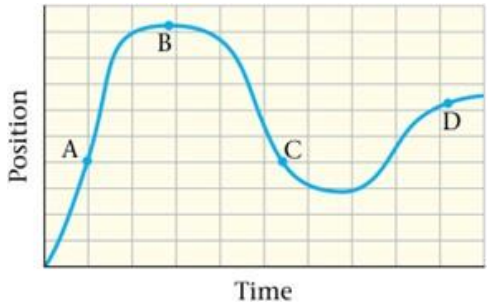
I. [70 points total] 21 Lecture Questions

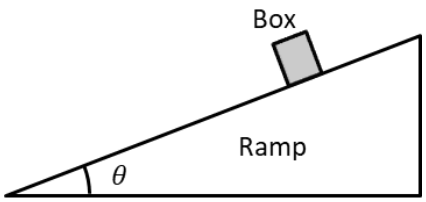
1. [3 points] The figure at right shows a position-versus-time graph. At which lettered point is the object slowing down with a positive acceleration?
   A. Point A
   B. Point B
   C. Point C
   D. Point D
   E. None of the above



2. [3 points] A ball is launched at 25 m/s on level ground at an angle so that it undergoes projectile motion. During the flight of the ball, its minimum speed is 14 m/s. How high above the ground is the ball when it reaches the maximum height in the flight? Neglect air resistance.
   A. 10 m
   B. 18 m
   C. 22 m
   D. 32 m
   E. 44 m

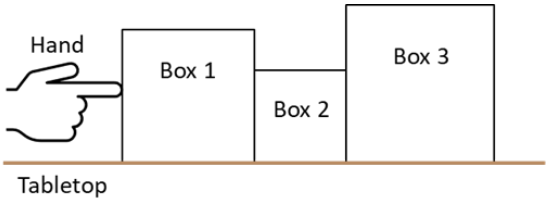
3. [3 points] Susan, driving north at 60 mph, and Trent, driving east at 45 mph, are approaching an intersection. What is Trent's speed in Susan's reference frame?
   A. 15 mph
   B. 40 mph
   C. 75 mph
   D. 110 mph
   E. None of the above

4. [3 points] A 2.5 kg block is stationary on a ramp that is inclined at θ = 26° from horizontal as shown. The coefficient of static friction between the box and the ramp surface is 0.65. What is the magnitude of the static friction force of the ramp on the box?



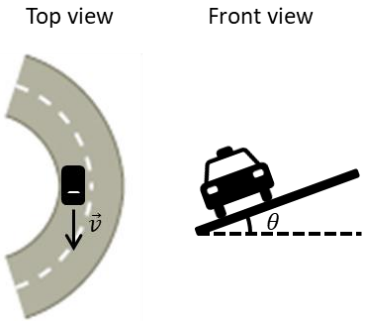
   A. 7.0 N
   B. 11 N
   C. 14 N
   D. 22 N
   E. 25 N

5. [3 points] Three boxes, 1, 2, and 3, are on a frictionless level surface. When a hand exerts a 19-N force to the right on Box 1 as shown, the boxes accelerate. The masses of Boxes 1, 2, and 3 are 2.0 kg, 1.5 kg, and 4.0 kg, respectively. What is the magnitude of the normal force exerted by Box 1 on Box 2?

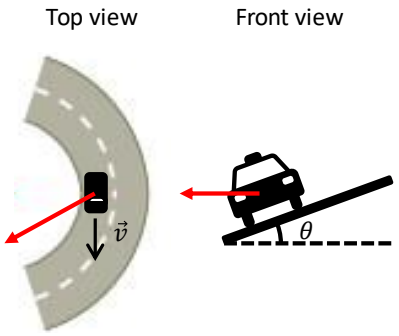


   A. 3.8 N
   B. 6.3 N
   C. 11 N
   D. 14 N
   E. 19 N

6. [3 points] Suppose that a car is going around a banked circular curve while remaining at the same altitude. The figure at right shows the top and front view of the car. The velocity of the car at the instant shown in the top view points toward the bottom of the page, and its magnitude is **increasing**. Which of the choices below best represents the direction of the acceleration of the car in the top and front views?



A.



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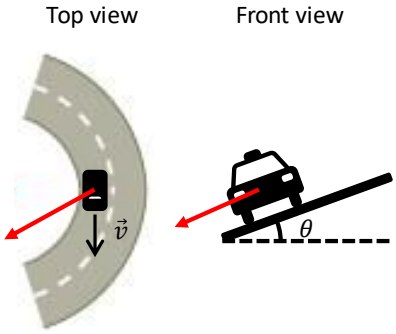

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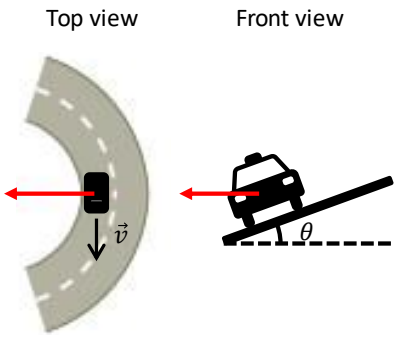
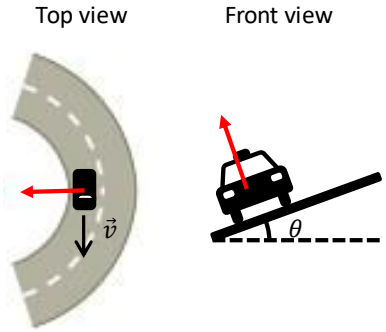
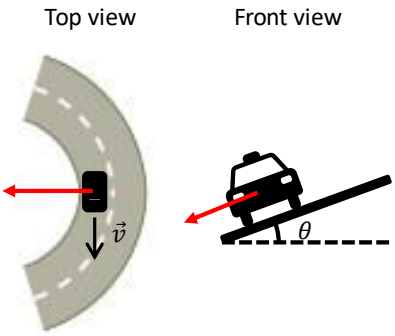


D.



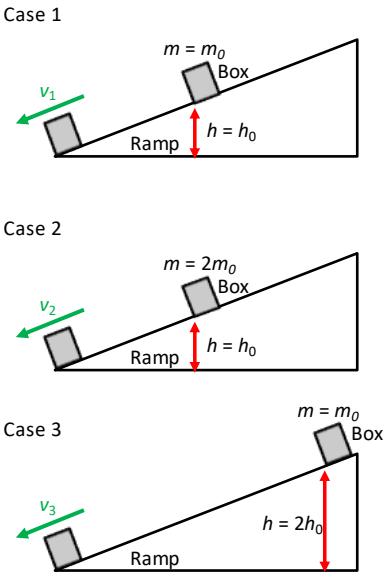
E.



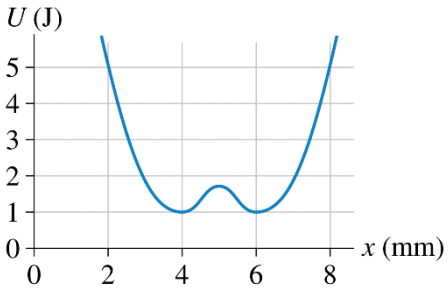
7. [3 points] Suppose that a 2.5-kg box is initially hanging at rest from a rope. Now the rope is pulled upward. When the box is 2.2 m above where it was initially, the box is moving with speed of 1.5 m/s. How much work was done on the box by the force exerted by the rope?
   A. -51 J
   B. 2.8 J
   C. 8.3 J
   D. 54 J
   E. 57 J

8. [3 points] A 52-kg skydiver is falling through the air. At $t = t_0$, she reaches her terminal speed. Between $t = t_0$ and $t = t_1$ ($t_1 > t_0$), 5100 J of thermal energy is created through air drag. How far did she fall between $t = t_0$ and $t = t_1$?
   A. 10 m
   B. 98 m
   C. 110 m
   D. 130 m
   E. 520 m

9. [4 points] In Case 1, a small box with a mass $m = m_0$ is placed at rest on a frictionless ramp at a height $h = h_0$ above the bottom of the ramp. It then slides down and reaches the bottom of the ramp. In Case 2, the scenario is the same as Case 1, except the mass of the box is $m = 2m_0$. In Case 3, the scenario is the same as Case 1, except the initial height is $h = 2h_0$. Rank from largest to smallest the final speeds of the box in these cases, v_1, v_2, and v_3.
   A. $v_1 = v_2 = v_3$
   B. $v_3 > v_1 = v_2$
   C. $v_2 > v_1 = v_3$
   D. $v_1 = v_3 > v_2$
   E. $v_1 = v_2 > v_3$



10. [4 points] The figure shows a potential energy diagram for an object-earth system. The object has a mass of 0.20 kg and oscillates between 2.0 mm and 8.0 mm. What is the maximum speed of the object?



    A. 3.2 m/s
    B. 4.5 m/s
    C. 5.5 m/s
    D. 6.3 m/s
    E. 7.1 m/s

Use the following scenario for the following two questions.

Two gliders, Glider 1 (1.2 kg) and Glider 2 (2.0 kg), are on a frictionless horizontal air track. Glider 1 moves toward Glider 2 with an initial velocity of 3.0 m/s and collides with it. After the collision, they stick together and move with a velocity of 2.6 m/s.

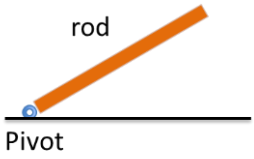
11. [4 points] Was Glider 2 moving before the collision? If so, what is its initial velocity?
    A. No.
    B. Yes. -0.40 m/s
    C. Yes. 5.6 m/s
    D. Yes. 1.8 m/s
    E. Yes. 2.4 m/s

12. [3 points] What is the average acceleration of the Glider 1 during the collision if the duration of the collision is 5.0×10^{-3} seconds?
    A. 96 m/s^2
    B. 2.0×10^{-3} m/s^2
    C. 2.4×10^{-3} m/s^2
    D. 120 m/s^2
    E. 80 m/s^2

13. [4 points] Two uniform thin beams are joined end-to-end as shown to make a single object. The left beam is 12 kg and 1.00 m long, and the right beam is 6.0 kg and 2.00 m long. How far from the left end of the left beam is the center of mass of the object?

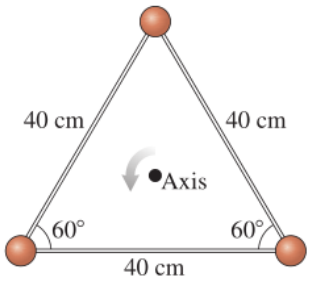
A. 0.38 m
B. 1.0 m
C. 1.3 m
D. 1.5 m
E. 2.4 m

14. [4 points] Suppose that a uniform thin rod of length 0.82 m is pivoted on the floor on one end. Initially it is standing upright. When let go, the rod falls by rotating about the pivot. At some instant during the fall, the tangential acceleration of the free end is g (the acceleration of gravity). What is the angle of the rod measured from the floor at that instant?



A. At any angle as the tangential acceleration of the end is always g.
B. 71°
C. 48°
D. 80°
E. 85°

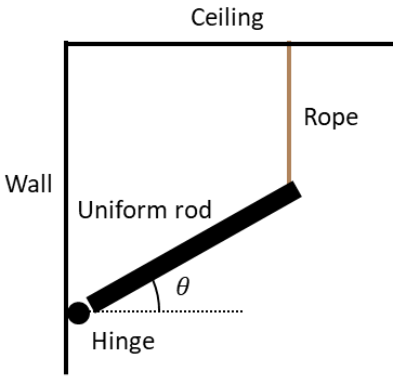
15. [3 points] Three 0.160 kg masses are connected by massless, rigid rods as shown. What is the triangle's moment of inertia about the axis through the center?



A. $2.6 \times 10^{-2}\ \mathrm{kg \cdot m^2}$
B. $7.7 \times 10^{-2}\ \mathrm{kg \cdot m^2}$
C. $1.0 \times 10^{-1}\ \mathrm{kg \cdot m^2}$
D. $3.1 \times 10^{-1}\ \mathrm{kg \cdot m^2}$
E. None of the above

Use the following scenario for the following two questions.

A uniform rod with a hinge on one end is suspended from a vertical rope and remains at rest as shown.

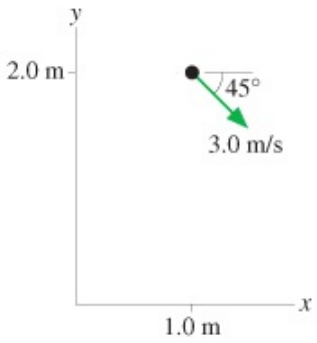


16. [3 points] In which approximate direction is the force by the hinge acting on the rod?

Side view

17. [3 points] If the mass of the uniform rod is 15 kg, what is the tension in the rope?
    A. 7.5 N
    B. 74 N
    C. 88 N
    D. 150 N
    E. Not enough information is given to answer.

18. [3 points] What is the magnitude of the angular momentum relative to the origin of the 0.52-kg particle shown?



A. 0.85 kg m^2/s
B. 2.4 kg m^2/s
C. 2.6 kg m^2/s
D. 3.3 kg m^2/s
E. 3.5 kg m^2/s

19. [4 points] Three identical very dense masses of 4600 kg each are placed on the *x* axis. One mass is at x_1 = -1.10 m, one is at the origin, and one is at x_2 = 3.00 m. What is the magnitude of the net gravitational force on the mass at the origin due to the other two masses?

A. 2.2×10^{-7} N
B. 2.9×10^{-7} N
C. 1.0×10^{-3} N
D. 1.3×10^{-3} N
E. 1.0×10^{-1} N

20. [3 points] A rocket is launched straight up from the Earth's surface at a speed of 16000 m/s. What is its speed when it is very far away from the earth? (Radius of Earth = 6.4×10^6 m, mass of Earth = 6.0×10^{24} kg)
    A. 9.82 km/s
    B. 11.4 km/s
    C. 14.6 km/s
    D. 17.3 km/s
    E. 19.5 km/s

21. [4 points] A GPS satellite orbits Earth at an altitude (distance above the surface of the Earth) of 20.2×10^6 m. How long does it take for the satellite to complete one complete orbit? (Radius of Earth = 6.4×10^6 m, mass of Earth = 6.0×10^{24} kg)
    A. 1.9 hours
    B. 7.9 hours
    C. 12 hours
    D. 24 hours
    E. We need to know the mass of the GPS satellite.

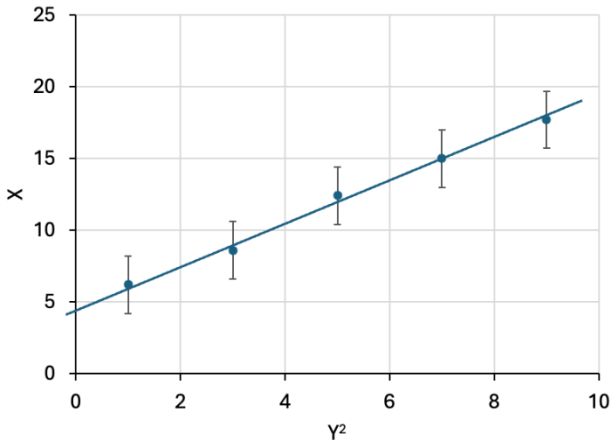
II. [15 points total] 4 Lab Questions

22. [4 points] A group of students has conducted Lab D2 to determine the coefficient of static friction between a shoe and a wooden board. In their experiment, they placed an empty shoe on the board and found that as they lifted the board, the shoe started to move when the board made an angle of 30° with the horizontal. They now place an object of mass 400 g in the shoe and repeat the experiment.

    Which of the following best represents the angle at which the shoe should start to move?

    A. At a larger angle than 30°
    B. At a smaller angle than 30°
    C. At 30°
    D. Not enough information – we need to know the mass of the shoe
    E. Not enough information – we need to know the coefficient of static friction

23. [3 points] A student has drawn a graph of quantity X versus the square of quantity Y (Y^2). They have also drawn a best-fit line on the graph as shown. Which of the following is true?



    A. Quantity X is proportional to quantity Y
    B. Quantity X is proportional to quantity Y^2
    C. Quantity X is linearly related to quantity Y
    D. Quantity X is linearly related to quantity Y^2
    E. Quantity X is linearly related to quantity $\sqrt{Y}$

24. [4 points] A student measured the speed of a cart moving on a level frictionless table and found the square of the cart's speed (v^2) to be $(8.0 \pm 0.4)\ \mathrm{cm}^2/\mathrm{s}^2$. What was the fractional uncertainty in the speed v?

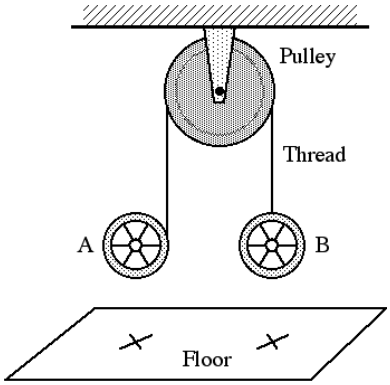
    A. 0.050
    B. 0.025
    C. 0.100
    D. 0.500
    E. 0.075

25. [4 points] A student uses a digital scale to measure the mass of an object. They find the reading on the scale is 14.36 g. How should they report the mass according to the rules developed in the lab?

    A. 14.36 ± 0.01 g
    B. 14.36 ± 0.005 g
    C. 14.360 ± 0.005 g
    D. 14.4 ± 0.1 g
    E. 14 ± 1 g

III. [15 points total] 5 Tutorial Questions

26. [3 points] Two identical spools are held the same height above the floor. A thread is wrapped many times around spool A. The same thread passes over a pulley, and is attached to a fixed point on spool B, so spool B will not rotate. An X is on the floor directly below each spool.



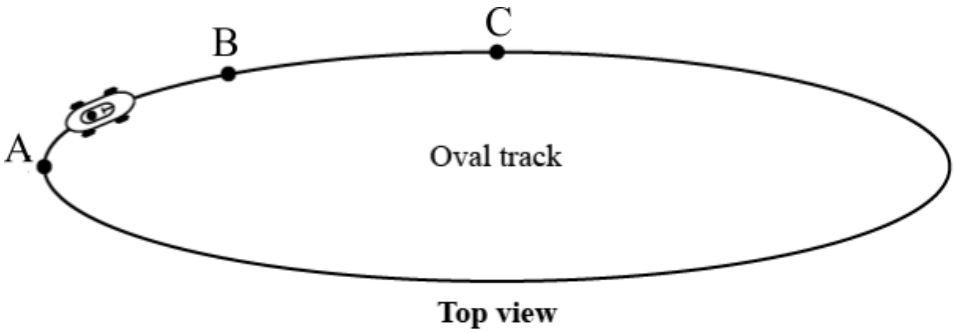
Both spools are released from rest at the same instant.

Assume that the pulley and thread are massless and that the axle of the pulley is frictionless.

Will spool A hit the floor *before, after,* or *at the same instant* as spool B?

A. before
B. after
C. at the same time
D. It depends on how far the spools have fallen

27. [3 points] A car moves clockwise at *constant speed* around the oval track. (Note: This is not a strobe photograph.)



Top view

Let $|\Delta\vec{v}_{AB}|$ be the magnitude of the change in velocity from point A to point B and $|\Delta\vec{v}_{BC}|$ be the magnitude of the change in velocity from point B to point C.

Which of the following best represents the relationship between the magnitudes of the two changes in velocity?

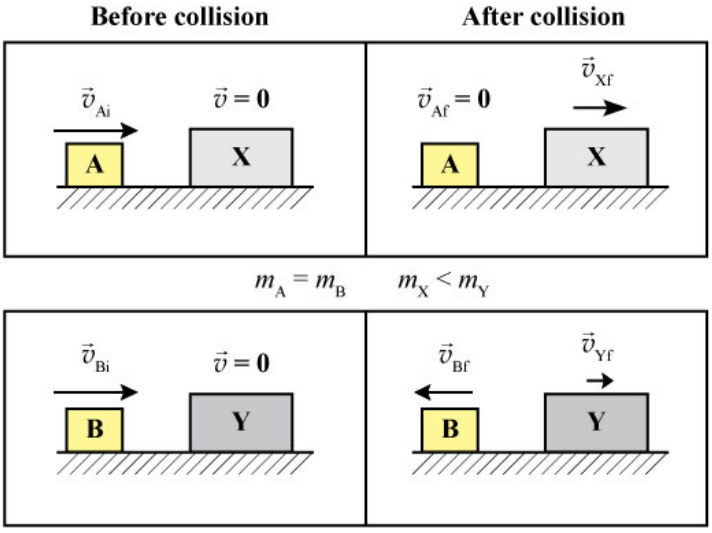
A. $|\Delta\vec{v}_{AB}| > |\Delta\vec{v}_{BC}|$
B. $|\Delta\vec{v}_{AB}| < |\Delta\vec{v}_{BC}|$
C. $|\Delta\vec{v}_{AB}| = |\Delta\vec{v}_{BC}|$
D. It depends on the speed of the car
E. It depends on the size of the track

The next two questions are based on the situation below.

Two experiments are conducted with gliders A and B on a level, frictionless track. Gliders A and B have the same mass and initial velocity. Glider X has less mass than Glider Y (*i.e.*, $m_X < m_Y$). The final speed of glider X is greater than that of glider Y (*i.e.*, $|\vec{v}_{Xf}| > |\vec{v}_{Yf}|$).

Experiment 1:
Glider A moves toward glider X (initially at rest). Afterward, glider A is at rest.

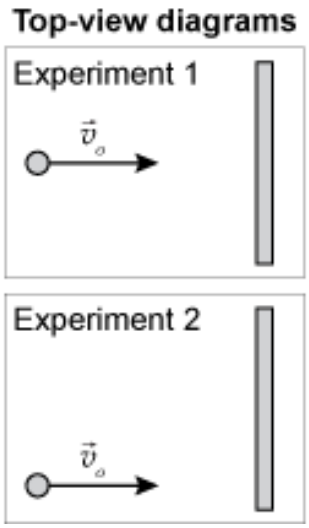
Experiment 2:
Glider B moves toward glider Y (initially at rest). Afterward, glider B has reversed direction.



28. [3 points] Is the magnitude of the *change in momentum* of **glider A** in Experiment 1 *greater than, less than,* or *equal to* the magnitude of the *change in momentum* of **glider B** in Experiment 2?
    A. Greater than
    B. Less than
    C. Equal to
    D. Not enough information to answer.

29. [3 points] Is the magnitude of the final momentum of **glider X** *greater than, less than,* or *equal to* the magnitude of the final momentum of **glider Y**?
    A. Greater than
    B. Less than
    C. Equal to
    D. Not enough information to answer.

30. [3 points] Two experiments are performed with the same puck and rod on a level, frictionless table. In each experiment: the puck moves with initial velocity $\vec{v}_0$ and does not spin; the rod is initially at rest; and the puck sticks to the rod after the collision. The puck and the rod have the same mass.



Experiment 1: the puck moves toward the center of the rod.

Experiment 2: the puck moves toward one end of the rod.

Is the final speed of the center of mass of the system in experiment 1 *greater than*, *less than*, or *equal to* that in experiment 2?

A. greater than
B. less than
C. equal to
D. None of the above