Chapter IV

Particle Kinetics Homework
Homework 4.A

Given: The truck shown below is travelling along I-65 when a deer runs out onto the highway. The truck is initially traveling at a speed of $v_0$ and decelerates at a constant rate.

Find: Find the minimum distance $s$ over which the truck can stop to ensure that its load does not shift (and the deer is safely avoided).

Use the following parameters in your analysis: $v_0 = 40 \text{ m/s}$, $W = 1000 \text{ N}$ and $\mu_s = 0.2$. 
Homework 4.B

**Given:** Particle P (of mass $m$) moves within a vertical plane inside a rough, circular slot. The coefficient of kinetic friction between particle P and the slot is $\mu_k$, and the radius of the slot is $r$. At the position shown below, the speed of P is known to be $v$.

**Find:** For this position:
(a) Determine the numerical value of the normal contact force of the slot on P;
(b) Determine the rate of change of speed of P.

![Diagram of a particle P moving within a circular slot](image)

Use the following parameters in your analysis: $m = 8$ kg, $\mu_k = 0.2$, $r = 2$ m and $v = 3$ m/s.
Homework 4.C

Given: The mechanism, shown below, consisting of a rotating disk, frictionless slot, cable, and block of mass \( m \), is driven at a constant speed \( \omega \) in the horizontal plane by a motor attached at point O.

Find: Determine:
(a) The tension in the cable;
(b) The normal force exerted on the block.

Use the following parameters in your analysis: \( \omega = 12 \text{ rad/s} \), \( h = 0.4 \text{ m} \), \( d = 0.6 \text{ m} \) and \( m = 10 \text{ kg} \).
Homework 4.D

Given: The mechanism, shown below, consisting of a rotating arm, frictionless slot, and block of mass \( m \), is driven at a constant speed \( \omega \) by a motor attached at point O.

Find: Determine:
(a) The tension in the cable at the instant shown provided \( \omega = 10 \text{ rad/s} \);
(b) The normal force exerted on the block provided \( \omega = 10 \text{ rad/s} \);
(c) The minimum angular velocity \( \omega \) necessary to keep the cable taut at the instant shown.

Use the following parameters in your analysis: \( r = 0.20 \text{ m} \), \( m = 10 \text{ kg} \) and \( \theta = 53.13^\circ \).
Homework 4.E

**Given:** The system shown below is released from rest in the configuration shown.

**Find:** Determine:
(a) The acceleration of block A;
(b) The acceleration of block B;
(c) The tension in the cable.

Use the following parameters in your analysis: \( m_A = 40 \text{ kg}, m_B = 80 \text{ kg}, \mu_s = 0.3, \mu_k = 0.15 \) and \( \theta = 60^\circ \).
Homework 4.F

Given: Particle P of mass $m$ slides in the direction shown within a tube with a speed of $v_{rel}$ relative to the tube as the tube rotates in the CCW sense with an angular speed of $\omega$ and angular acceleration $\alpha$.

Find: For this problem:

(a) Determine the acceleration of P;

(b) Determine the friction force acting on P.

Use the following parameters in your analysis: $m = 10$ kg, $\omega = 5$ rad/s, $\alpha = 2$ rad/s$^2$, $v_{rel} = 4$ m/s, $\mu_s = 0.6$, $\mu_k = 0.3$, $L = 0.4$ m and $h = 0.2$ m.
Homework 4.G

Given: Particles A and B (having masses of \( m_A \) and \( m_B \)) are interconnected by the cable-pulley system shown in the figure. Both particles are constrained to vertical motion with particle A able to slide on a smooth vertical rod. The system is released at \( s_A = 0 \) m with A traveling downward with a speed of \( v_{A1} \). Assume the pulleys to be small, massless and frictionless.

Find: Find the speed of particle A when A has reached the position of \( s_A \).

Use the following parameters in your analysis: \( m_A = 10 \) kg, \( m_B = 10 \) kg, \( v_{A1} = 5 \) m/s and \( s_A = 2 \) m.
Homework 4.H

Given: Blocks A and B (having masses of $2m$ and $m$, respectively) are connected by rigid, massless rod AB of length $L$. Block A is constrained to move along a smooth vertical guide, and B moves along a smooth, horizontal surface. The system is released from rest when A is at a height of $h_1$ ABOVE the path of B.

Find: Determine the speed of block A when A has dropped to a position that is at a distance of $h_2$ BELOW the path of B.

Use the following parameters in your analysis: $m = 10$ kg, $L = 0.5$ m, $h_1 = 0.4$ m and $h_2 = 0.3$ m.
Homework 4.I

**Given:** The collar shown below, of mass $m$ is pushed against a spring with stiffness $k$ until it is compressed $\Delta$ and then released. The coefficient of kinetic friction between the collar and rod is $\mu_k$.

**Find:** Determine the maximum height obtained by the collar as measured from the point of release. Assume that the collar remains on the rod at all times.

Use the following parameters in your analysis: $m = 2.5 \text{ kg}$, $k = 2000 \text{ N/m}$, $\Delta = 0.3 \text{ m}$, $\mu_k = 0.20$, and $\theta = 36.87^\circ$.  

### Diagram

![Diagram of the collar on a spring with friction](image)

Use the following parameters in your analysis: $m = 4 \text{ kg}$, $k = 2500 \text{ N/m}$, $\Delta = 0.01 \text{ m}$, $\mu_k = 0.15$ and $\theta = 30^\circ$. 

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Homework 4.J

Given: The collar, shown below, of mass $m$, starts from rest at point A. A constant force $F$ is applied to the collar in the direction shown. Note that the mechanism lies in the vertical plane. Assume all surfaces to be smooth.

Find: Determine the speed of the collar when it reaches point B.

Use the following parameters in your analysis: $mg = 10$ lb, $F = 6$ lb, and $r = 2$ ft.
Homework 4.K

**Given:** Pellets A and B (having masses $m$ and $3m$, respectively) are placed within a smooth tube trapping a small compartment of fuel. At a time when the pellets are initially at rest, the fuel is ignited. The combustion occurs over a short time $\Delta t$, and over this time the combustion applies equal and opposite forces on the pellets with this force idealized by the force time history $F(t)$ shown below.

**Find:** Determine the speed of each pellet at time $t_2$, where $t_2 > \Delta t$.

Use the following parameters in your analysis: $F_0 = 3000$ N, $\Delta t = 0.005$ s and $m = 0.75$ kg.
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Homework 4.L

Given: A particle of mass $m$ is dropped from rest when at a height $h_1$ above a rigid floor. The particle impacts the floor with a speed of $v_1$. This impact of the particle with the floor lasts for a short duration of time $\Delta t$, and after the impact is complete, the particle rebounds upward with a speed of $v_2$. The particle continues upward reaching a maximum height of $h_2$.

Find: For this problem:
(a) Determine the average force acting on the particle by the floor during impact in the presence of gravity;
(b) Determine the average force acting on the particle by the floor during impact in the absence of gravity;
(c) Compare your answers from (a) and (b);
(d) Determine the value of $h_2/h_1$.

Use the following parameters in your analysis: $\Delta t = 0.002$ s, $m = 15$ kg, $v_1 = 80$ m/s and $v_2 = 50$ m/s.
Homework 4.M

Given: A cannonball P of mass $m$ is fired toward a steel barrier on a stationary cart. At some time after rebounding from the barrier, the cannonball is observed to have a speed of $v_P$ and is moving in the direction shown below in the figure. Let $M$ be the combined mass of the cannon/cart. Assume that the cart is able to move without friction along the horizontal surface and ignore the influence of air resistance.

Find: For this problem:
(a) Determine the velocity vector of the cart after the cannonball bounces off the steel barrier at the instant shown below;
(b) If $\Delta t$ represents the elapsed time between the firing of the cannonball and the instant shown below, determine the average value of the horizontal force acting on the combined cannon/cart over the time period of $0 < t < \Delta t$.

Use the following parameters in your analysis: $mg = 50\text{ lb}$, $Mg = 250\text{ lb}$, $\Delta t = 0.4\text{ s}$, $\theta = 25^\circ$ and $v_P = 120\text{ ft/s}$.
Homework 4.N

**Given:** A smooth, circular slot is cut into block A with block A being constrained to move along a smooth, horizontal surface. The slot is vertical at the top surface of the block with the slot being horizontal at the right edge of the block, as shown in the figures below. In Position 1, block A is stationary, and a particle B is released from rest into the upper opening of the slot. At Position 2 shown below, particle B is exiting the slot at the right edge of the block. The masses of A and B are $M$ and $m$, respectively. The radius of the circular slot is $r$.

**Find:** Determine the velocity of block A and the velocity of particle B at position 2.

![Position 1 and Position 2](image)

Use the following parameters in your analysis: $m = 20$ kg, $M = 40$ kg and $r = 2$ m.
Homework 4.0

Given: A particle of mass \( m \) is projected horizontally to the right at a height \( h \) above a smooth, horizontal floor with a speed of \( v_0 \). The particle strikes the floor at a horizontal distance \( d \) from where it was initially projected. The coefficient of restitution of the impact of the particle with the floor is \( e \).

Find: For this problem:
(a) Determine the angle \( \theta_1 \) that the velocity of the particle has with the horizontal immediately before impact;
(b) Determine the angle \( \theta_2 \) that the velocity of the particle has with the horizontal immediately after impact.

Use the following parameters in your analysis: \( e = 0.6 \), \( h = 125 \) ft and \( v_0 = 150 \) ft/sec.

Use the following parameters in your analysis: \( e = 0.5 \), \( h = 150 \) ft and \( v_0 = 160 \) ft/s.
Homework 4.P

Given: Blocks A and B (having masses of $m$ and $M$, respectively) are initially traveling in directions perpendicular to each other with speeds of $v_{A1}$ and $v_{B1}$, respectively, as shown below in the figure. After impacting each other, A is traveling to the RIGHT with a speed of $v_{A2}$, and B travels with a speed of $v_{B2}$ (the direction of motion for B after impact is not known). Consider all surfaces to be smooth.

Find: For this problem:
(a) Determine the mass $M$ of block B;
(b) Determine the coefficient of restitution $e$ for the impact of A and B.

Use the following parameters in your analysis: $m = 3$ kg, $v_{A1} = 4$ m/s, $v_{B1} = 4$ m/s, $v_{A2} = 2$ m/s and $v_{B2} = 5$ m/s.
Homework 4.Q

Given: A satellite P of mass \( m \) is in orbit around a planet whose center is at E. At position 1 shown below, the satellite is at a distance \( R_1 \) from E and moving with a speed of \( v_1 \). At position 2 shown, P is at a distance of \( R_2 \) from E and moving with a speed of \( v_2 \) with the velocity of P oriented as shown below. Assume that the only force acting on the satellite is a gravitational force directed toward E, and that the planet is stationary.

Find: For this problem:
(a) Determine the speed of P at position 2, \( v_2 \), in terms of \( R_1 \), \( R_2 \), \( \theta_2 \) and \( v_1 \);
(b) Provide an argument explaining why your result in (a) does not depend on the gravitational force acting on the satellite.
Homework 4.R

Given: Rigid arm OA (having length $L$ and having negligible mass) is pinned to ground at end O. A particle of mass $M$ is attached to end A of OA. At instant 1, a pellet P (having a mass of $m$) strikes the stationary particle A with a speed of $v_{P1}$ in the direction shown below in the figure. At the end of a short time interval impact, P sticks to A.

Find: Determine the angular speed of arm OA immediately after P sticks to A.

Use the following parameters in your analysis: $\phi = 30^\circ$, $L = 4$ ft, $mg = 4$ lb, $Mg = 8$ lb and $v_{P1} = 150$ ft/s.
Homework 4.S

Given: Particles A and B (having masses of 2m and m, respectively) are attached to a rod with a length of L and with negligible mass. The bar is released from rest at when it is at an angle of $\theta_1$ from the vertical, as shown below for Position 1. At the instant when the bar passes through the vertical position (Position 2), particle A is released from the bar, with particle B remaining attached to the bar.

Find: Find the maximum angle $\theta_3$ reached by the bar after particle A is released.

Use the following parameters in your analysis: $\theta_1 = 56.13^\circ$, $m = 10$ kg and $L = 3$ m.
Homework 4.T

Given: A particle P, having a mass of \( m \), is free to slide on a smooth, lightweight bar. The bar is free to rotate in a horizontal plane about a vertical shaft passing through O. A spring, having a stiffness \( k \) and unstretched length \( R_0 \), is connected between P and O. The spring is compressed to half of its unstretched length and released when the bar has a rotational speed of \( \omega_1 \), as shown in the figure below left.

Find: For the position when \( R = R_0 \) (shown in the figure below right):
(a) Determine the rotation rate \( \omega_2 \) of the bar;
(b) Determine the value of \( \dot{R} \).

Use the following parameters in your analysis: \( m = 10 \text{ kg} \), \( k = 400 \text{ N/m} \), \( R_0 = 2 \text{ m} \) and \( \omega_1 = 5 \text{ rad/s} \).