thin ring *2* of the same mass *m* are connected by an inextensible thread. Ring 2 can roll without slipping along a plane with an inclination angle of 30°. The thread coming off the ring parallel to the inclined plane is thrown over a stationary block. The mass of the block, friction in the hinge and the ring rolling resistance can be neglected. At the beginning the system was at rest.

Find the dependence $v = v(s)$, where *v* is the point 1 velocity, *s* is its displacement, for the following cases:

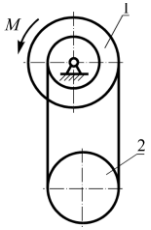
1) the resistance forces of the medium are neglected; (3 points)
2) it is taken into account the resistance force of the medium acting on point 1 $R = \frac{3}{4}\alpha m g v^2$, where coefficient $\alpha > 0$. (7 points).

Problem D-2



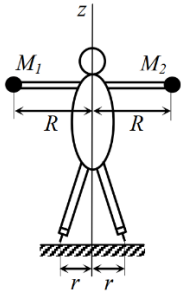
A homogeneous plate with the shape of a circle quarter of radius *R* rotates around the vertical axis. At what angular velocity of the plate the force of lateral pressure on the lower support *B* is equal to zero? The distance between the supports should be considered equal to *R*.

Problem D-3



A homogeneous disk 1 of mass $m_1 = 2m$ has a cylindrical protrusion of negligible mass with a wound thread on it. The thread covers a homogeneous disk 2 of radius *R* and mass $m_2 = m$. It is known that the thread left branch tension does not depend on the system motion law. Determine the angular acceleration of disk 1 under the action of a driving torque *M*. Consider the free sections of the thread to be vertical.

Problem D-4



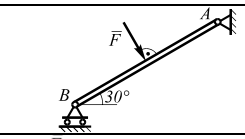
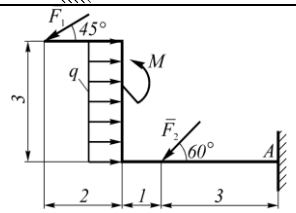
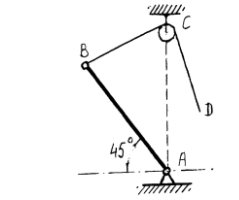
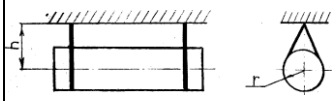
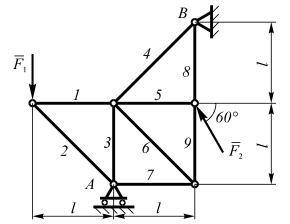
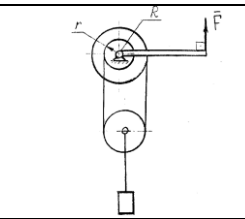
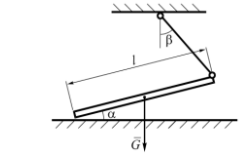
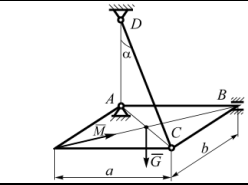
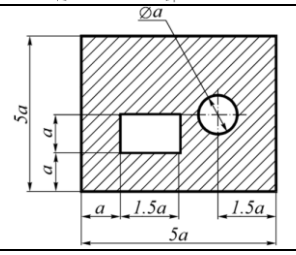
A skater of mass m_0 rotates around a fixed vertical axis *z*. The coefficient of sliding friction between the skates and the ice (along the blades of the skates) is *f*. The distances from the skater's skates to the *z* axis are constant and equal to *r* (it is assumed that this is ensured only by the muscular efforts of the skater, and not due to friction). At the initial moment, the skater holds dumbbells M_1 and M_2 of mass *m* each at distances *R* ($R > r$) with outstretched arms. The skater then begins to bend his arms so that the dumbbells remain at the same height, symmetrically to each other relative to the *z*-axis and the skater's body. At the end of the bend, the distances from the dumbbells to the *z* axis are equal to *r*.

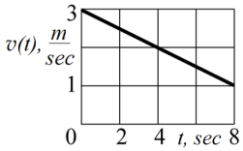
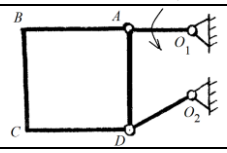
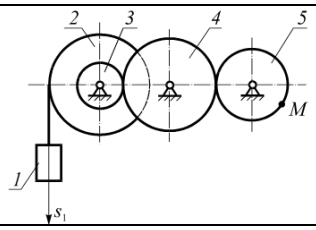
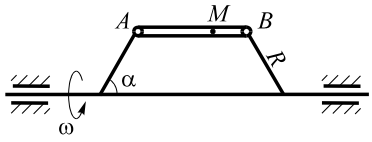
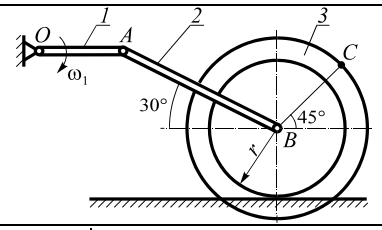
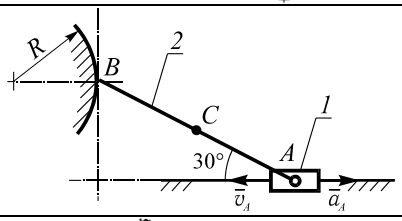
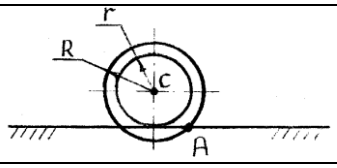
What time does it take for the skater to bend his arms if his angular velocity remains constant and equal to ω?

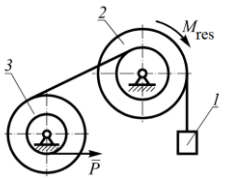
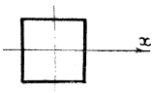
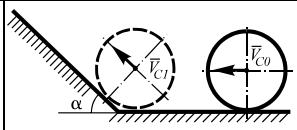
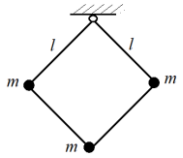
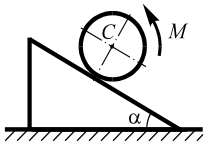
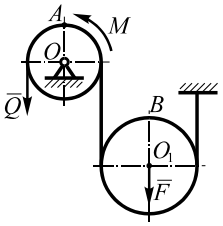
A skater without taking into account his hands should be considered as an absolutely rigid body. The masses of the arms and the size of the skates and dumbbells should be neglected.

2023 INTERNATIONAL ENGINEERING MECHANICS CONTEST (ASIAN REGION)
The Brain-ring Team Contest

Statics

1		A weightless beam *AB* is held in the position shown in the figure by connections *A* and *B*. Determine the reaction of mechanical connection at point *A* if a force $F = 10\sqrt{3}$ kN is applied in the middle of the beam.
2		The fixed support in point *A* keeps a weightless frame in the equilibrium. Determine the value of the distributed load intensity *q* for the case when the fixed support torque is equal to zero if $F_1 = 5\sqrt{2}$ kN; $F_2 = 4\sqrt{3}$ kN; $M = 30$ kNm.
3	A body of 2*m* mass is suspended from the end of a vertically hanging spring (the mass of the spring can be neglected). Another body of mass *m* is suspended at the middle of the stretched spring. Determine the final length of the stretched spring at the system equilibrium. The spring stiffness coefficient is *c*, and its unstretched length is l_0.	
4		The window frame *AB*, shown in the figure as sectional drawing, is opened by rotating around a horizontal axis *A* with the help of a cable *BCD*, thrown over block *C* (the dimensions of the block can be neglected). Points *A* and *C* lie on the same vertical; the weight of the frame is applied in its middle. Find the angle φ between the reaction force of hinge *A* and the vertical line if *AB* = *AC*.
5		A pipe of weight *P* and radius *r* hangs on two cable loops. The height *h* is known. Determine the tensile force on each branch of the loop.
6		Determine the reaction of the rod 5 if $F_1 = 10\sqrt{3}$ N; $F_2 = 12$ N.
7		What force *F* should be applied to the end of the differential gate handle to hold a load of weight *G* = 500 N? Handle length *l* = 98 cm; $r_1 = 20$ cm; $r_2 = 10$ cm. The masses of the blocks and of the handle can be neglected.
8		A uniform beam of weight *G* is in equilibrium and rests on a non-smooth surface (friction coefficient is *f*). Calculate the smallest value of angle α for the case of the body equilibrium if angle β is known?
9		A uniform rectangular plate of weight *G* is kept in the equilibrium state by the spherical joint *A*, a hinge *B* and a rod *CD*. The angle between the rod and the vertical line is α. The pair of forces with torque *M* acts the plate, the vector of this torque is shown in figure. Find the reaction of rod *CD* if $a = 0.6$ m, $b = 0.4$ m, $\alpha = 30°$, $M = 10$ Nm, $G = 12$ N.
10		Determine the distance from the center of gravity of the hatched figure to the center of the cut circle.

11	The point moves uniformly along a flat trajectory, the radius of curvature of the trajectory is specified as a function of time $\rho = t\,(3–t)$ (t in seconds). At what time moment the acceleration of the point is minimal?	
12		The law material point velocity change $v(t)$ is shown in the figure. Determine the displacement of the point at time t = 3 s.
13		Define which point of the mechanism has the highest value of velocity for the position shown in the figure.
14	The point, after received a certain initial velocity, began to move with constant acceleration around a circle with a radius of 10 m. After the point moved ten complete rounds around the circle, its velocity decreased by half. What was the displacement of the point when the point stopped?	
15	The angular acceleration of a disk (its radius is 10 cm) varies according to the law $\varepsilon = 5t^2$ rad/sec^2. Determine the linear velocity of the point on the rim of the disk after its rotating by the angle of $\varphi = 10\pi$ rad, if $\omega_0 = 0$ at the initial moment of time .	
16		Determine velocity of point M at time moment equal to 2 sec, if the radii of the shown wheels $r_4 = 0.8r_2 = 1.2r_5 = 2r_3 = R$ and the first body moves according to the law $s_1 = 4t^2–1$, m.
17		A body rotates about an axis with the angular velocity $\omega = 10t – 6t^2$ rad/sec; a material point M moves from point A to point B along the body with relative velocity $v_r = 35\sin\dfrac{\pi t}{4}\dfrac{\text{cm}}{\text{sec}}$; find the absolute acceleration of the point M for its position shown in the figure for the time $t = 1$ sec; $R = 6$ cm; $\alpha = 60°$.
18		Find the point C velocity if $\omega_1 = 2\dfrac{\text{rad}}{\text{sec}}$; $OA = 12$ cm; $AB = 20$ cm; $BC = 6$ cm; $r = 4$ cm.
19		Given: v_A = 30 cm/sec; a_A = 20 cm/sec^2; BC = 15 cm, AB = 50 cm. Find the point B acceleration if $R \to \infty$.
20		Point A, located at the intersection of the rail with the outer car wheel rim, is currently moving with velocity v = 5 m/s. Determine the train velocity if r = 50 cm, R = 56 cm.

21	A tram of mass m = 10000 kg is at rest on a horizontal track. The traction force, varying according to the law $F = 2000t$ N begins to act the tram. The movement of the tram is impeded by resistance forces, the reduced coefficient of friction is f = 0.02. Determine the tram velocity at time t = 2 sec.	
22	A bullet of mass m, taken as a material point, is fired from a gun inclined at a certain angle to the horizontal, with initial velocity v_0. At the highest point of the trajectory its kinetic energy is equal to E. Determine the angle of inclination of the gun barrel axis to the horizon.	
23	A material point of mass m = 2 kg moves in space under the action of a force F. Determine the module of the point acceleration if $\bar{F} = 3\bar{i} + \sqrt{11}\,\bar{j} - 4\bar{k}$ (N).	
24	An empty container of weight 10 kg, installed on scales, is filled with water flowing from a height of 1 m. What will be the scales indicator at t = 20 sec after the start of filling, if the filling rate of the container is constant and it is 45 liters per minute.	
25		The system of three bodies moves under the action of force $P = 10mg$. In addition, a system of forces acts on the system, creating the resistance torque $M_{res} = mgR$. Given: $m_1 = m$, $m_2 = 2m$, $m_3 = m$. Wheels radii: $R_2 = 2r_2 = R$, $R_3 = 2r_3 = 0.8R$. The radii of inertia of rotationally moving bodies are related to radius R: $i = \frac{1}{\sqrt{2}} R$. Determine the acceleration of the body 1.
26		A square body is made of four identical homogeneous rods with masses m and lengths l each. Determine the moment of inertia of this body about the x-axis (this axis coincides with the symmetry axis of the square).
27		A solid homogeneous disk rolls along a horizontal plane without sliding and the velocity of its center is equal to v_{C0}. Determine what velocity v_{C1} the disk center will have at the first moment after an inelastic collision with a plane making an angle α with the horizon.
28		Three balls with equal masses m are fixed in the three corners of a square assembled from thin weightless needles of length l. The square is hung by a free corner. Find the frequency of small oscillations of the system if they occur in the plane of the square.
29		The wheel slides along a plane inclined at an angle α to the horizon under the action of a torque M applied to it. Find the acceleration of the wheel center of mass C if the sliding friction coefficient is equal to f.
30		The mechanism shown in the figure is under the influence of forces Q, F and a pair of forces with a torque M. The initial data: AO = 20 cm, BO_1 = 40 cm, Q = 150 N, M = 150 Nm, α = 30°, β = 45°. Determine the modulus of force F for the case of uniform motion point O_1.

Note: the acceleration of gravity g=9.8 m/s^2; the value π = 3.14.