# Physics 151 Exam 3 Review Suggestions

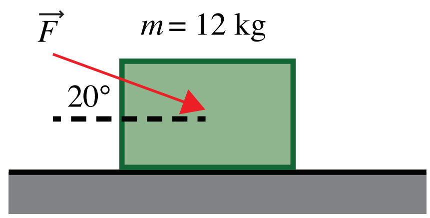
1. *Work and Energy* – How is work defined. If you are given the position of an object at a series of times and the net force on it at each of those times, how do you calculate the net work done on the object? You should know how to do this calculation even if the forces are not constant, and are at an angle to the object's motion. For example, if you made a data table consisting of the forces you measured when you pushed and pulled on a low friction cart in activity 5.5.1 (a) and you had happened to measure the position of the cart with a motion detector at the same time, how would you go about calculating the net work that you did on the cart?

2. *Mechanical Energy Conservation* – Is mechanical energy always conserved in collision processes? What is the difference between an elastic, an inelastic, and a supereleastic collision? You may want to look this up in your text as it's not covered in the Activity Guide (although we did cover it in class). Under what circumstances is mechanical energy conserved? You may want to review the conceptual themes in Units 10 and 11.

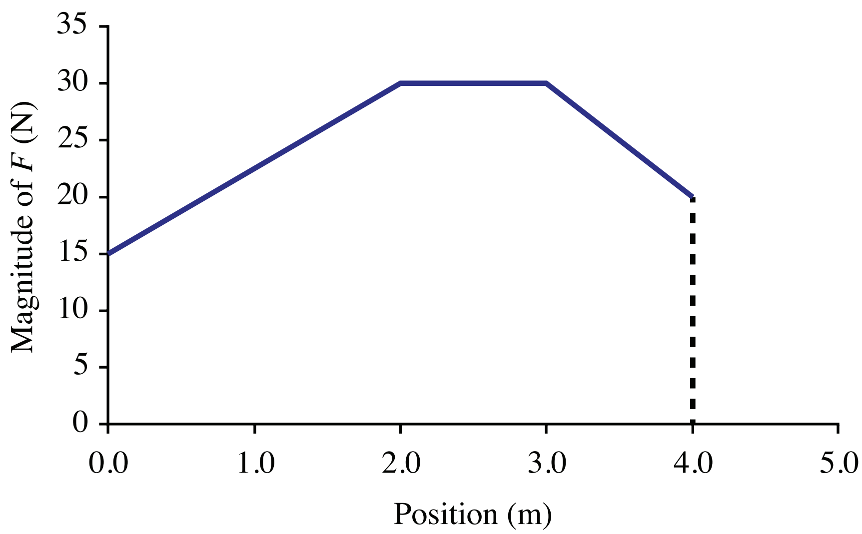
3. *Rotational Motion*-- If you know the magnitude and direction of the force on an object and the moment arm between that force and the axis of rotation of the object, can you determine the magnitude and direction of the torque that acts on the object? Can you calculate the torque acting on an object using either the angle method and right-hand rule or the formal cross product method? If you are given the equation for the rotational inertia of an object as a function of its dimensions and you know the dimensions of the object and its rotational velocity can you calculate its rotational momentum? It's rotational kinetic energy? How can you determine the direction of the rotational momentum? Under what circumstances is rotational momentum conserved? Can rotational momentum be conserved when rotational kinetic energy is not conserved in an inelastic collision? How can conservation of rotational momentum be used to explain why rotation is used to stabilize moving objects? For example, why does a quarterback, when throwing a pass, put spin on the football?

**1. (25 points) Work and Energy**

A block with mass 12 kg is being pushed along a horizontal floor by a force $\vec{F}$ as shown in the following diagram. The coefficient of kinetic friction between the block and floor is $\mu_k = 0.12$. At clock reading $t = 0.0$ s and position $\vec{x}_1 = 0.0 \text{ m } \hat{x}$ the block has an instantaneous velocity of $\vec{v}_1 = 2.0 \text{ m/s } \hat{x}$.

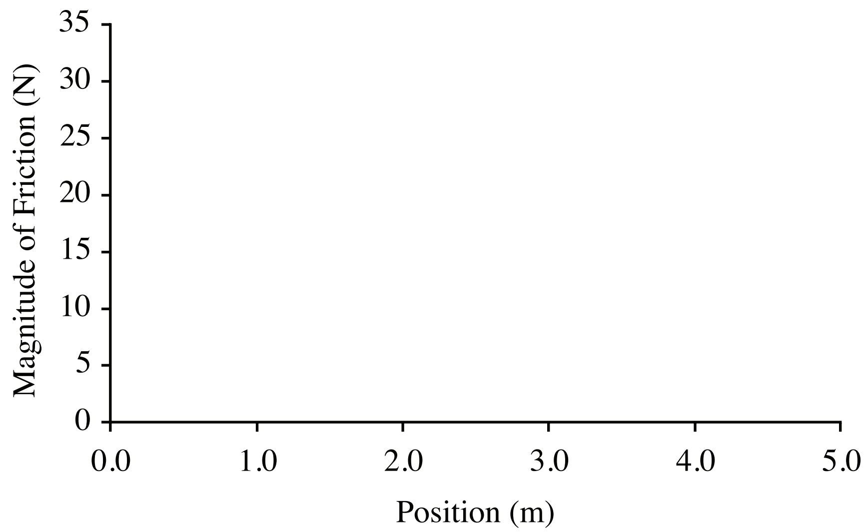



The force $\vec{F}$ is applied to the block at the instant it is in position $\vec{x}_1 = 0.0 \text{ m } \hat{x}$. The direction of $\vec{F}$ remains fixed, but its magnitude varies with position as shown in the following graph. (***Note***: Assume that you can read the graph to 2 significant figures.)




(a) **(5 pts.)** Find the work done by the applied force $\vec{F}$ in the displacement of the block from position $\vec{x}_1 = 0.0 \text{ m } \hat{x}$ to position $\vec{x}_2 = 4.0 \text{ m } \hat{x}$.

(b) **(5 pts.)** Since the applied force $\vec{F}$ varies with position, the normal force $\vec{F}^{norm}$ and hence the kinetic friction force $\vec{F}_k^{fric}$ will also vary with position. Calculate and graph the magnitude of the kinetic friction force as a function of position. (***Hint***: To create the graph, you don't need to calculate $F_f$ for *every* position between 0.0 m and 4.0 m – just at a few select ones.)




(c) **(5 pts.)** Find the work done by the friction force $\vec{F}_k^{fric}$ in the displacement of the block from position $\vec{x}_1 = 0.0 \text{ m } \hat{x}$ to position $\vec{x}_2 = 4.0 \text{ m } \hat{x}$.

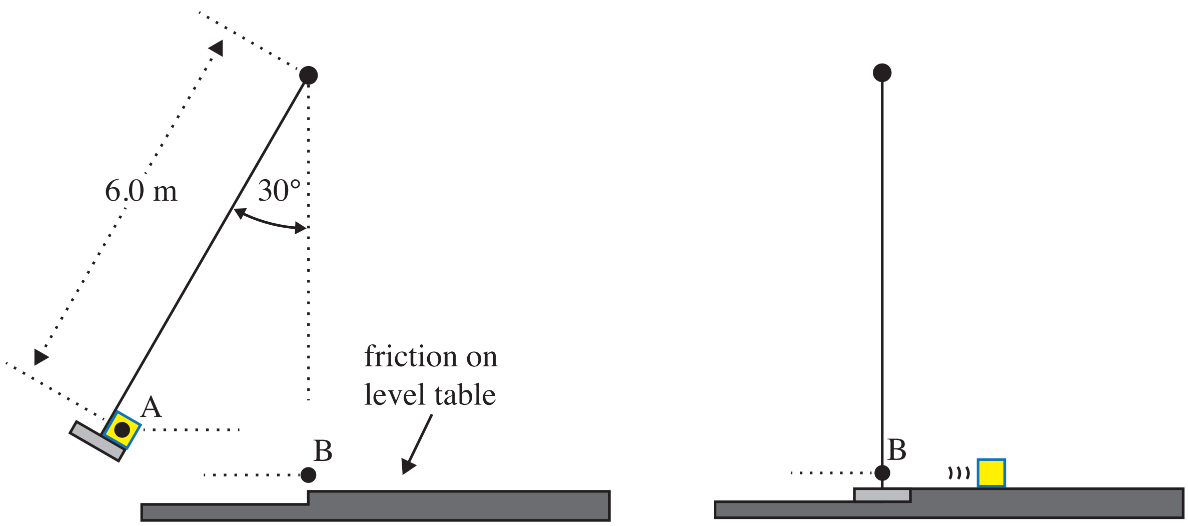
(d) **(5 pts.)** Find the *velocity* of the block the instant it is at position $\vec{x}_2 = 4.0 \text{ m } \hat{x}$. Express your result using vector notation.

(e) **(5 pts.)** Find how far the block will slide beyond position $\vec{x}_2 = 4.0 \text{ m } \hat{x}$ if the force $\vec{F}$ abruptly drops to zero at $\vec{x}_2 = 4.0 \text{ m } \hat{x}$ and remains zero from there on. (You may ***not*** use kinematics to answer this question.)

**2. (15 points) Work and Energy**

A **25 kg block** is placed on a swing. The swing is then pulled back such that the angle the rope makes with the vertical is **30°**, and **released from rest**. At the bottom of its path, the swing hits a lip of a level table, such that the swing stops but the block continues to slide forward. The block slides a **distance of 2.0 m** before **coming to rest**.

**Note:** you may **not** use kinematics for any part of this problem. You may use **1)** Work-Energy Theorem, or **2)** Conservation of Mechanical Energy. For each part, please specify which you are using.



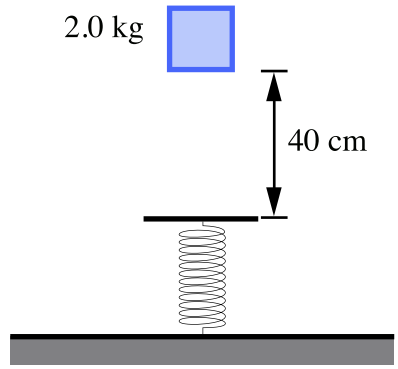

(a) **(5 pts.)** If we define the block's gravitational potential energy to be zero when it is at point A, what is its potential energy at the bottom of the swing? Explain your reasoning and show your equations and calculations.

(b) **(5 pts.)** What is the block's speed at the bottom of the swing (the instant the swing hits the lip)? Explain your reasoning and show your equations and calculations. (If you need the result from a previous part of this question that you couldn't get, choose a reasonable number and proceed. Explicitly state that this is what you are doing.)

(c) **(5 pts.)** What is the coefficient of friction between the block and the level table? Explain your reasoning and show your equations and calculations. (If you need the result from a previous part of this question that you couldn't get, choose a reasonable number and proceed. Explicitly state that this is what you are doing.)

**3. (30 points) Mechanical Energy**

A 2.0 kg block is dropped onto a spring from a height of 40 cm above the spring. While you aren't given the value of the spring constant, you do know that it takes 98.0 N to compress the spring by 5.00 cm. (You may ***not*** use kinematics to answer any part of this question.)




(a) **(5 pts.)** Using a column graph format, sketch the relative magnitudes of the kinetic energy, gravitational potential energy, spring (elastic) potential energy, and total mechanical energy of the system for when the block is first released. ***Briefly explain your reasoning. Hint*:** where are you going to define zero gravitational potential energy?

$K$ $U_{grav}$ $U_{spring}$ $E_{mech}$

(b) **(5 pts.)** Using a column graph format, sketch the relative magnitudes of the kinetic energy, gravitational potential energy, spring (elastic) potential energy, and total mechanical energy of the system for when the block first contacts the spring. ***Briefly explain your reasoning.***

$K$ $U_{grav}$ $U_{spring}$ $E_{mech}$

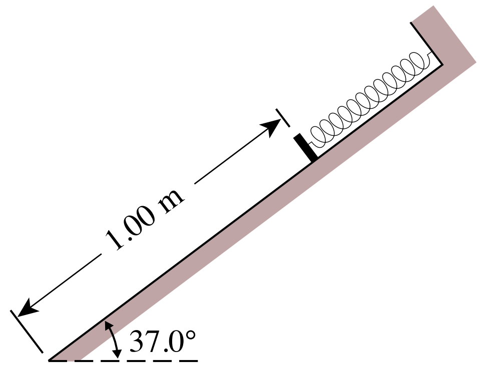
(c) **(5 pts.)** Using a column graph format, sketch the relative magnitudes of the kinetic energy, gravitational potential energy, spring (elastic) potential energy, and total mechanical energy of the system for when the block has fully compressed the spring. ***Briefly explain your reasoning.***

$K$ $\quad$ $U^{grav}$ $\quad$ $U^{spring}$ $\quad$ $E^{mech}$

(d) **(10 pts.)** Find the maximum distance the spring is compressed. ***Hint*:** the quadratic equation is your friend for this question.

(e) **(5 pts.)** Find the *velocity* (not just the speed) of the block just as it touches the spring.

**4. (25 points) Spring at the Top of an Incline**




In the figure to the right, a spring with a spring constant $k$ = 170. N/m is at the top of a 37.0° frictionless incline. The lower end of the incline is 1.00 m from the end of the spring, which is at its relaxed length.

A 2.00 kg canister is pushed against the spring until the spring is compressed 20.0 cm. It is now held stationary in this position. The value of $g$ to three significant figures is 9.81 N/kg.

(a) **(8 pts.)** What is the total mechanical energy of the system, in joules? Explain your reasoning. (Wait until the end, after all your algebra is completed, to substitute in numbers, with proper units, and express your final answer with the correct units and number of significant figures.)

(b) **(2 pts.)** In part (a), what did you choose as your reference point for gravitational potential energy? Address why you chose that particular point.

(c) Now the canister is released from rest. What is the speed of the canister at the instant the spring returns to its relaxed length (which is the instant the canister loses contact with the spring)?

(i) **(4 pts.)** First, explain what physical principle(s) you will use to solve this problem, and **justify your choice**. You may choose from **1)** Impulse-Momentum Theorem, **2)** Conservation of Momentum, **3)** Work-Energy Theorem, or **4)** Conservation of Mechanical Energy.

(ii) **(8 pts.)** Now show your solution. (Wait until the end, after all your algebra is completed, to substitute in numbers, with proper units, and express your final answer with the correct units and number of significant figures.)

(d) **(3 pts.)** Would your answer to part (c) have changed if you chose a different reference point for gravitational potential energy? Explain.

**5. (25 points) Rotational Motion and Torque**

A Physics 211 student is studying the efficiency of braking systems for her project. Her ultimate goal is to obtain the coefficient of kinetic friction between a solid disk and a brake pad. A schematic diagram of her experimental apparatus is shown in figure 1. She starts the disk spinning with a motor, and it reaches a particular rotational speed. Then she removes the motor and applies the brake with a **constant force of 1 N**. Her rotary motion sensor starts taking data just as the brake is applied. On one particular run she obtains the data shown in figure 2, which she has analyzed using a "modelingWorksheet.xls" spreadsheet and some additional curve fitting software tools to get the SDM of each coefficient. With your knowledge of fundamental mechanics and your experience with curve fitting and modeling, you should be able to infer her experimental strategy from the information displayed on the chart. The disk has a **radius of 10 cm**, and a **mass of 1 kg. Ignore the bearing friction in this problem.**

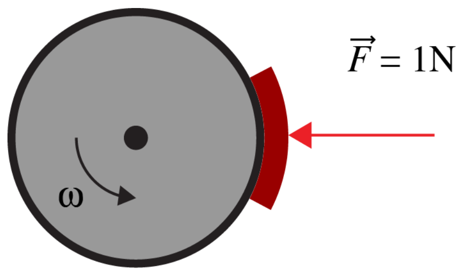



**Figure 1**

| | | |
|---|---|---|
| $c_0 =$ | 0.0134 | ± 0.1432 |
| $c_1 =$ | 62.9199 | ± 0.1659 |
| $c_2 =$ | -8.0446 | ± 0.0400 |
| *Friction Brake* | | |
| angle (rad) | | |
| time (s) | $\theta$-exp. (rad) | $\theta$-th (rad) |
| 0.0 | 0.0 | 0.0 |
| 0.2 | 12.2 | 12.3 |
| 0.4 | 24.0 | 23.9 |
| 0.6 | 35.0 | 34.9 |
| 0.8 | 45.0 | 45.2 |
| 1.0 | 55.0 | 54.9 |
| 1.2 | 64.0 | 63.9 |
| 1.4 | 72.0 | 72.3 |
| 1.6 | 80.0 | 80.1 |
| 1.8 | 87.0 | 87.2 |
| 2.0 | 94.0 | 93.7 |

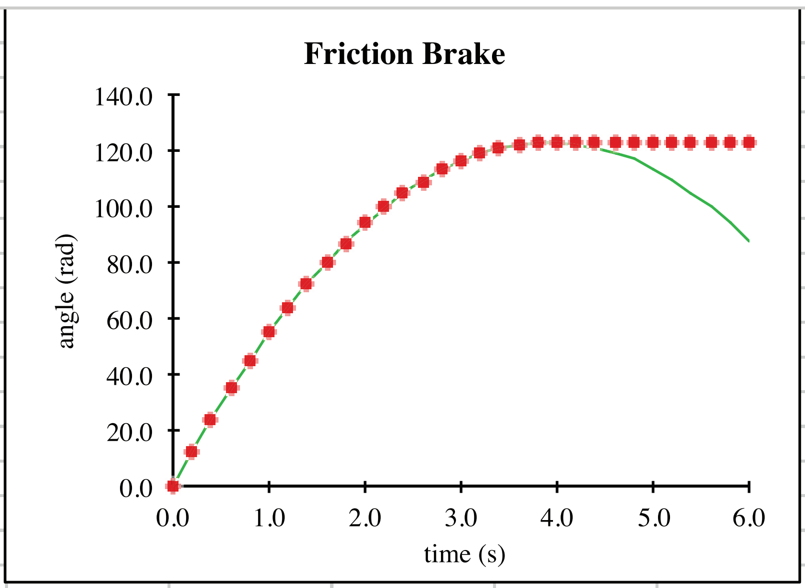



**Figure 2**

(a) **(5 pts.)** Explain her experimental strategy, *i.e.*, what assumptions is she making and what steps must she take to find the coefficient of friction?

(b) **(5 pts.)** What is the initial rotational speed of the disk, including its experimental uncertainty?

(c) **(5 pts.)** Is the rotational acceleration a constant? If yes, what is its magnitude, including its experimental uncertainty? Justify your answer from the information given in the problem.

(d) **(5 pts.)** When the brake is applied, it generates a torque on the disk. Is the torque constant? How do you know? If yes, determine its magnitude. (If you need the result from a previous part of this question that you couldn't get (*i.e.*, $\omega$ and/or $\alpha$), choose a reasonable number and proceed. Explicitly state that this is what you are doing.)

(e) **(5 pts.)** Determine the value of the coefficient of friction of the brake pad against the disk. Make sure that you clearly show all your steps and reasoning. (Again, if you need the result from a previous part of this question that you couldn't get (*i.e.*, $\omega_1$ $\alpha$, and/or $\tau$), choose a reasonable number and proceed. Explicitly state that this is what you are doing.)

**6. (20 points) Rotational Motion and Torque**

A day-care worker pushes tangentially on a small hand-driven merry-go-round and is able to stop it uniformly from an initial spinning rate of 30 rpm (revolutions per minute) in 10.0 s. The vector that represents the initial rotational velocity is pointing up. Assume the merry-go-round is a disk of diameter 5.0 m and has a mass of 800 kg, and two children (each with a mass of 25 kg) sit opposite each other on the edge of the merry-go-round.

(a) **(5 pts.)** Find the rotational acceleration (magnitude and direction) of the merry-go-round. Explain your reasoning and show your equations and calculations.

(b) **(5 pts.)** Find the rotational inertia of the system. Explain your reasoning and show your equations and calculations. ***Hint*:** the two children may each be treated as a point object.

(c) **(5 pts.)** Find the torque (magnitude and direction) required to produce the rotational acceleration found in part (a). Explain your reasoning and show your equations and calculations.

(d) **(5 pts.)** Find the magnitude of the force required to produce the torque found in part (c). Explain your reasoning and show your equations and calculations.