Quick Note: At the time of publication of this document, I have not yet seen the Midterm Exam. The practice problems in this document are what I would consider useful problems for you to study in preparation for the exam. Your studying approach should not be limited to working through this set of problems, nor should you interpret these problems as an official study guide for your exam. Email me (michaelm@physics.utah.edu) if you have any questions about the problems.

1 Wanted Dead or Alive
You are driving in your car and approach an exit off of the highway at 67 km/hr. The exit is an unbanked curve and you do not slow down for it. Your grandmother, a passenger in the car, notices that your Bon Jovi air freshener (hanging from the rear view mirror) makes an angle of 15° with the vertical. After mocking you for being a Bon Jovi fan, she shares this angle information with you and asks you what the radius of curvature for the exit is. What do you tell her?

2 Incline No Friction
A block slides from rest at the top of an incline without friction. The angle that the incline makes with the horizontal is 30°. The height of the incline is 1 meter. Determine the speed of the block at the bottom of the incline. Do this problem TWO separate ways: first, using Newton’s 2nd Law and the kinematic equations, and second, using the definition of work and the work-kinetic energy theorem.

3 Incline Yes Friction
Same block, same incline. Now add friction between the block and the incline with a coefficient of friction of \( \mu = .41 \). Determine the speed of the block at the bottom of the incline. Use your favorite method.

4 Look at the Size of That Mass
A certain particle of mass “m” and velocity “v” undergoes a change such that its new mass is “2m” and its new velocity is “(1/2) v”... What is the ratio of initial kinetic energy to final kinetic energy?

5 There’s No Crying in Baseball
You are given the following two vectors: \( \vec{A} = (3, 5, 1) \) and \( \vec{B} = (1, -2, -3) \). Compute the dot product for these two vectors. Then, find the angle between vectors \( \vec{A} \) and \( \vec{B} \). After you finish that, compute the angle between the vector \( \vec{B} \) and the negative z-axis. Then, bring $5.00 to your TA on Thursday.
6 Fear Gonzo

A 10 kg box is shown in the diagram below in a state of equilibrium (it is motionless). When no force is applied from the left, the spring extends 20 centimeters from its natural length. Find the force $F$ applied from the left if the spring extends 10 centimeters for the situation shown below. $\theta = 30^\circ$. Beware of Gonzo.

7 King of Thebes

A woman racing her son has half the kinetic energy of the son, who has half the mass of the mother. The woman speeds up by $1.0 \text{ m/s}$ and then has the same kinetic energy as the son. What were the original speeds of the woman and her son? Also, how old is the woman?

8 Shakeovitch Staravinski

A ski lift raises 100 passengers averaging 150 lbs a height of 500 feet in 60 seconds at a constant speed. What average power is required for the lift?

9 Horizontal Spring

A mass of 0.64 kilograms is attached to a spring of spring constant $k = 1320 \text{ N/m}$. The spring is horizontal and attached to a rigid wall. The mass is touching the ground and between the two of them exists a coefficient of friction $\mu = 0.34$. If the spring is compressed 1.2 centimeters, and the mass is released when the spring reaches its equilibrium length, then determine the total distance traveled by the mass.

10 Vertical Spring

A 250 g block is dropped onto a vertical spring with spring constant $k = 2.5 \frac{N}{\text{cm}}$. The block becomes attached to the spring, and the spring compresses 12 cm before momentarily stopping. While the spring is being compressed, what work is done by the block’s weight? By the spring? What was the speed of the block just before it hits the spring? If the impact speed is doubled, what is the maximum compression of the spring?
11 And the Spies Came Out of the Water

Marie is a spy currently spending a rough winter in Zagreb, Croatia. One of her objectives is to destroy a bridge which insurgents have been using as a supply route. As she approaches the bridge, she notices that it is inclined an angle $\alpha$ above the horizontal (as reported in the briefing). The bridge is partially covered with ice (there happens to be more ice at the bottom of the incline than at the top). The coefficient of friction (both static and kinetic) can be written as $\mu = Ax$, where $x$ is the distance measured along the incline and $A$ is a constant. Marie is using a remote-controlled explosive device. The concept here is that she wants to slide the device up the inclined bridge, have it come to rest at a suitable location and then detonate the device. Show me that the condition for success in this mission is:

$$v_0^2 \geq \frac{3g \sin \alpha}{A \cos \alpha}$$

12 Roger Went Loopy on Us

Use the diagram below to solve this problem. A small block of mass “m” can slide along the frictionless loop-the-loop track. The block is released from rest at Point P. What is the net force acting on the block at Point Q? At what height above the bottom of the loop should the block be released so that it is on the verge of losing contact with the track at the top of the loop?

13 The Black Rectangle

Use the diagram below to solve this problem. A 2 kg block is on a rough incline and is connected to a spring of negligible mass with spring constant $k = 100$ N/m. The block is released from rest when the spring is un-stretched and the pulley is frictionless. The block moves 20 cm down the incline before coming to rest. Find the coefficient of kinetic friction between the block and the incline.
14 Basic Work Problem

You push a box across the floor with a force of 120 Newtons. The box has a mass of 5 kg. The force is directed in such a way that the line of force makes an angle of $\theta=58^\circ$ with the vertical. What is its speed after a pushing distance of 3.2 meters?

15 Slip ’N Slide

Imagine you are on a water slide of height “h”. It is curved and ramps up again at the bottom to a height of “h/5”. When you reach the end of the ramp, you are projected at an angle $\theta$ above the horizon. Find the maximum height to which you will rise after leaving the end of the water slide ramp. Your answer can only contain “h” and $\theta$. Be sure to “check” your answer by looking at the physical significance of the angles 0° and 90°.

16 Circular Track with Friction

A block of mass 0.5 kg is pushed a distance x against a spring with $k=450$ N/m. When released the block slides along a frictionless horizontal surface to a point B, the bottom of a vertical circular track of radius R=1 meter. The track is not smooth. When the block reaches point B, its speed is 12 m/s. It undergoes a constant 7 Newton force along the track. What was the initial compression of the spring? What is the speed of the block at the top of the circular track? Does the block even reach the top or does it fall off on the way up?

17 Hot in Herre

Determine the center of mass for the Earth-Sun system. What is interesting about the position that you have determined?
18 Center of Mass - Cylinder
Consider a cylinder with a height of “h” and a radius of “R”. The density of this cylinder is not uniform; in fact, it varies with position such that \( \rho = \alpha y^2 \) (where \( \alpha \) is an unknown constant). Determine the center of mass for this cylinder.

19 Center of Mass - Square
Consider two squares placed side by side (they are just barely touching). Each square has sides of length “a”. The square on the left has a density (mass per unit area) of \( \sigma = \sigma_1 \) and the square on the right has a density of \( \sigma = \sigma_2 \). Find the center of mass for this system.

20 You Want a Toe?
In the movie “The Big Lebowski”, Jeff Lebowski (known as “The Dude”) frequently goes bowling. The Dude drinks far too many White Russians and his stomach shows it (his mass is \( m_d = 95 \text{ kg} \)). The Dude’s bowling ball has a mass of \( m_b = 6.2 \text{ kg} \). The typical length of a bowling lane (measured from foul line to the front pin) is 60 feet. The distance we want is from the foul line to the center of mass of the 10 pins (which we’ll approximate as 19 meters). Assume each pin has a mass of \( m_p = 1.5 \text{ kg} \). Determine the center of mass for the whole system (Dude, ball, pins) when the Dude is just about to release the bowling ball at the foul line. Where is the center of mass of the system when the bowling ball is just about to strike the first pin?

21 Calmer Than You Are
Next, suppose the Dude is able to roll his bowling ball at a speed of \( v = 11 \text{ m/s} \). Determine the center of mass of the whole system (Dude, ball, pins) as a function of time (assume that the Dude releases the ball at the foul line at time \( t = 0 \)).

22 Until it Goes Click
The Dude has just knocked down 9 pins. He is now going for the spare. Let’s suppose that the ball strikes the pin in a completely inelastic collision. Using the velocity and masses previously given, determine the speed of the objects after the collision.

23 Love on the Blue Line
You (\( m_y = 80 \text{ kg} \)) and your sweetie (\( m_s = 55 \text{ kg} \)) are on an ice rink and holding onto opposite sides of a 10 meter long pole with negligible mass. You want to exchange a kiss and begin pulling yourselves along the pole until you meet. How far does your sweetie move before the kiss?

24 Love on the Green Line
Your old sweetie wasn’t a very good kisser, so you find a new one. You take your new sweetie (\( m_s \)) for a nice picnic in a canoe (\( m_c = 30 \text{ kg} \)) along the Green River. With the canoe at rest, you and your sweetie exchange seats in the canoe (the seats happen to be 3 meters apart from one another and are symmetrically placed with respect to the canoe’s
center). You notice that the canoe moves 40 cm with respect to a partially submerged log during the exchange. How much does your new sweetie weigh?

25 Red Pill or the Blue Pill

A red pill is dropped at t=0. A second pill (blue, this time), having a mass twice that of the first, is dropped from the same position at t= 100 µs. Where is the center of mass of this system (the two pills) at t= 300 µs? How fast is the center of mass moving at this point?

26 Playdoh

A mass \( m_1 = .5 \) kg of sticky playdoh is released by a spring (of spring constant \( k = 2500 \) N/m) after having been compressed a distance \( x = 4 \) cm. This mass slides along a frictionless surface and strikes a block of wood of mass \( m_2 = 1 \) kg. The playdoh sticks to the block of wood and that system slides along a surface with friction (coefficient is \( \mu = .31 \)). Determine the speed of the playdoh just before impact with the wood. Determine the speed of the playdoh/wood system just after the collision. How much kinetic energy is lost in the collision? Determine how far the playdoh/wood system travels before coming to rest.

27 The John Galt Line

A railroad car of the John Galt Line moves at a constant speed of \( v = 3.20 \) m/s under a grain elevator. Grain drops into the car at a rate of 540 kg/min. What force must be applied to the railroad car to keep it moving at a constant speed? Ignore friction.

28 She Packed My Bags Last Night Pre-Flight

Consider a rocket at rest deep in space. What must be its mass ratio (ratio of initial mass to final mass) in order that, after firing its engine, the rocket’s speed is twice that of the exhaust.

29 Stranded

You are on a block of ice in the middle of a lake (combined mass equal to M). You have two stones with you such that \( M = 6m_1 = 12m_2 \). To get the block of ice moving you decide to throw the stones off in the opposite direction with a velocity of \( v_s \) (relative to the boat). Which is the best option to maximize your speed: (a) throw both stones at the same time, (b) throw stone 1 before stone 2, or (c) throw stone 2 before stone 1. Justify your answer.

30 A Proof

Two objects of the same mass \( m \) collide with one another in a purely elastic collision. Show that, if the the collision is not “head-on”, then the angle of separation between the two masses after the collision must be 90°.
31 Totally Inelastic Collision

Two skaters collide and are involved in a purely inelastic collision. The first skater with \( m_1 = 83 \text{ kg} \) is originally travelling due East with speed \( v_1 = 6.2 \text{ km/hr} \), while the second skater with \( m_2 = 55 \text{ kg} \) is travelling due North with speed \( v_2 = 7.8 \text{ km/hr} \). Determine the velocity (magnitude and direction!) of the skaters after the impact.

32 Impulsive

A 300 g ball with a speed of \( v = 6 \text{ m/s} \) strikes a wall making a 30° angle with the vertical and then rebounds with the same speed and angle. It is in contact with the wall for 10 ms. Find the impulse on the ball. What was the average force exerted on the ball by the wall?

33 Rearden Steel

A railroad freight car of mass \( M \), again on the John Galt Line, collides with a stationary caboose car. They couple together and 27% of the initial kinetic energy is lost to heat, sound and vibrations. Find the mass of the caboose.

34 Reverse Collision

A 20 kilogram object is moving along the positive \( x \)-axis with a speed of 200 m/s when it explodes into 3 separate pieces. One part (of mass 10 kilograms) moves with speed 100 m/s along the positive \( y \)-axis. A second part (of mass 4 kilograms) moves with speed 500 m/s along the negative \( x \)-axis. What is the velocity of the third part (of mass 6 kilograms). How much energy was released in the explosion? Ignore gravitational effects.

35 Collision With Spring

A 1 kilogram block at rest on a horizontal frictionless surface is attached to a massless, unstretched spring with spring constant \( k = 200 \text{ N/m} \). The other end of the spring is fixed to a rigid wall. A 2 kilogram block slides with a speed of 4 m/s and collides with the 1 kilogram block. If the two blocks stick together after the collision, by how much is the spring compressed when the system momentarily comes to rest.

36 Totally Elastic Collision

A block of mass 5 kg is located on a curve ramp a height 5 meters above the horizontal. At the bottom of the curved ramped lies a mass of 10 kg which is at rest. If the first block is released from rest and makes an elastic collision with the second block, to what height will the first block recoil back up the curved ramp?

37 The Mixing Bowl

Two ice cubes (one with twice the mass of the other) are released from rest from opposite ends of the top of a mixing bowl (height of 8 centimeters). The ice cubes undergo an elastic collision. Find the speed of each ice cube before the collision and after the collision. Then, determine to what height each ice cube will rise.