McGill University

PHYS 101

(Introduction to Mechanics for the Life Sciences)

FINAL EXAM

December 06, 2013
9:00 AM – noon

Examiner: K.J. Ragan x6518
Associate Examiner: J. Crawford x7029

Student name:
ID:

The exam comprises two parts on seven pages (including this page): 9 short answer questions (4 points each), and 6 problems (8 points each). A 3-page formula sheet is attached to the back of the exam. No books (except translation dictionaries) or notes of any kind are allowed. Calculators are allowed.

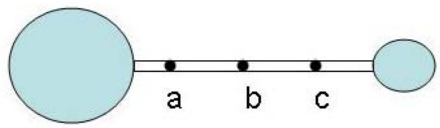
Answer **the short answer questions** with a few words or a few short phrases.
For the **problems**, show all your work.

Put all answers in the **answer booklets** provided (**nothing** on this question sheet will be marked!), and return this exam paper with the booklet(s).

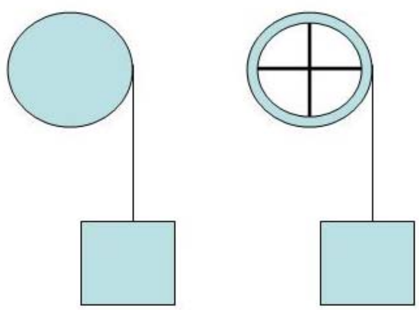
Good luck !

Short answer questions (answer all): you should not need to do any calculations for these questions, and should answer in **a few words, a few short phrases, or a simple sketch. Explain your reasoning – don't just quote an answer.** In some cases you might find it useful to quote an appropriate formula.

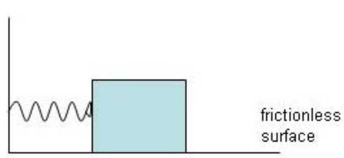
1) [4 pts] The dumbbell shown in the drawing is composed of two unequal masses (the left one is more massive) connected by a massless rod. Is the center of mass of the dumbbell at point a, b, or c? Explain your reasoning.



2) [4 pts] The solid cylinder (on the left in the drawing below) and the cylindrical shell (on the right) have the same mass and radius, and are mounted on frictionless horizontal axles. A massless rope is wrapped around each of them and connected to a block. The two blocks have the same mass and are held the same distance above the ground, and then released simultaneously. Which block reaches the ground first, and why?

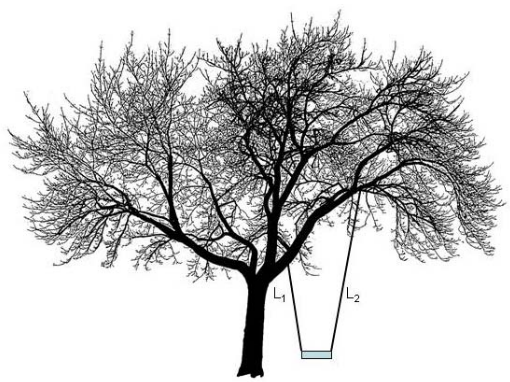


3) [4 pts] A mass placed on a frictionless surface and connected to a spring oscillates horizontally, as shown below. At time t=0, the mass is at the equilibrium point of the spring and moving to the right. Draw graphs of x vs. t, kinetic energy (KE) vs. t, and potential energy (PE) vs. t, for times from t=0 to t=T (where T is the period of the oscillator). Indicate clearly the times t=0, t=T/4, t=T/2, t=3T/4, and t=T.



4) [4 pts] At a fairground you see a new competition called a “wave race”: two identical ropes are attached to a wall, and each rope is held by a person. At a given signal, each person tries to send a wave along the rope towards the wall – the winner is the person whose wave arrives first. You notice most people try to shake the rope faster or harder to try to win – but you’ve just aced Physics 101 and know you can win this! What do you do to increase your wave speed and win? Explain your answer.

5) [4 pts] A friend of yours is proudly showing off the new swing that he’s built in a tree in his back yard (see diagram below). The swing is level and the ropes are sturdy – but you immediately see at a glance that this is a bad design, and that the friend’s young daughter won’t be pleased with the swing. With your knowledge of simple harmonic motion and pendula, explain why not.



6) [4 pts] Is a make-up mirror (a small mirror used for applying make-up to your face) a convex or a concave mirror? Explain your answer using your knowledge of the mirror equation, and knowing that a good make-up mirror will give you an image that is upright, with magnification that is greater than one.

7) [4 pts] a) Draw a single v-vs-t graph that illustrates a drag race (a short, straight-path race) between two vehicles (each vehicle will be represented by one curve on the graph). Each vehicle accelerates at a constant rate up to a maximum speed, and then stays at that speed. Car A’s acceleration is larger than car B’s, but its top speed is smaller than that of car B. b) Mark on your graph the time when the two cars are side by side for the first time after the start of the race. c) Can you determine in advance who will win the race? If so, who wins – and if not, why not? Explain your answers as fully as possible.

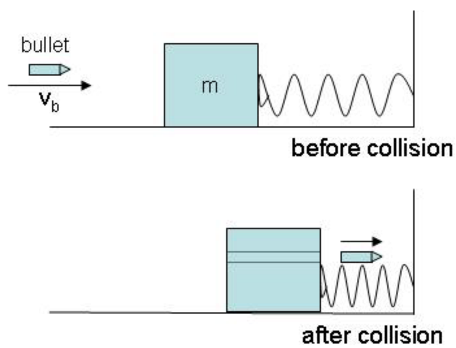
8) [4 pts] An astronaut is on a ‘space-walk’ and working outside of the International Space Station (ISS) in low-Earth orbit. She drops a tool. Will it fall to Earth? Explain why or why not.

9) [4 pts] Two brothers, Adonis and Baccus, are at a water park. There are two water slides (which we can consider frictionless) with straight slopes that start at the same height and end at the same height. Adonis chooses slide A, which is longer and has a more gradual (smaller) slope than slide B (which Baccus chooses). Baccus says he prefers his slide, because he reaches a faster speed – and he notes that it took him less time to get to the bottom than it took Adonis on slide A. Adonis says the speeds at the bottom are the same. Who's right, and why?

<u>Long problems (do **all** of them). Show all your work!</u>

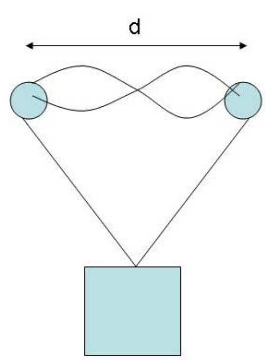
1) [8 pts] A bullet (mass: 5.00 grams) moving with an initial speed of 400. m/s is fired into, and passes through, a block whose mass is 1.0 kg, as shown in the diagram. The block, initially at rest on a flat and frictionless surface, is connected to a spring with a spring constant of k=900. N/m. After the collision, the block moves 5.00 cm to the right before starting to rebound.

a. What is the speed at which the bullet emerges from the block?
b. What is the mechanical energy lost in the collision?



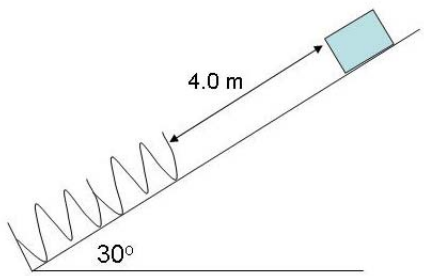
2) [8 pts] In the diagram below, an object of mass 12.0 kg hangs at rest from a string wrapped around two light, frictionless pulleys. The string is of total length 5.0 m and a mass-per-unit-length of μ=0.00100 kg/m. The two pulleys are separated by the distance d=2.0 m.

a. What is the tension in the string (for this part, ignore the mass of the string).
b. At what frequency must the string vibrate to form the standing-wave pattern shown?



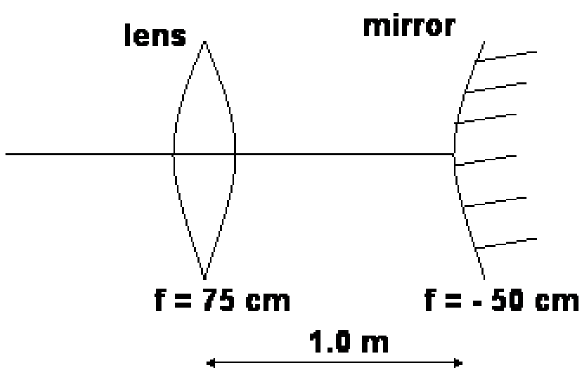
3) [8 pts] A 12.0 kg box slides 4.00 m down a frictionless ramp as shown below, then collides with a spring whose spring constant is 500. N/m.

a. What is the maximum compression of the spring?
b. At what compression of the spring does the box have its maximum speed (Hint: find the position where the force on the box is zero)?
c. What is the initial acceleration of the box when it starts back up the ramp after maximum compression?



4) [8 pts] A lens and mirror are placed as in the diagram below. The focal lengths are f = +75 cm and f = -50 cm, respectively, and they are 1.0 m apart. An object is placed 1.0 m to the left of the lens.

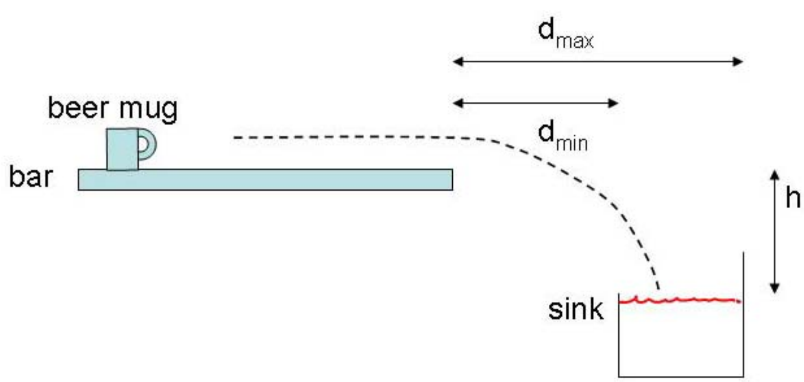
a. Draw an approximate ray diagram (it doesn't have to be to scale, but should show the key features of the object and the image). Use it to predict approximately where the final image will be located.
b. Calculate the location of the final image.
c. Calculate the total magnification. Is the final image upright or inverted?



5) [8 pts] A friend of yours works in a bar as a bartender, and you decide to improve his life by making his job easier. In particular, he has to take empty beer mugs from the bar and put them in the sink (see the diagram below) – and of course, since students come in after exams for a drink, there are a lot of dirty beer mugs to move. You realize that he could send them sliding down the bar and they would land in the sink if they had the right initial speed. You wonder if you can find a **single speed** (so that he can easily learn to slide them correctly) for **different conditions**: in particular, if the bar is clean (larger coefficient of kinetic friction between the mug and the bar), or if there is some beer spilt on it (lower coefficient of kinetic friction).

The vertical distance from the bar to the surface of the water in the sink is h=0.65m; the horizontal distances from the edge of the bar to the front and back of the sink are d_{min}=1.2m and d_{max}=1.8m. The coefficients of kinetic friction are μ_k=0.25 for a clean bar, and μ_k=0.15 for a bar with beer spilt on it. Your friend stands at a point along the bar which is 5.6m from the edge of the bar, and an empty beer mug has a mass of 0.325kg.

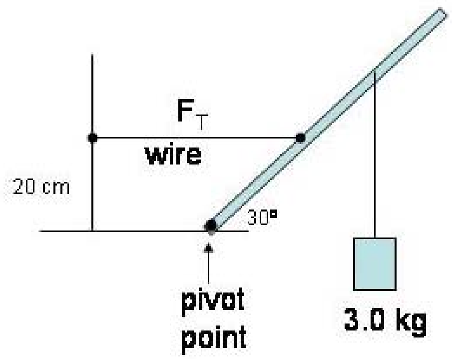
a) Find the minimum horizontal speed the mug must have when it leaves the bar so that it lands in the sink (at the near edge).
b) Using the speed you found in a), calculate the bartender's "launch speed" (ie, the initial sliding speed) for the **high-friction** case (μ_k=0.25).
c) Using the speed you found in b) as the initial sliding speed, analyse the **low-friction** case: find the speed the mug will have when it leaves the bar, and determine whether it lands in the sink (or hits the far wall and shatters, thus making your friend lose his job).
d) [for one extra point] Your bartender friend loves your new system, but the next time you visit him you realize he's still walking over to the sink every time he has a shot glass (a glass that's smaller than a beer mug – it's mass is only 0.125 kg) to put there. Does the mass of the glass matter, or can he launch them at the same speed as the mugs without worry (assume the same coefficients of friction as for the beer mug)?



(sixth question on next page)

6) [8 pts] In the diagram shown, the uniform rod is free to pivot about its base in the plane of the paper. It is motionless and stable at an angle of 30 degrees from the horizontal.The rod has a mass of 4.0 kg and a length of 60.0 cm. The 3.0 kg mass is suspended 40.0 cm from the pivot end of the rod. The wire is anchored 20 cm (vertically) above the pivot point, and is horizontal.

Find the tension F_T in the wire. Hint: consider the different **torques** about the pivot point. The moment of inertia for a rod of mass M and length L, about its end, is 1/3 ML^2.



Happy holidays !