1 Problem Set 1

1. (12-82 Hibbeler, 9e) The center of the wheel is travelling at 60 ft/s. If it encounters the transition of two rails such that there is a drop of 0.25 m, at the joint between the rails, determine the distance $s$ to point $A$ where the wheel strikes the next rail. ($s = 2.16$ ft)

2. (12-96 Hibbeler, 9e) The missile at $A$ takes off from rest and rises vertically to $B$, where its fuel runs out, in 8 s. If the acceleration varies with time as shown, determine the height and speed of the missile at $B$, i.e. $h_B$ and $v_B$. If by internal controls the missile is suddenly pointed $45^\circ$ as shown, and allowed to travel in free flight, determine the maximum height attained, $h_C$, and the range $R$ to where it crashes. ($h_B = 426.67$ m, $v_B = 160$ m/s, $h_C = 1079.1$ m, $R = 2.98$ km)

3. (12-125 Hibbeler, 9e) The race car travels around the circular track with a speed of 16 m/s. When it reaches point $A$ it increases its speed at $\dot{v} = \frac{4}{3} v^{1/4}$ m/s$^2$, where $v$ is in m/s. Determine the velocity and acceleration of the car when it reaches point $B$. Also, how much time is required for the car to travel from $A$ to $B$? ($v_B = 47.55$ m/s, $a_B = 11.83$ m/s$^2$, $t = 10.11$ s)

4. (12-130 Hibbeler, 9e) The ball is kicked with an initial speed $v_A = 8$ m/s at an angle $\theta = 40^\circ$ with the horizontal. Find the equation of the path, $y = f(x)$, and then determine the velocity of the ball and the normal and tangential components of its acceleration when $t = 0.25$ s. ($\ddot{v} = 6.13\dot{x} + 2.70\dot{y}$ m/s, $a_t = -3.96$ m/s$^2$, $a_n = 8.98$ m/s$^2$)

5. (12-155 Hibbeler, 9e) For a short time the roller coaster travels along the track defined by the equation $r = 200 \cos(2\theta)$ ft, where $\theta$ is in radians. If the angular speed of the radial coordinate line is $\dot{\theta} = 0.008t^2$ rad/s, where $t$ is in seconds, determine the radial and transverse components of the car’s velocity and acceleration at the instant $\theta = 30^\circ$. Note: when $t = 0$, $\theta = 0^\circ$. ($v_r = -93.53$ ft/s, $v_\theta = 27$ ft/s, $a_r = -68.67$ ft/s$^2$, $a_\theta = -41.21$ ft/s$^2$)
6. (12-156 Hibbeler, 9e) The motion of the particle B is controlled by the rotation of the grooved link OA. If the link is rotating at a constant angular rate $\dot{\theta} = 6 \text{rad/s}$, determine the magnitudes of the velocity and acceleration of B at the instant $\theta = \pi/2 \text{rad}$. The spiral path is defined by the equation $r = 400 \text{mm}$, where $\theta$ is in radians. ($v = 446.9 \text{mm/s}, a = 3.66 \text{m/s}^2$)

7. (12-167 Hibbeler, 9e) The car travels along a road which for a short distance is defined by $r = 200/\theta \text{ft}$, where $\theta$ is in radians. If it maintains a constant speed of $v = 35 \text{ft/s}$, determine the radial and transverse components of its velocity when $\theta = \pi/3 \text{rad}$. ($v_r = -24.2 \text{ft/s}, v_\theta = 25.3 \text{ft/s}$)

2 Problem Set 2

1. (12-175 Hibbeler, 9e) The mine car C is being pulled up the incline using the motor M and the rope and pulley arrangement shown. Determine the speed $v_P$ at which a point P on the cable must be travelling toward the motor to move the car up the plane with a constant speed of $v = 2 \text{m/s}$. ($v_P = 6 \text{m/s}$)

2. (12-184 Hibbeler, 9e) If motors A and B draw in their attached cables with an acceleration of $a = 0.2t \text{m/s}^2$, where $t$ is in seconds, determine the speed of the block when it reaches a height $h = 4 \text{m}$, starting from rest. Also, how much time does it take to reach this height? ($t = 5.43 \text{s}, v_C = 2.21 \text{m/s}$)
3. (12-194 Hibbeler, 9e) The motor $C$ pulls in the cable with an acceleration $a_C = 3t^2 \text{ m/} s^2$, where $t$ is in seconds. The motor $D$ draws in its cable at $a_D = 5 \text{ m/} s^2$. If both motors start at the same instant from rest when $d = 3 \text{ m}$, determine (a) the time needed for $d = 0$, and (b) the relative velocity of block $A$ with respect to block $B$ when this occurs. ($t = 1.07 \text{ s}$, $\vec{v}_{A/B} = 5.93 \text{ m/} s$)

4. (12-200 Hibbeler, 9e) Two planes $A$ and $B$ are flying side by side at a constant speed of $900 \text{ km/} h$. Maintaining this speed, plane $A$ begins to travel along a spiral path $r = 1500 \theta \text{ km}$, where $\theta$ is in radians, whereas plane $B$ continues to fly in a straight line. Determine the speed of plane $A$ with respect to plane $B$ when $r = 750 \text{ km}$. ($\vec{v}_{A/B} = 834\angle117.6^\circ \text{ m/} s$)

5. (13-11 Hibbeler, 9e) The two boxcars $A$ and $B$ have a weight of $20,000 \text{ lb}$ and $30,000 \text{ lb}$, respectively. If they are freely coasting down the incline when the brakes are applied to, and locking, all the wheels of car $A$, determine the force in the coupling $C$ between the two cars. The coefficient of kinetic friction between the wheels of $A$ and the tracks is $\mu_k = 0.5$. The wheels of car $B$ are free to roll. Neglect the mass of the car $B$ wheels in the calculation. Suggestion: Solve the problem by representing single resultant normal forces acting on $A$ and $B$, respectively. ($5976 \text{ lbf}$, compression)

6. (13-26 Hibbeler, 9e) A freight elevator, including its load, has mass $500 \text{ kg}$. It is prevented from rotating by using the track and wheels mounted along its sides. Starting from rest, in $t = 2 \text{ s}$, the motor $M$ draws in the cable with a speed of $6 \text{ m/} s$, measured with respect to the elevator. Determine the constant acceleration and tension in the cable. Neglect the mass of the pulleys and cables. ($\vec{a} = 0.75 \text{ m/} s^2 \uparrow$, $T = 1320 \text{ lbf}$)
7. (13-27 Hibbeler, 9e) The safe $S$ has a weight of 200 lb and is supported by the rope and pulley arrangement shown. If the end of the rope is given to a boy of weight 90 lb, determine his acceleration if in the confusion he doesn’t let go of the rope. Neglect the mass of the pulleys and rope. ($\ddot{a}_B = 2.30 \text{ m/s}^2$)

2. (13-47 Hibbeler, 9e) The tractor is used to lift the 150 kg load with $B$ the 24 m long rope, boom, and pulley system. If the tractor is travelling to the right with an acceleration of $3 \text{ m/s}^2$ and has a velocity of $4 \text{ m/s}$ at the instant $s_A = 5 \text{ m}$, determine the tension in the rope at this instant. When $s_A = 0$, $s_B = 0$. ($T = 1802 \text{ N}$)

3. Problem Set 3

1. (13-35 Hibbeler, 9e) The 30 lb crate is being hoisted upward with a constant acceleration of $6 \text{ ft/s}^2$. If the uniform beam $AB$ has a weight of 200 lb, determine the components of reaction at $A$. Neglect the size and mass of the pulley at $B$. Hint: First find the tension in the cable, then analyze the forces on the beam using statics.

3. (13-48 Hibbeler, 9e) Cylinder $B$ has mass $m$ and is hoisted using the cord and pulley system shown. Determine the magnitude of force $F$ as a function of the cylinder’s vertical position $y$ so that when $F$ is applied the cylinder rises with a constant acceleration $a_B$. Neglect the mass of the cord, pulleys, hook and chain.
4. (13-61 Hibbeler, 9e) An acrobat has weight 150 lb and is sitting on a chair which is perched on top of a pole as shown. If by a mechanical drive the pole rotates downward at a constant rate from $\theta = 0^\circ$, such that the acrobat’s center of mass $G$ maintains a constant speed of $v_a = 10 \text{ ft/s}$, determine the angle $\theta$ at which he begins to "fly" out of the chair. Neglect friction and assume that the distance from the pivot $O$ to $G$ is $\rho = 15 \text{ ft}$. ($\theta = 78.05^\circ$)

5. (13-75 Hibbeler, 9e) The 10-lb suitcase slides down the curved ramp for which the coefficient of kinetic friction is $\mu_k = 0.2$. If at the instant it reaches point $A$ it has speed of $5 \text{ ft/s}$, determine the normal force on the suitcase and the rate of increase of its speed. ($N = 5.88 \text{lbf}, a_t = 23.0 \text{ ft/s}^2$)

6. (13-98 Hibbeler, 9e) The particle has mass 1 kg and is confined to move along the smooth vertical slot due to the rotation of the smooth arm $OA$. Determine the force of the rod on the particle and the normal force of the slot on the particle when $\theta = 30^\circ$. The arm has angular acceleration of $\ddot{\theta} = 2 \text{ rad/s}^2$ and angular velocity $\dot{\theta} = 3 \text{ rad/s}$ when $\theta = 30^\circ$. ($\vec{F}_{OA} = 20.9 \angle 60^\circ \text{ N}, \vec{N} = 10.4 \text{ N}$)

7. (13-99 Hibbeler, 9e) For a short time, the 250 kg roller coaster car is travelling along the spiral track such that its position measured from the top of the track has components $r = 8 \text{ m}$, $\theta = (0.1t + 0.5) \text{ rad}$, and $z = -0.2t \text{ m}$, where $t$ is in seconds. Determine the magnitudes of the components of force which the track exerts on the car in the $r, \theta, z$ directions at the instant $t = 2 \text{ s}$. Neglect the size of the car. ($F_R = 20 \text{ N}, F_\theta = 0, F_z = 2453 \text{ N}$)
8. (13-110 Hibbeler, 9e) The pilot of an airplane executes a vertical loop which in part follows the path of a cardoid, \( r = 600 \left( 1 + \cos \theta \right) \) ft, where \( \theta \) is in radians. If his speed at \( A \) (\( \theta = 0^\circ \)) is a constant \( v_P = 80 \) ft/s, determine the vertical force the seat belt must exert on him to hold him to his seat when the plane is upside down at \( A \). He weighs 150 lb. \((N = 112.7 \text{ N})\)

2. (16-27 Hibbeler 9e) Determine the distance the load \( W \) is lifted in \( t = 5 \) s using the hoist. The shaft of the motor \( M \) turns with an angular velocity \( \omega = 100 (4 + t) \) rad/s, where \( t \) is in seconds. \((\Delta s = 2.9 \text{ m})\)

4 Problem Set 4

1. (16-21 Hibbeler, 9e) The aerobic machine manufactured by Precor, Inc. transfers pedalling power to a flywheel \( F \), which develops resistance using an AC-powered electromagnet. If the operator initially drives the pedals at 12 rev/min, and then begins an angular acceleration of 8 rev/min\(^2\), determine the angular velocity of the flywheel after 2 revolutions of the pedal arm. Note that the pedal arm is fixed-connected to the chain wheel \( A \), which in turn drives the sheave \( B \) using the fixed-connection clutch gear \( D \). The poly-V belt wrapped around the sheave, then drives the pulley \( E \) and fixed-connected flywheel. \(( \dot{\omega} = 484 \text{ rpm} \uparrow)\)

3. (16-54 Hibbeler, 9e) The gear rests in a fixed horizontal rack. A cord is wrapped around the inner core of the gear so that it remains horizontally tangent to the inner core at \( A \). If the cord is pulled to the right with a constant velocity of 2 ft/s, determine the velocity of the center of the gear, \( C \). \((\vec{v}_C = 1.33 \text{ m/s}, \rightarrow)\)
4. (16-70 Hibbeler, 9e) At the instant shown, the truck is travelling to the right at 8 m/s. If the pipe does not slip at B, determine its angular velocity if its mass center G appears to an observer on the ground to remain stationary. ($\omega = 5.33 \text{ rad/ s}$)

5. (16-125 Hibbeler, 9e) A single pulley having both an inner and outer rim is pin-connected to the block at A. As cord CF unwinds from the inner rim of the pulley with the motion shown, cord DE unwinds from the outer rim. Determine the angular acceleration of the pulley and the acceleration of the block at the instant shown.

6. (16-133 Hibbeler, 9e) The man stands at the platform at O and runs out toward the edge such that when he is at A, $y = 5 \text{ ft}$, his mass center has a velocity of $2 \text{ ft/s}$ and an acceleration of $3 \text{ ft/s}^2$, both measured with respect to the platform and directed along the $y$ axis. If the platform has the angular motions shown, determine the velocity and acceleration of his mass center at this instant. ($\vec{v}_A = -2.5\hat{i} + 2\hat{j} \text{ ft/s}$, $\vec{a}_A = -3\hat{i} + 1.75\hat{j} \text{ ft/s}^2$)

5 Problem Set 5

1. (17-26 Hibbeler, 9e) The machine has a mass of 1500 kg and rests on the bed of the truck and on the smooth surface at B. If it does not slip at A, determine the maximum acceleration of the truck so that the machine will not move relative to the truck. Also, what are the horizontal and vertical components of reaction at A when this occurs? ($a_G = 4.905 \text{ m/s}^2$, $A_x = 7357.5 \text{ N} \rightarrow$, $A_y = 14.72 \text{ N} \uparrow$)

2. (17-36 Hibbeler, 9e) The pipe has a length of 3 m and a mass of 500 kg. It is attached to the back of the truck using a 0.6 m long chain AB. If the coefficient of kinetic friction at C is $\mu_k = 0.4$, determine the acceleration of the truck if the angle $\theta = 10^\circ$ with the road as shown. ($a_G = 2.33 \text{ m/s}^2$)
3. (17-48 Hibbeler, 9e) The handcart has a mass of 200 kg and center of mass at $G$. Determine the magnitude of the largest force $P$ that can be applied to the handle so that the wheels at $A$ or $B$ continue to maintain contact with the ground. Neglect the mass of the wheels. ($P = 1998$ N)

4. (17-42 Hibbeler, 12e) The uniform crate has a mass of 50 kg and rests on the cart having an inclined surface. Determine the smallest acceleration that will cause the crate to either slip or tip relative to the cart. What is the magnitude of this acceleration? the coefficient of static friction between the crate and the cart is $\mu_s = 0.5$. ($a = 2.01 \text{ m/s}^2$)

5. (17-48 Hibbeler, 12e) The 50 kg uniform crate rests on the platform for which the coefficient of static friction is $\mu_s = 0.5$. If the supporting links have an angular velocity $\omega = 1 \text{ rad/s}$, determine the greatest angular acceleration $\alpha$ they can have so that the crate does not slip or tip at the instant $\theta = 30^\circ$. ($\alpha = 0.59 \text{ rad/s}^2$)

6. (17-52 Hibbeler, 12e) Determine the greatest acceleration with which the 1000 kg forklift can raise the 750 kg crate, without causing the wheels at $B$ to leave the ground. The centers of mass for the forklift and crate are located at $G_1$ and $G_2$, respectively. ($a = 4.72 \text{ m/s}^2$)

6 Problem Set 6

1. (17-54 Hibbeler, 9e) The pendulum consists of a 20-lb sphere and a 5-lb slender rod. Determine the reaction at the pin $O$ just after the pendulum is released from the position shown. ($O_x = 0$, $O_y = 1.94 \text{lbf}$)

2. (17-59,60 Hibbeler, 9e) A motor supplies a constant torque $M = 2 \text{ Nm}$ to a 50 mm diameter shaft $O$ connected to the center of the 30 kg flywheel. The resultant bearing friction $F$, which
the pin exerts on the shaft acts tangent to the supporting shaft and has magnitude 50 N. Determine how long the torque must be applied to the shaft to increase the rotational speed of the flywheel from 4 rad/s to 15 rad/s. The flywheel has a radius of gyration of $k_O = 0.15$ m about its center. If the motor is disengaged from the shaft once the flywheel is rotating at 15 rad/s, so that $M = 0$, determine how long it will take before the resultant bearing frictional force $F = 50$ N stops the flywheel from rotating. ($t_{12} = 9.90$ s, $t_{23} = 8.10$ s)

5. (17-96 Hibbeler, 9e) The spool has a mass of 100 kg and a radius of gyration of $k_G = 0.3$ m. If the coefficients of static and kinetic friction at A are $\mu_s = 0.2$ and $\mu_k = 0.15$, determine the angular acceleration of the spool if the cord and force $P = 50$ N are directed vertically upward (i.e. rotate the cord and 90° counterclockwise from the position shown in the figure). ($\bar{\alpha} = 0.55 \text{ rad/s}^2$)

6. (17-101 Hibbeler, 9e) A uniform rod having a weight of 10 lb is pin-supported at A from a slider block of negligible mass which slides on a horizontal track. Note: Replace the roller shown in the figure with a block. If the rod is initially at rest, and a horizontal force $F = 15$ lbf is applied to the block, determine the acceleration of the block. The coefficient of kinetic friction between the block and the track is $\mu_k = 0.2$. Neglect the dimension d and the size of the block in the computations. ($\bar{a}_A = 167.5 \text{ m/s}^2$)
7 Problem Set 7

1. (14-17 Hibbeler, 11e) The 100 lb block slides down the incline plane for which the coefficient of kinetic friction is \( \mu_k = 0.25 \). If it is moving at \( 10 \text{ ft/s} \) when it reaches point \( A \), determine the maximum deformation of the spring needed to momentarily arrest the motion. \( (s = 2.565 \text{ ft}) \)

2. (14-20 Hibbeler, 11e) The motion of a truck is arrested using a bed of loose stones \( AB \) and a set of crash barrels \( BC \). If experiments show that the stones provide a rolling resistance of 160 lb per wheel and the crash barrels provide a resistance as shown in the graph, determine the distance \( x \) the 4500 lb truck penetrates the barrels if the truck is coasting at \( 60 \text{ ft/s} \) when it approaches \( A \). Take \( s = 50 \text{ ft} \) and neglect the size of the truck. \( (x = 5.44 \text{ ft}) \)

3. (14-34 Hibbeler, 11e) The 10 lb block is pressed against the spring so as to compress it 2 ft when it is at \( A \). If the plane is smooth, determine the distance \( d \), measured from the wall, to where the block strikes the ground. Neglect the size of the block. \( (d = 36.28 \text{ ft}) \)

4. (14-38 Hibbeler, 11e) The spring has stiffness \( k = 50 \text{ lbf/ft} \) and an unstretched length of 2 ft. As shown, it is confined by the plate and wall using cables so that its length is 1.5 ft. A 4 lb block is given a speed \( v_A \) when it is at \( A \), and it slides down the incline having a coefficient of kinetic friction \( \mu_k = 0.2 \). If it strikes the plate and pushes it forward 0.25 ft before stopping, determine its speed at \( A \). Neglect the mass of the plate and spring. \( (v_A = 5.80 \text{ ft/s}) \)

5. (14-55 Hibbeler, 11e) The elevator \( E \) and its freight have a total mass of 400 kg. Hoisting is provided by the motor \( M \) and the 60 kg block \( C \). If the motor has an efficiency \( \epsilon = 0.6 \), determine the power that must be supplied to the motor when the elevator is hoisted upward at a constant speed of \( v_E = 4 \text{ m/s} \). \( (P_{in} = 22.24 \text{ kW}) \)

6. (14-56 Hibbeler, 11e) The 50 kg crate is hoisted up the 30° incline by the pulley system and the motor \( M \). If the crate starts from rest and by constant acceleration attains a speed of 4 m/s after travelling 8 m along the plane, determine the power that must be supplied to the motor at this instant. Neglect friction along the plane. The motor has an efficiency of \( \epsilon = 0.74 \). \( (P_{in} = 1595.9 \text{ kW}) \)
7. (14-83 Hibbeler, 11e) Just for fun, two 150 lb engineering students A and B intend to jump off the bridge from rest using an elastic cord (bungee cord) having a stiffness of $k = 80 \text{lbf/ft}$. They wish to just reach the surface of the river, when A, attached to the cord, lets go of B at the instant they touch the water. Determine the proper unstretched length of the cord to do the stunt, and calculate the maximum acceleration of student A and the maximum height he reaches above the water after the rebound. From your results, comment on the feasibility of doing this stunt. ($L = 90 \text{ft}$, $a_{\text{max}} = 483 \text{ft/s}^2$, $y_{\text{max}} = 218.9 \text{ft}$, Stoopid!)

8. (14-88 Hibbeler, 11e) The Raptor is an outside loop roller coaster in which riders are belted into seats resembling ski-lift chairs. If the cars travel at $v_o = 4 \text{m/s}$ when they are at the top of the hill, determine their speed when they are the top of the loop, and the reaction of the 70 kg passenger on his seat at this instant. The car has a mass of 50 kg. Neglect friction and the size of the car and passenger. ($v = 7.43 \text{m/s}$, $N = 86.6 \text{N}$)

9. (14-94 Hibbeler, 11e) A tank car is stopped by two spring bumpers A and B, having stiffness of $k_A = 15 \times 10^3 \text{lbf/ft}$ and $k_B = 20 \times 10^3 \text{lbf/ft}$, respectively. Bumper A is attached to the car, whereas bumper B is attached to the wall. If the car has weight $25 \times 10^3 \text{ lb}$ and is freely coasting at $3 \text{ft/s}$, determine the maximum deflection of each spring at the instant the bumper stops the car. ($s_A = 0.516 \text{ft}$, $s_B = 0.387 \text{ft}$)