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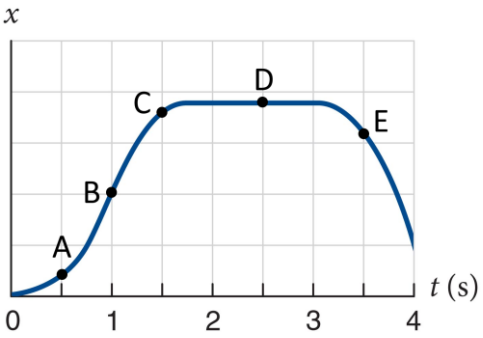
I. [70 points total] 21 Lecture Questions

Use the following scenario for the next 2 questions.

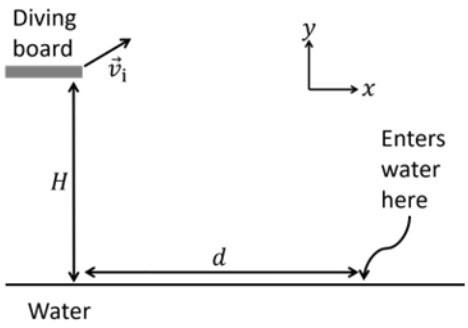
A point-like particle moves along the x-axis, and its position vs. time is shown in the graph at right. Different instants are labeled by letters A through E.



1. [3 points] At which instant is the acceleration of the particle the greatest? Note that a positive number is greater than a negative number. A

2. [3 points] Is the magnitude of the total work done on this point-like particle in the interval between B and D *greater than*, *less than*, or *equal to* the magnitude of the total work done on this particle in the interval between B and E?
   A. Greater than
   B. Less than
   C. Equal to
   D. Not enough information is given.

3. [3 points] A diver jumps from the edge of a platform with an initial velocity of $\vec{v}_{\mathrm{i}} = (2.3\,\hat{\imath} + 1.2\,\hat{\jmath})\ \mathrm{m/s}$. The platform is a height $H = 8.5\ \mathrm{m}$ above the water level. The diver enters the water a horizontal distance of d away from the platform. Neglect air resistance. What is the distance d?
   A. 4.4 m
   B. 2.8 m
   C. 3.0 m
   D. 3.3 m
   E. 16 m



Use the following scenario for the next 2 questions.

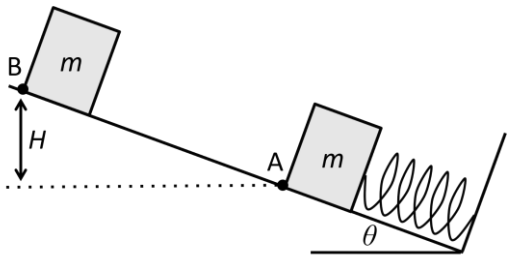
Suppose that a car is initially at rest on a flat circular road of radius 190 m. At $t = 0$ s, the car starts moving with a constant angular acceleration of 1.5×10^{-2} rad/s^2.

4. When does the centripetal acceleration of the car reach 1.2 m/s^2?
   A. $t = 0.59$ s
   B. $t = 0.80$ s
   C. $t = 120$ s
   D. $t = 28$ s
   E. $t = 5.3$ s

5. [3 points] At the moment that the centripetal acceleration of the car is 1.2 m/s^2, what should be the minimum coefficient of static friction between the road and the tires so that the car does not skid?
   A. 0.12
   B. 0.26
   C. 3.1
   D. 0.32
   E. 0.29

Use the following scenario for the next 3 questions.

A box with a mass $m = 2.2\ \text{kg}$ is on an incline that makes an angle $\theta = 28°$ from horizontal. The box is initially held by a hand at rest at position A, compressing an ideal spring with a negligible mass as shown at right. When released, the box rises up to the maximum height at position B, which is a vertical distance $H = 1.3\ \text{m}$ above position A.



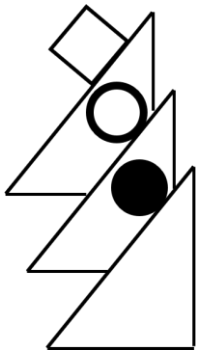
6. [3 points] Suppose that the magnitude of the spring force on the box when the box is held at rest initially is 15 N. What is the magnitude of the force by the hand on the box if it is directed down along the incline? For this part, assume that the incline and the box surfaces have negligible friction.
   A. 4.0 N
   B. 4.9 N
   C. 9.2 N
   D. 15 N
   E. 25 N

7. [3 points] Which of the following items are included in the system if the total energy of the system does not change as the box moves from position A to position B? For this part, assume that the incline and the box surfaces have negligible friction.
   A. Box alone
   B. Box and incline
   C. Box, incline and the Earth
   D. Box, incline, spring, and the Earth
   E. More than one choice above

8. [3 points] How much work does the spring do on the system of the box, the incline, and the Earth as the box moves from position A to position B? For this part, suppose that the incline and the box surfaces are rough with a coefficient of kinetic friction between them of 0.75.
   A. -40 J
   B. -68 J
   C. 68 J
   D. 40 J
   E. Not enough information is given to determine.

9. [4 points] Suppose that the top of a uniform rod with a mass of 1.5 kg leans against a frictionless wall, and the bottom rests on a rough floor with the rod making an angle of 60° with respect to the floor. What is the magnitude of the frictional force on the rod by the floor?
   A. Not enough information is given.
   B. 4.2 N
   C. 8.5 N
   D. 13 N
   E. 25 N

10. [4 points] A block, a hoop and a solid ball each with the same mass are held at the same height on three identically sloped ramps. The block is on a frictionless surface, and the hoop and the ball are on a rough surface with enough friction for the hoop and the ball to roll without slipping. The block, the hoop, and the ball are released. Which object is moving slowest at the bottom of the incline?

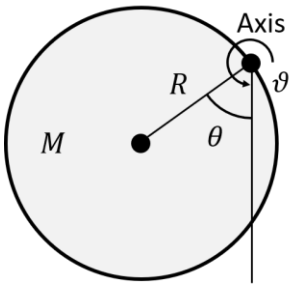


   A. Block
   B. Ball
   C. Hoop
   D. The hoop and the ball are both moving at the same speed which is slower than the block.

Use the following scenario for the next 2 questions.

A disk with a radius $R = 1.2$ m is suspended at its rim by a horizontal axis. The disk can swing about the axis without friction. The front view of the disk is shown at right for an instant when the center of the disk makes an angle $\theta = 52°$ from the vertical with respect to the axis. The moment of inertia of the disk about the axis is 51 kg·m^2.

Front view



11. [4 points] What is the mass of the disk?
    A. 24 kg
    B. 28 kg
    C. 35 kg
    D. 53 kg
    E. 71 kg

12. [3 points] At the instant shown, what is the magnitude of the rotational acceleration of the disk about the axis?
    A. 3.4 rad/s^2
    B. 4.3 rad/s^2
    C. 5.4 rad/s^2
    D. 8.2 rad/s^2
    E. 9.3 rad/s^2

Use the following scenario for the next 2 questions.

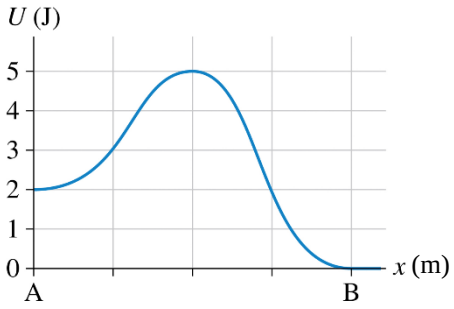
A dwarf planet, Pluto, orbits around the sun in an elliptical orbit. When Pluto is closest to the sun, it is 4.4×10^{12} m away from the sun and moving at 6100 m/s. When Pluto is farthest from the sun, it is 7.4×10^{12} m from the sun. Consider only the interactions between Pluto and the sun, and ignore any other interactions in the universe. The mass of the sun is 2.0×10^{30} kg, and the mass of Pluto is 1.3×10^{22} kg.

13. [4 points] When Pluto is farthest from the sun, what is the speed of Pluto?
    A. 2000 m/s
    B. 3100 m/s
    C. 3600 m/s
    D. 6100 m/s
    E. 10000 m/s

14. [4 points] What is the change in the gravitational potential energy of the sun-Pluto system as Pluto goes from the closest to the sun to the farthest from the sun?
    A. -1.6×10^{29} J
    B. $+1.6 \times 10^{29}$ J
    C. -2.3×10^{29} J
    D. $+2.3 \times 10^{29}$ J
    E. $+3.9 \times 10^{29}$ J

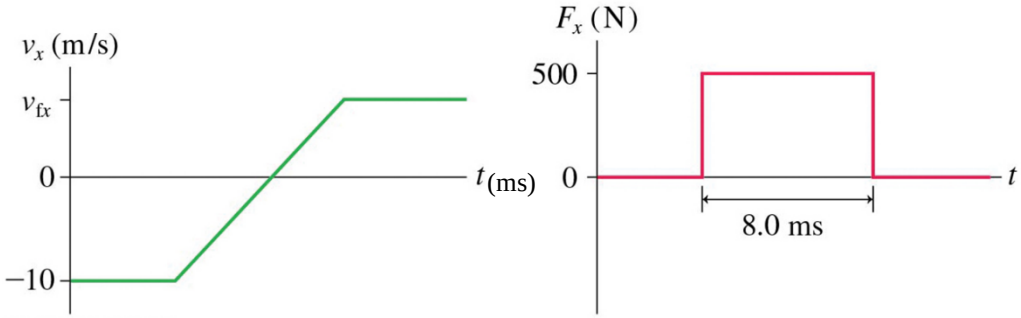
15. [3 points] The water in a river flows downstream at 3.0 m/s relative to the riverbank. A boat is motoring upstream against the flow at 5.0 m/s relative to the water. What is the boat's speed relative to the riverbank?
    A. 8.0 m/s
    B. 6.0 m/s
    C. 5.0 m/s
    D. 3.0 m/s
    E. 2.0 m/s

16. [3 points] The figure shows a potential energy diagram for a particle-earth system. What minimum speed does the particle need to be moving at point A to reach point B? The mass of the particle is 0.20 kg.



    A. 0 m/s
    B. 4.5 m/s
    C. 5.5 m/s
    D. 6.3 m/s
    E. 7.1 m/s

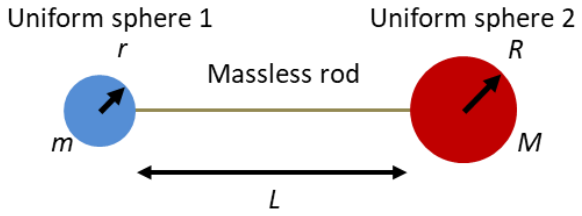
17. [3 points] A 0.25 kg ball collides with a wall. The figure below shows the ball's velocity and the net force exerted on the ball by the wall, both as a function of time. What is v_{fx}, the ball's rebound velocity?



    A. 5.0 m/s
    B. 6.0 m/s
    C. 10 m/s
    D. 16 m/s
    E. 26 m/s

18. [3 points] A 0.30 kg bird flying along at 7.00 m/s sees a 0.015 kg insect heading straight toward it with a speed of 35.0 m/s (as measured by an observer on the ground, not by the bird). The bird opens its mouth wide and enjoys a nice lunch. What is the bird's speed immediately after swallowing? (from practice problems)
    A. 4.2 m/s
    B. 5.0 m/s
    C. 5.3 m/s
    D. 8.3 m/s
    E. 8.8 m/s

19. [4 points] A massless rod of length L = 0.80 m is attached to two uniform spheres 1 and 2 as shown. Sphere 1 has a mass of m = 2.5 kg and a radius of r = 0.15 m, and sphere 2 has a mass of M = 4.5 kg and a radius of R = 0.20 m. How far **from the left side of sphere 1** is the center of gravity of the combination of these objects?



    A. 0.18 m
    B. 0.51 m
    C. 0.70 m
    D. 0.79 m
    E. 0.89 m

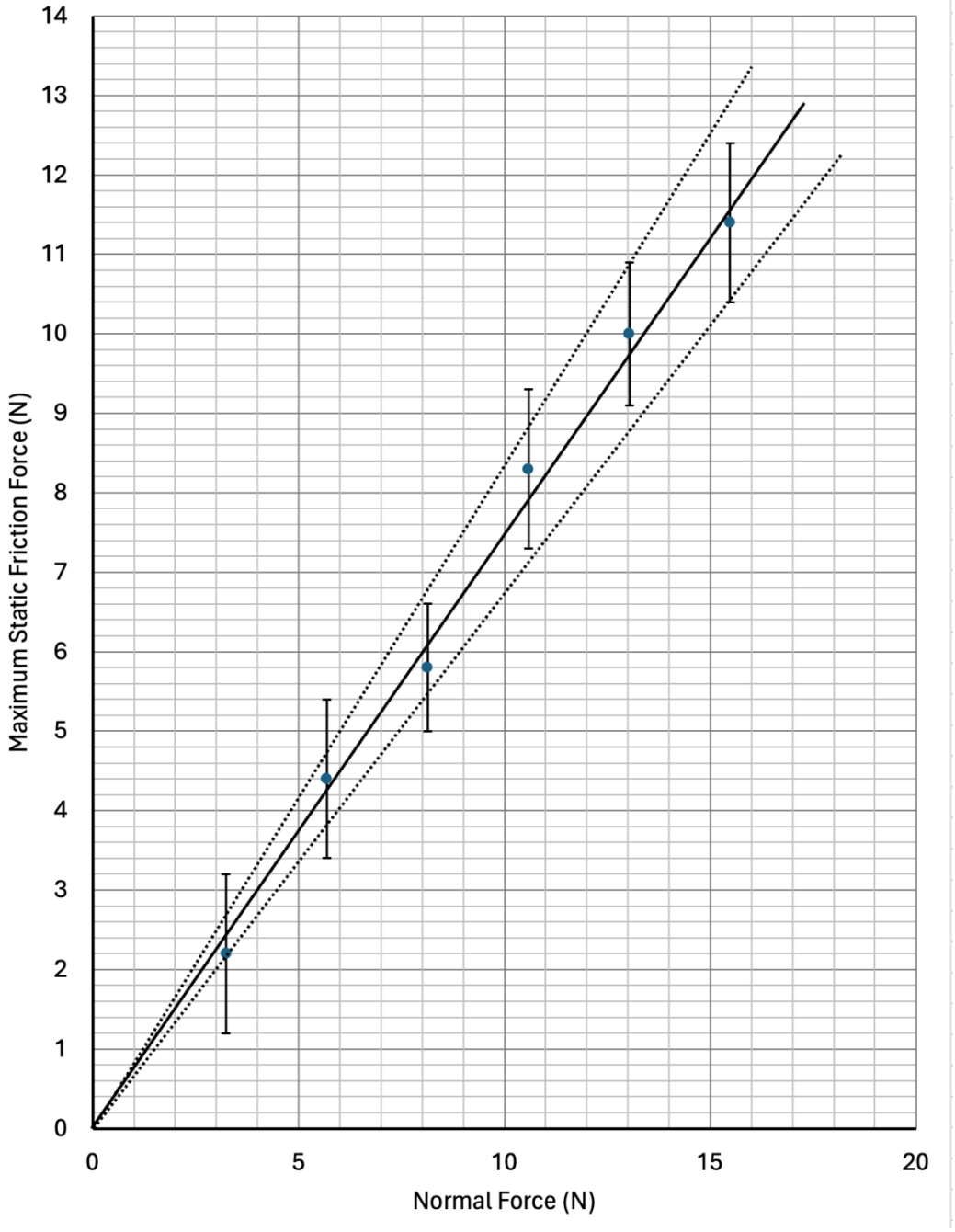
20. [3 points] Planet Z is 8000 km in diameter. The free-fall acceleration on Planet Z is 10 m/s^2. What is the mass of Planet Z? (From practice problems)
    A. 6.0×10^{23} kg
    B. 1.2×10^{24} kg
    C. 2.4×10^{24} kg
    D. 4.8×10^{24} kg
    E. 9.6×10^{24} kg

21. [4 points] The asteroid belt circles the sun between the orbits of Mars and Jupiter. One asteroid has a period of 6.4 earth years. What is the asteroid's orbital radius? Note that the earth is 1.5×10^{11} m from the sun.
    A. 9.3×10^{9} m
    B. 4.5×10^{10} m
    C. 5.2×10^{11} m
    D. 8.3×10^{11} m
    E. 2.4×10^{12} m

II. [15 points total] 4 Lab Questions

22. [4 points] A group of students have conducted Lab D1 to determine the coefficient of static friction between a shoe and a wooden board. They form the graph below. Which value below best shows what they could report for the coefficient of static friction?

A.	B.	C.	D.	E.
0.75 ± 0.09	0.8 ± 0.2	0.92 ± 0.06	1.1 ± 0.8	1 ± 1



23. [3 points] A student made a graph of quantity X versus Y^2 (the square of quantity Y) and is able to draw a best-fit line on the graph through the origin. Which of the following **best** represents the relationship shown by the best fit line? (Choose one answer only.)
    A. Quantity X proportional to quantity Y
    B. Quantity X is proportional to quantity Y^2
    C. Quantity X is linearly related to quantity Y but not proportional to quantity Y
    D. Quantity X is linearly related but not proportional to quantity Y^2
    E. Quantity X is linearly related to quantity $\sqrt{Y}$

24. [4 points] A group of students has measured the speed of a cart (v) moving across a horizontal table to be $4.1\ \mathrm{cm/s} \pm 0.6\ \mathrm{cm/s}$. They need to determine the square of the cart's speed (v^2). Which of the following quantities correctly reports the magnitude of the square of the cart's speed?
    A. $(6.81 \pm 4.92)\ \mathrm{cm^2/s^2}$
    B. $(16.8 \pm 4.92)\ \mathrm{cm^2/s^2}$
    C. $(16.8 \pm 4.9)\ \mathrm{cm^2/s^2}$
    D. $(17 \pm 2)\ \mathrm{cm^2/s^2}$
    E. $(7 \pm 5)\ \mathrm{cm^2/s^2}$

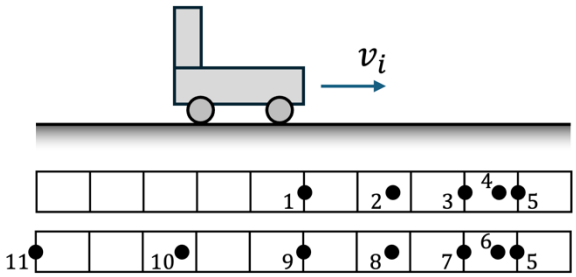
25. [4 points] A group of students conduct the experiment in Lab D1 and plot a graph of the maximum static friction force vs normal force for their shoe. They find the best fit line passes through the origin for their data. The slope of their line is 0.4.

    They notice that the maximum static frictional force for the shoe alone is 1.5 N. Suppose the students were to put a 3.0 N object into the shoe. What would be the best guess for the approximate maximum static friction force for the shoe-object system?

    A. 1.6 N
    B. 2.7 N
    C. 3.0 N
    D. 31.5 N
    E. One needs to know the mass of the shoe in order to answer

III. [15 points total] 5 Tutorial Questions

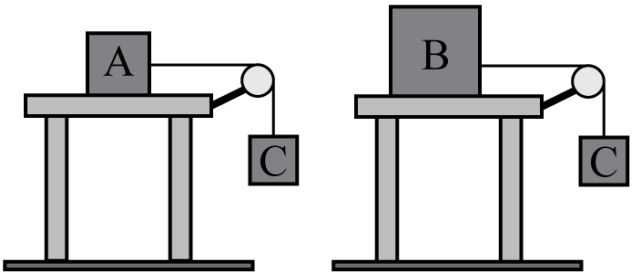
26. [3 points] A cart with a fan is given a push to the right on a horizontal table. The fan blows air, so the cart slows down and turns around. The motion diagram at right shows the position of the cart at instants separated by equal time intervals.



Compare the magnitude of the cart's average velocity between t_1 and t_3 and between t_1 and t_7.

A. $|\vec{v}_{\text{ave }1,3}|$ is greater than $|\vec{v}_{\text{ave }1,7}|$
B. $|\vec{v}_{\text{ave }1,3}|$ is less than $|\vec{v}_{\text{ave }1,7}|$
C. $|\vec{v}_{\text{ave }1,3}|$ is equal to $|\vec{v}_{\text{ave }1,7}|$
D. Not enough information to answer

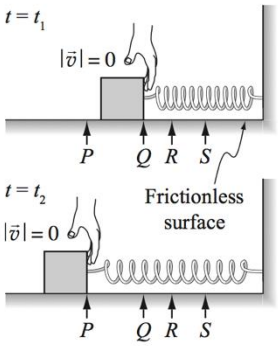
27. [3 points] Block A and block B with different masses ($m_A < m_B$) are each on a rough, horizontal surface. Each is attached to identical blocks C by an inextensible, massless string. The string passes over an ideal (massless, frictionless) pulley. *All blocks remain at rest*.



Is the magnitude of the friction force on block A *greater than, less than* or *equal to* magnitude of the friction force on block B?

A. Greater than
B. Less than
C. Equal to
D. We need to know the coefficient of static friction in each case.
E. We need to know both the coefficient of static and kinetic friction in each case.

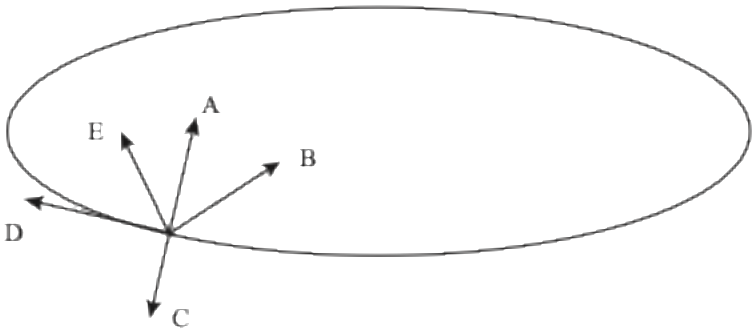
28. [3 points] A block is connected to a spring, as shown. At time t_1, the block is at point *Q*, and the spring is at its equilibrium length. The block is pushed to the left, stretching the spring. At time t_2, the block is at point *P*. The block begins and ends at rest.



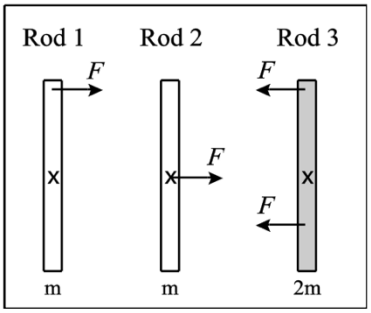
Over the interval from t_1 to t_2, is the absolute value of the work on the block by the hand *greater than, less than,* or *equal to* the absolute value of the work on the block by the spring?

A. Greater than
B. Less than
C. Equal to
D. Not enough information to answer.

29. [3 points] An object moves **clockwise** with increasing speed around an oval track as shown. Which of the arrows (A to E) best represents the acceleration of the object at the point indicated on the diagram? [Answer: E]



30. [3 points] Three uniform rods are at rest on a flat, frictionless surface. Rods 1 and 2 have mass *m* and rod 3 has mass 2*m*. Forces of equal magnitude (*F*) are applied at different points on the rods, as shown. The center of mass of each rod is indicated by an '×'.



After a very short time interval, Δt, which of the following represents the ranking of the **final translational kinetic energies** of the rods?

A. $K_{trans,1} = K_{trans,2} = K_{trans,3}$
B. $\boldsymbol{K_{trans,3} > K_{trans,1} = K_{trans,2}}$
C. $K_{trans,3} > K_{trans,2} > K_{trans,1}$
D. $K_{trans,1} > K_{trans,2} = K_{trans,3}$
E. None of the above.