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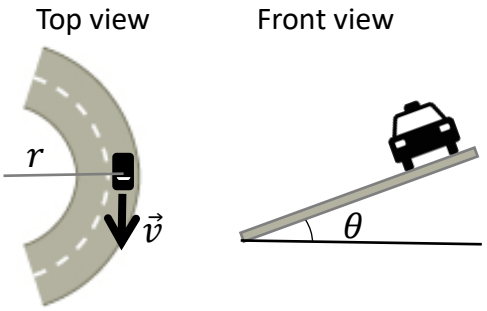
I. [45 pts] Multiple Choice (5 pts each): Mark your answer on BOTH the bubble sheet and this page.

1. [5 pts] You are designing a road that has a radius of curvature of r and is banked at an angle of θ. If cars of up to mass m are permitted on the highway, what is the maximum speed a car could go and still stay in its lane when it hits a patch of frictionless ice?



   A. $\sqrt{rg\tan(\theta)}$

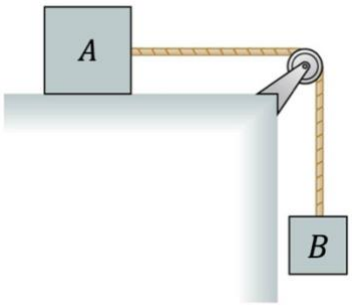
   B. $\sqrt{rg\sin(\theta)}$

   C. $\sqrt{rmg\cos(\theta)}$

   D. $r\sqrt{mg\cos(\theta)}$

   E. Cannot be determined from the information given

2. [5 pts] Block A, with mass m_A, is accelerated across a frictionless table by the falling block B, with mass m_B. The string is massless, and the pulley is both massless and frictionless. Defining the system as only block A, how much work does the tension force do during a time Δt that starts when the blocks are released from rest? (Assume that neither block hits the floor or the pulley during that time.)



   A. 0

   B. $\frac{m_A[g(\Delta t)]^2}{2}$

   C. $\frac{1}{2m_A}[m_B g(\Delta t)]^2$

   D. $\left(\frac{m_A m_B g}{m_A+m_B}\right)(\Delta t)$

   E. $\frac{m_A}{2}\left(\frac{m_B g(\Delta t)}{m_A+m_B}\right)^2$

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3. [5 pts] A 5.0-kg block initially at rest is pulled to the right along a horizontal surface by a constant horizontal force of 18 N. The coefficient of static friction between the block and the surface is 0.16 and the coefficient of kinetic friction between the block and the surface is 0.12. What is the change in thermal energy of the block-floor system after the block has moved 4.0 m?

   A. 24 J

   B. 31 J

   C. 41 J

   D. 48 J

   E. 72 J

4. [5 pts] An elevator has a mass of 2000 kg and is carrying passengers who have a combined mass of 300 kg. A constant friction force of 2100 N acts in opposition to the elevator's motion upward. If the upward force is provided by a motor, how much power delivered by the motor is required to lift the elevator at a constant speed of 2.00 m/s?

   A. 35,000 W

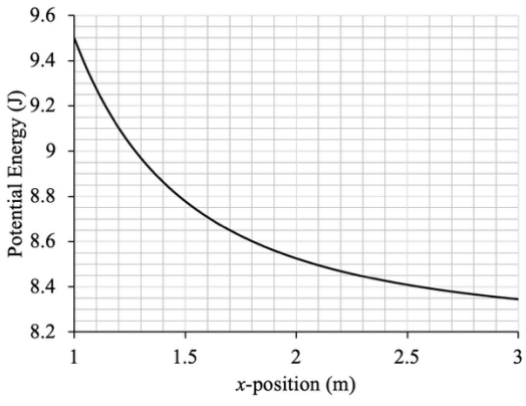
   B. 40,900 W

   C. 43,400 W

   D. 49,300 W

   E. Cannot be determined from the information given

5. [5 pts] A particle is rolling around in a potential well given by $U_G(x) = 1.3x^{-2} + 8.2$, where U is in Joules and x is in meters. The function is also plotted at right for the range $x = 1$ m to $x = 3$ m. What is the force on the particle when it is at position $x = 2.1$ m?



   A. -5.46 N

   B. -0.28 N

   C. 0.28 N

   D. 7.7 N

   E. 8.5 N

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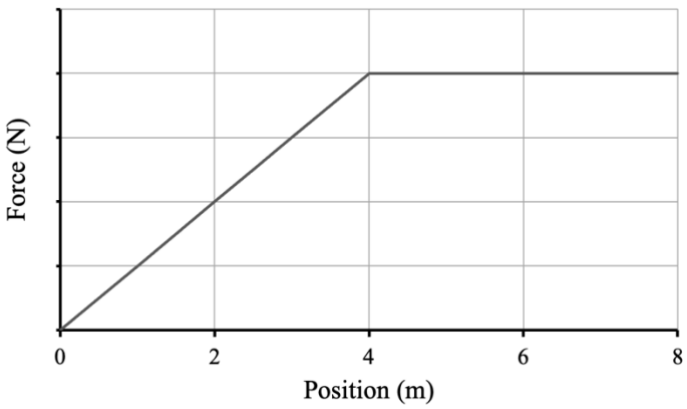
6. [5 pts] The graph at right shows the force applied to an object as the object moves from $x = 0$ m to $x = 8$ m. The force is applied parallel to its displacement and the object is at rest at $x = 0$ m and moves with a speed v at $x = 4$ m. What is the speed of the object at $x = 8$ m? Assume there are no other forces acting on the object.



A. $\frac{3}{2}v$

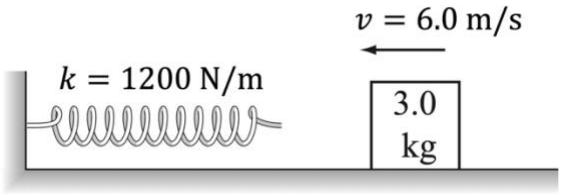
B. $\sqrt{2}v$

C. $\sqrt{3}v$

D. $2v$

E. $4v$

7. [5 pts] A block of mass 3.0 kg is moving across a horizontal, frictionless surface at a speed of 6.0 m/s. It then collides with a spring with spring constant $k = 1200$ N/m. Determine the maximum compression of the spring.



A. 0.12 m

B. 0.21 m

C. 0.30 m

D. 0.55 m

E. 0.81 m

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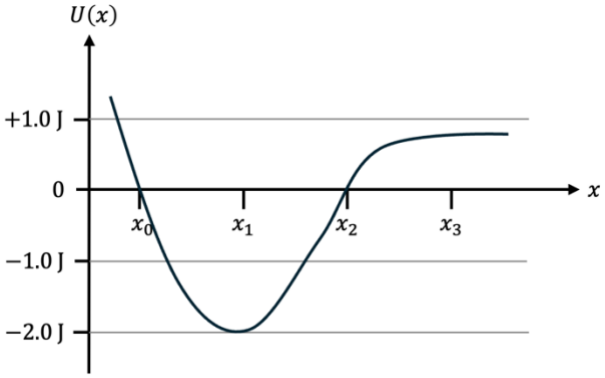
8. [5 pts] A conservative force has the potential energy function $U(x)$, shown in the graph at right. A particle moving in one dimension under the influence of this force has 1.0 J of kinetic energy when it is at position x_1. Which of the following is a correct statement about the motion of the particle?



   A. It oscillates with maximum position x_2 and minimum position x_0.

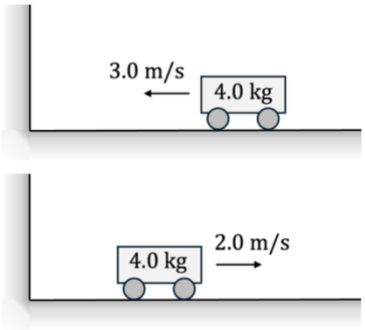
   B. It moves to the right of x_3 and does not return.

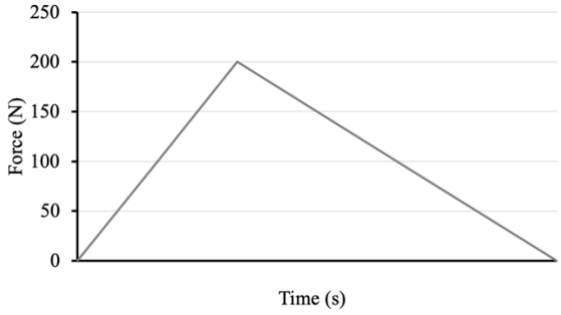
   C. It moves to the left of x_0 and does not return.

   D. It comes to rest at either x_0 or x_2.

   E. It cannot reach either x_0 or x_2.

9. [5 pts] A 4.0-kg cart moves with a speed of 3.0 m/s along a frictionless track toward a wall. After colliding with the wall, the cart moves to the right with a speed of 2.0 m/s. The graph at right shows the force exerted on the cart while it is contact with the wall. How long is the cart in contact with the wall?





   A. 0.02 s

   B. 0.04 s

   C. 0.1 s

   D. 0.2 s

   E. 0.4 s

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II. [15 points total] Lab multiple-choice questions

The situation below applies to the following two questions.

10. [5 pts] A group of students measures the time it takes a coffee filter to fall 1.50 m. They drop the filter three times and calculate the **standard deviation** for the time measurements. (See table.)

Trial	Time (s)
1	1.89
2	2.01
3	1.82
Average time	1.90666
Standard deviation	0.09609

Which one of the following choices represents a correct reporting of the average time and its uncertainty according to the guidelines in the labs?

A. 1 ± 0.1 s

B. 2 ± 0.1 s

C. 1.9 ± 0.09 s

D. 1.9 ± 0.1 s

E. 1.91 ± 0.09 s

11. [5 pts] The students calculate the velocity of the coffee filter from the previous question on a calculator and obtain 0.78671329 m/s. What is the uncertainty in the velocity to one significant figure? Assume that the uncertainty in the distance is small enough that it can be ignored.

A. 0.1 m/s

B. 0.04 m/s

C. 0.05 m/s

D. 0 m/s

E. More information is needed.

12. [5 pts] A group of students conduct Lab A2 in which a ball rolls down a ramp. They release the ball from rest 10 times and record the time at which the ball reaches the mark that is 20 cm from the start.

    They calculate the following:

    - the average time,
    - the maximum deviation of the individual times from the average time, and
    - the standard deviation of the times.

    Which of the following would you expect to be true in general?

    A. The maximum deviation is ***greater than*** the standard deviation.

    B. The maximum deviation is ***equal to*** the standard deviation.

    C. The maximum deviation is ***less than*** the standard deviation.

    D. Not enough information to answer.

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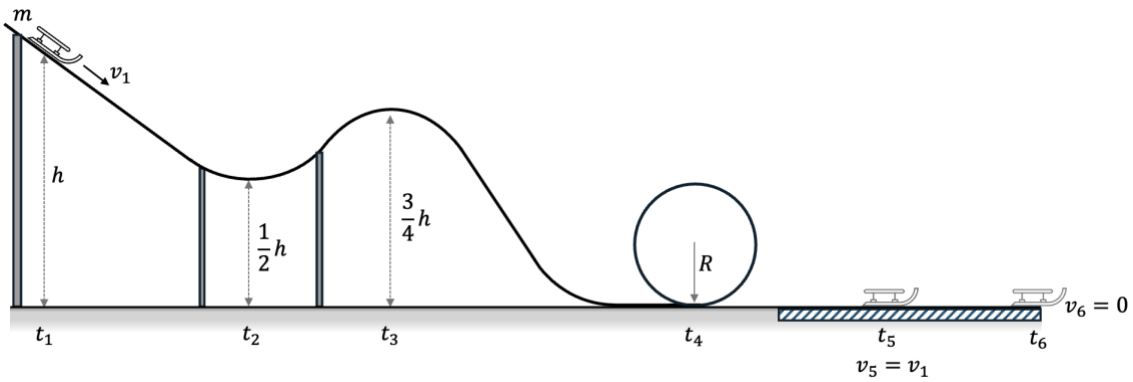
III. Lecture long-answer questions (25 points total)

At t_1, a sled of mass m moves down a frictionless track with an initial speed v_1 as shown below. After descending through a height h, the sled encounters a loop-the-loop. It goes around once and then comes to rest after traversing a rough track that has a coefficient of friction μ_k. We will ask a series of questions about the motion of the sled. Times and other variables are shown in the sketch. Ignore air resistance.

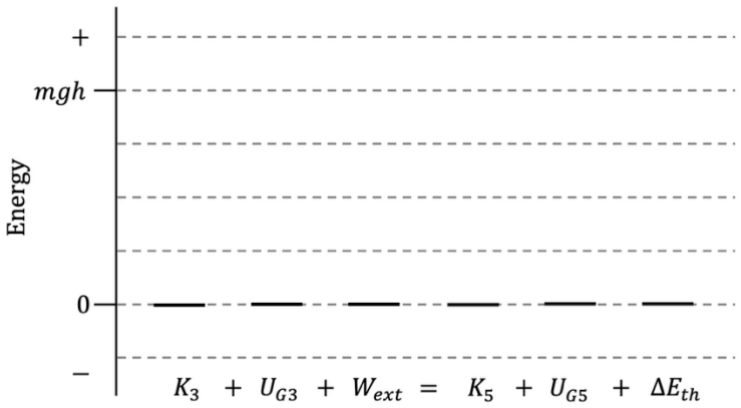


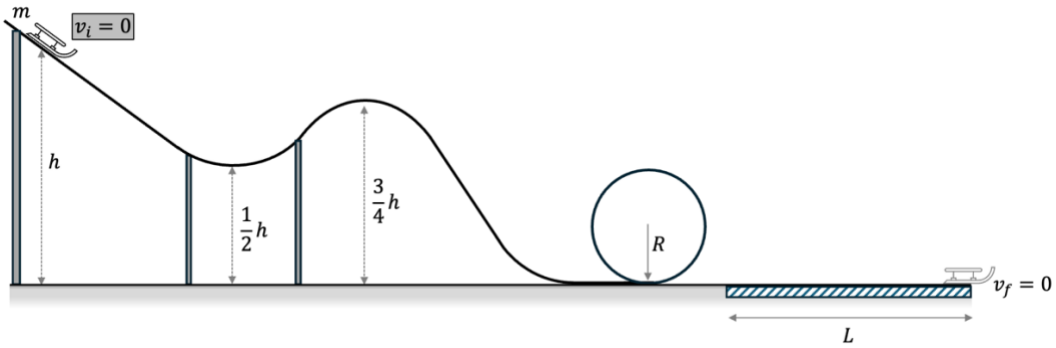
13. [5 pts] In terms of the variables given in the problem and the free-fall acceleration g, what is the speed v_4 of the sled at time t_4, just before it encounters the loop-the-loop? Show your work.

14. [6 pts] Consider a system that includes the sled, the Earth and the track.

    At t_1, assume that the kinetic energy of the sled is **1/4th** of the potential energy of the system at this instant. The potential energy of the system at the ground level is zero.

    Using the template at right, draw an Energy Bar Chart for the sled-Earth-track system for the time interval from t_3 to t_5.





For the next three questions, suppose that the initial velocity (v_i) of the sled is zero as shown above.

15. [5 pts] After passing through the loop-the-loop, the sled slows and stops after traveling a distance L over a rough patch with coefficient of friction μ_k. What is the length L in terms of the other variables in the problem? Show your work.

16. [4 pts] **Note that $v_i = 0$**. The loop-the-loop has a radius R. What is the minimum speed the sled can have at the top of the loop, v_{top}, such that it makes it safely all the way around the loop? Express your answer in terms of the variables given in the problem and the free-fall acceleration g. Show your work.

    Hint: What is the minimum value of the normal force exerted on the sled when it is at the top of the loop?

17. [5 pts] Noting that the sled is initially **at rest**, $v_i = 0$**,** what is the largest value of ***R*** (in terms of ***h*** and other variables) that would keep it on the track and allow it to make the entire loop-the-loop before exiting? Show your work.

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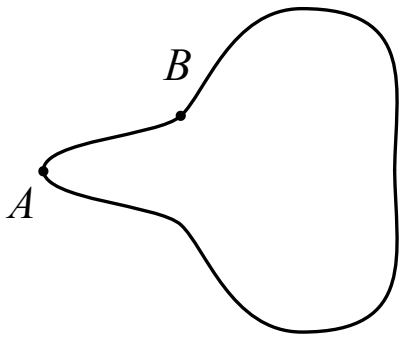
IV. Tutorial and lab long answer questions (15 points total)

18. [6 pts] A car moves clockwise at **constant** speed around the track shown in the top-view diagram at right. Two points, *A* and *B* on the track are marked.

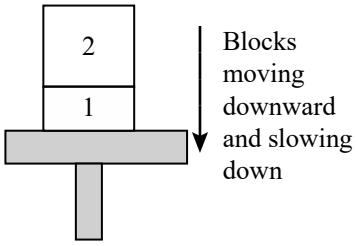


    a. [3 pts] Draw ***velocity*** vectors at each point. Draw them to make clear the relative magnitudes. State explicitly if the magnitudes are the same. Label them v_A and v_B.

    b. [3 pts] Draw ***acceleration*** vectors at each point. Draw them to make clear the relative magnitudes. State explicitly if the magnitudes are the same. Label them a_A and a_B.

Use the following scenario for the next two questions.

Two blocks, 1 and 2 are placed on a platform as shown at right. The mass of block 1 is less than that of block 2. The platform is moving downward and slowing down.



19. [4 pts] Is the magnitude of the **force by the platform on block 1** *greater than, less than,* or *equal to* the **force by block 2 on Block 1**? Explain.

20. [5 pts] While the platform is slowing down, is the total work done on **block 1** *positive, negative,* or *zero?* Explain.