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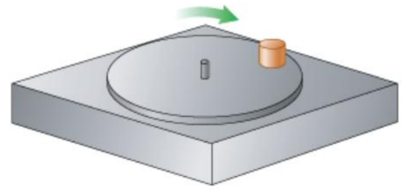
I. [45 points total] Lecture multiple-choice questions

1. [5 points] A cylinder sits on a circular turntable that is rotating at a constant speed as shown at right. The coefficient of static friction between the cylinder and the turntable is 0.080, and the cylinder is located 0.15 m from the center of the turntable. What is the maximum speed that the cylinder can move along its circular path without slipping off the turntable?



   A. 0.12 m/s
   B. 0.34 m/s
   C. 2.3 m/s
   D. 5.2 m/s
   E. We need to know the mass of the cylinder to answer.

2. [5 points] An ice skater is pulled by a horizontal rope in the negative x-direction across the ice, and there is negligible friction between the skates and the ice. Which of the following quantities could possibly be the work done by the rope on the skater, W_{rope}, the displacement of the skater $\Delta\vec{x}$, and the tension exerted by the rope on the skater, $\vec{T}_{\text{rs}}$, in this motion?
   A. W_{rope} = – 120 J, $\Delta\vec{x}$ = –2 m $\hat{\imath}$, $\vec{T}_{\text{rs}}$ = + 60 N $\hat{\imath}$
   B. W_{rope} = + 120 J, $\Delta\vec{x}$ = –2 m $\hat{\imath}$, $\vec{T}_{\text{rs}}$ = – 60 N $\hat{\imath}$
   C. W_{rope} = – 120 J, $\Delta\vec{x}$ = –2 m $\hat{\imath}$, $\vec{T}_{\text{rs}}$ = – 60 N $\hat{\imath}$
   D. W_{rope} = + 120 J, $\Delta\vec{x}$ = +2 m $\hat{\imath}$, $\vec{T}_{\text{rs}}$ = – 60 N $\hat{\imath}$
   E. W_{rope} = – 120 J, $\Delta\vec{x}$ = +2 m $\hat{\imath}$, $\vec{T}_{\text{rs}}$ = + 60 N $\hat{\imath}$

3. [5 points] A small 1000 kg airplane's engine supplies 2.0 kN of thrust. Starting from rest, it reaches a take-off speed of 40 m/s in a distance of 600 m. What is the increase of thermal energy of the plane and runway system due to friction and drag?
   A. -400,000 J
   B. 0 J
   C. 400,000 J
   D. 800,000 J
   E. 1,200,000 J

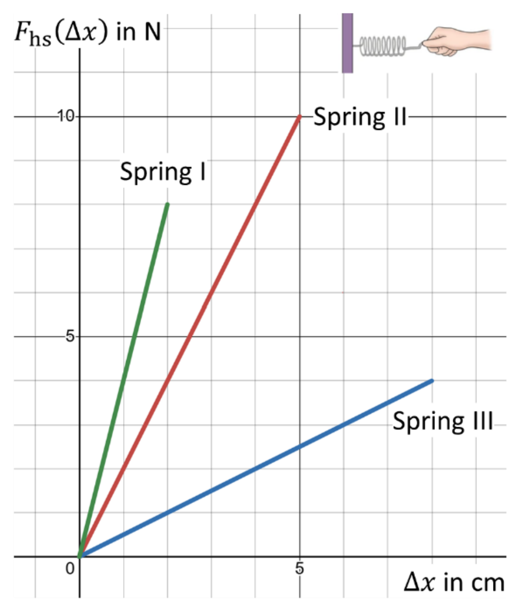
4. [5 points] A running coach is reviewing video from various races in order to make comparisons between her runners. She's compiled the data shown and would like to rank the runners based on the average power exerted in the given time intervals. Which of the following is the correct ranking from MOST to LEAST average power exerted?

Runner	Mass (kg)	Δx (m)	initial speed (m/s)	final speed (m/s)	time interval (s)
P	70	8.25	4	7	1.5
R	70	10.0	0	8	2.5
S	80	17.5	5	9	2.5

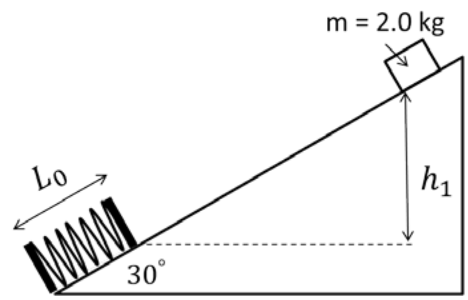
A. S > P > R
B. R = S > P
C. R > S > P
D. S > P = R
E. P > S = R

5. [5 points] Consider three different springs: I, II, and III. For each spring one end is attached to a wall, and you pull the other end to a maximum spring displacement. The graph shows your pulling force, F_{hs}, versus the spring displacement, Δx, for each spring. Rank the spring constants from the smallest to the largest.

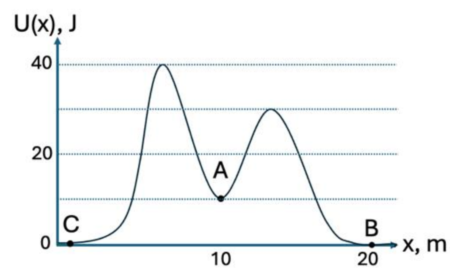
A. $k_{\mathrm{III}} < k_{\mathrm{II}} < k_{\mathrm{I}}$
B. $k_{\mathrm{I}} < k_{\mathrm{II}} < k_{\mathrm{III}}$
C. $k_{\mathrm{II}} < k_{\mathrm{I}} < k_{\mathrm{III}}$
D. $k_{\mathrm{III}} < k_{\mathrm{I}} < k_{\mathrm{II}}$
E. $k_{\mathrm{I}} < k_{\mathrm{III}} < k_{\mathrm{II}}$



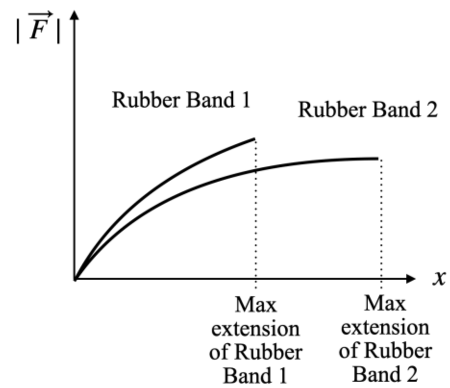
6. [5 points] A block of mass 2.0 kg is released from rest on a frictionless incline at a height h_1 of 1.0 m from the top of a spring. The incline angle is 30.0°. The spring is initially at its equilibrium length L_0 = 0.20 m and has a spring constant k = 2000 N/m. At the instant when the spring is compressed by d = 0.13 m, what is the speed of the block?
   A. 0 m/s
   B. 1.6 m/s
   C. 2.0 m/s
   D. 2.3 m/s
   E. Not enough information



7. [5 points] The graph at right shows the potential energy as a function of the position of a 1.0 kg particle. What is the speed needed for a particle starting at B to reach point A but not point C?
   A. 4.5 m/s < v, no maximum speed
   B. 7.7 m/s < v, no maximum speed
   C. 4.5 m/s < v < 7.7 m/s
   D. 4.5 m/s < v < 8.9 m/s
   E. 7.7 m/s < v < 8.9 m/s



8. [5 points] Consider two rubber bands, 1 and 2. One end of each rubber band is held in place, and the other end is stretched from its equilibrium position by a hand, and the hand force necessary to stretch it is measured. There is no energy dissipation in the system.



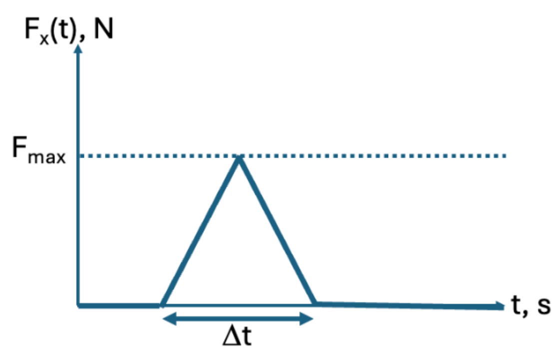
A graph of the hand force as a function of the displacement of the rubber band ends is shown at right.

How does the increase in potential energies of the two rubber bands compare when they are completely stretched?

A. $\Delta U_1 < \Delta U_2$
B. $\Delta U_1 > \Delta U_2$
C. $\Delta U_1 = \Delta U_2$
D. We need to know how the spring constants of the rubber bands compare.

9. [5 points] A ball of mass *m* hits a wall and rebounds with the same speed *v*. The figure below shows the force of the wall on the ball during the collision. What is the value of F_{max}?

A. $\frac{1}{2}\frac{mv}{\Delta t}$
B. $\frac{mv}{\Delta t}$
C. $2\frac{mv}{\Delta t}$
D. $4\frac{mv}{\Delta t}$
E. $8\frac{mv}{\Delta t}$



II. [15 points total] Lab multiple-choice questions
Answer the following three questions based on the methods developed in the labs. For calculating uncertainty, use standard deviation.

10. [5 points] A group of students have measured the following four times for a coffee filter to fall through 1.5000 m. The students have also estimated an uncertainty of ± 0.0005 m in their distance measurement of 1.5000 m.

Trial	Time (seconds)
1	1.15
2	1.23
3	1.16
4	1.20

What is the fractional uncertainty in the speed?

A. 0.025
B. 0.028
C. 0.031
D. 0.035
E. 0.041

11. [5 points] A different group of students have determined that for a particular mass of their coffee filter, their average time is 1.21 s with a fractional uncertainty of 0.024. What was their standard deviation (in seconds)?

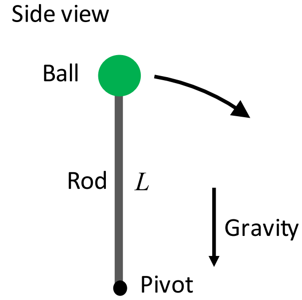
A. 0.02 s
B. 0.20 s
C. 0.03 s
D. 0.30 s
E. 0.06 s

12. [5 points] Suppose you had to calculate a value *D*, where *D* = *E*/*F*. The value *E* is given as 31.9 cm ± 4.1 cm, and the value *F* is given as 9.52 s ± 0.12 s. Which one of the following is how you could report the value of D based on the guidelines introduced in the lab?

A. 3.35 cm/s ± 0.43 cm/s
B. 3.351 cm/s ± 0.431 cm/s
C. 3.4 cm/s ± 0.431 cm/s
D. 3.4 cm/s ± 0.2 cm/s
E. 3.35 cm/s ± 0.29 cm/s

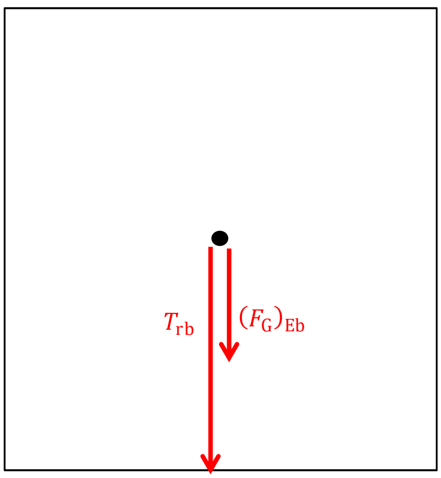
III. [25 points total] Lecture free response questions
You must show your work to get the full credit.

Consider the following scenario for the next two questions.
A small ball with mass m is attached to one end of a rod. The other end of the rod is pivoted such that the rod rotates freely, and the ball undergoes circular motion. At the moment the ball is the top of the path as shown, the rod exerts a force on the ball with a magnitude $2mg$, where g is the free-fall acceleration.



13. [4 points] In the box below, draw a free-body diagram for the ball at the moment shown. Make sure to label each force indicating the type of the force, the object exerting the force, and the object on which the force acts.

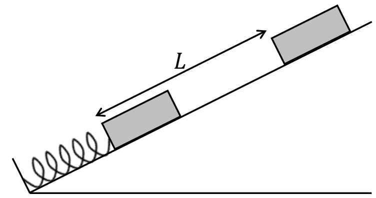
FBD of the ball



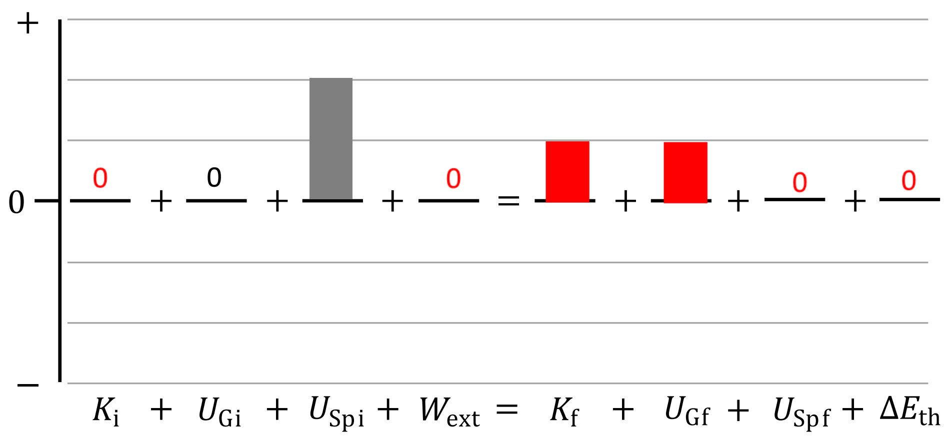
[1 point] Identifying force by the rod on the ball (It is tension, but if it's a "general force", that's OK)
[2 points] The direction of the force by the rod on the ball is downward
[1 point] identifying gravitational force
[-1 point] for each incorrect force

14. [5 points] What is the expression for the speed of the ball at the moment shown in terms of the variables given in the problem?
Newton's 2nd law in the vertical direction: $F_{\text{net}\,r} = T_{sb} + mg = 3mg = ma.$
The ball is in a circular motion, so it has centripetal acceleration: $a = \frac{v^2}{L}$
$3mg = m\frac{v^2}{L}$, or $v = \sqrt{3Lg}$
[2 points] correct answer
[1 point] Applying Newton's 2nd law in the vertical direction
[1 point] the acceleration is the centripetal acceleration
[1 point] Centripetal acceleration is of the form $\frac{v^2}{L}$

Use the following scenario for the next two questions.
A tilted track has a spring at the base. A glider on the track slides with negligible friction. The glider is initially at rest and pushed against the spring compressing it by a distance d. Then the glider is let go and travels a distance L up the incline when it reaches the maximum height. Note that $d \ll L$.

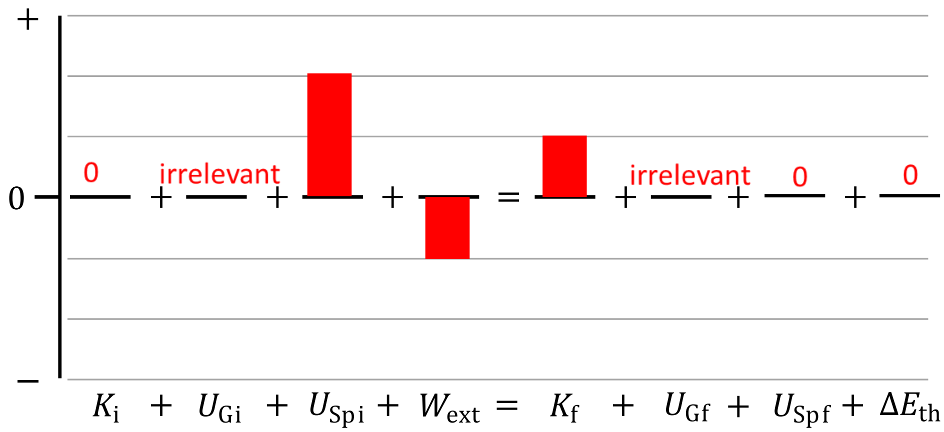


15. [6 points] Consider a system containing the glider, the spring, and the earth. The figure below is an incomplete energy bar chart for the system from the time the glider is released until it has traveled $\frac{L}{2}$ (halfway to the maximum height). Complete the chart. Make sure to draw it to the correct relative scale. If the quantity is zero, indicate so explicitly.



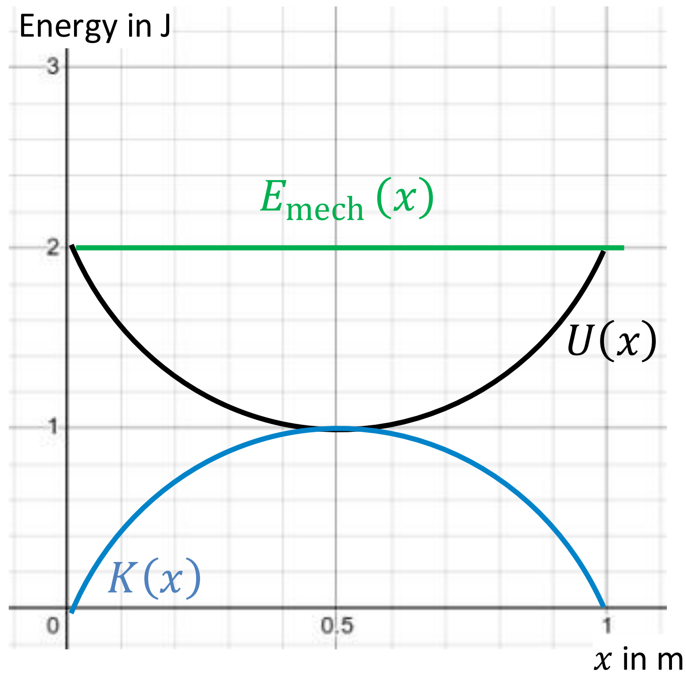
[1 point] Initial kinetic energy is zero.
[1 point] external work is zero.
[1 point] final kinetic energy is 1 unit high.
[1 point] final gravitational potential energy is 1 unit high.
[1 point] final elastic potential energy is zero.
[1 point] change in thermal energy is zero.

16. [6 points] Consider another system containing just the glider and the spring. Complete the chart for the same time interval. Make sure to draw it to the correct relative scale compared to the chart in Q15. If the quantity is zero or irrelevant, indicate so explicitly.



[0.5 points each] K_i and K_f are the same height as it is in Q15.
[1 point each] U_Gi and U_Gf are both irrelevant or zero.
[0.5 points each] U_Sp1 and U_Spf are the same height as Q15
[0.5 points] Delta E_th = 0 or the same as Q15
[1.5 points] W_ext = K_f - U_Spi.

17. [4 points] A small particle near the bottom of a U-shaped track is sliding back and forth between $x = 0$ m and $x = 1$ m without any resistive force acting on it. The graph below shows the gravitational potential energy versus x of the particle for a system that consists of the particle and the earth. In the graph below add the following graphs and label them clearly.
    A. Kinetic energy of the system versus x, $K(x)$
    B. Total mechanical energy of the system versus x, $E_{\text{mech}}(x)$



[1 point] Correct $K(x)$ shape

[1 point] $E_{\text{mech}}(x)$ is a horizontal line

[1 point] $E_{\text{mech}}(x)$ is the sum of K + U.

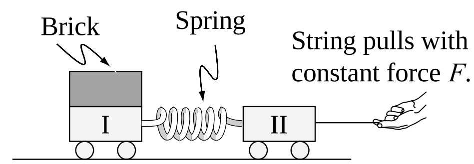
[1 point] $E_{\text{mech}}(x) = 2\text{J}$

IV. [15 points total] Tutorial free response questions (All three questions in this section are independent of one another.)

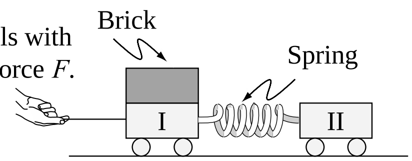
18. [5 points] Two identical carts are connected by a spring. On top of Cart I is a brick with mass equal to that of each cart.

In case A, the carts are pulled by a string to the right. In case B, the string pulls to the left, as shown. In each case, the string exerts a constant force of magnitude *F*.

Case A



Case B

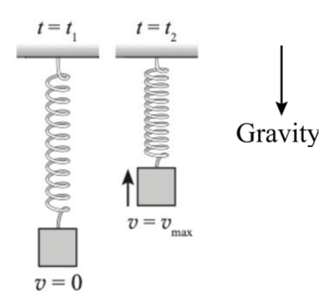


In which case is the spring length greater? Explain. (Assume the carts have been pulled for a long time so the spring is not oscillating. Ignore friction and the spring mass.)

The entire system has the same net force in both cases, so the accelerations are equal. The spring force is the net force on the cart I/brick system in case A. The spring force is the net force on cart II in case B. The mass of the cart I/brick system is greater, so the spring force is greater in case A and so the stretch is greater.

+ 2 pts correct answer (longer in case A)
+1 pt accelerations are equal
+ 2 pts spring force equal to net force on I in case A and on II in case B

19. [5 points] A block hangs from a spring as shown. At t_1 the string is stretched, and the block is at rest. At t_2 the block is moving upward. Let system S_1 consist of the block alone. Neglect air resistance.

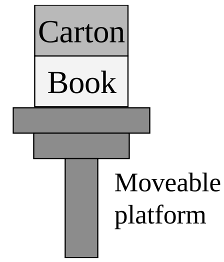


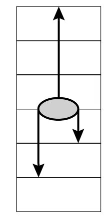
For the interval $\Delta t = t_2 - t_1$, is $W_{\text{net ext}}$, the net work done by external forces on system S_1 *positive, negative,* or *zero?* Explain.

The block alone has no potential energy, and the internal energy is unchanged in this process. Thus, the work done on S_1 is equal to the change in its kinetic energy. Since ΔK is positive, the next external work must be positive.

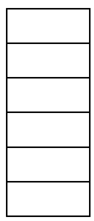
+ 2 pts correct answer (net work is positive)
+1 pt system of block alone has no potential energy
+1 pt ΔK block is positive
+1 pts Wnet ext = ΔK

20. [5 points] Two objects, a book and a carton are on a platform that can move upward or downward. The motion is not given, but the diagram at far right shows the relative magnitudes and directions of all the forces on one of the two objects (either the book or the carton).





In the space below, sketch a **possible** free-body diagram for the other object. (More than one diagram may be possible, but you need only sketch one.) **An explanation is not required** but draw your forces to the same scale as in the diagram above and label the forces to indicate the object exerting the force and the object on which the force is exerted.



Solution: The given diagram shows $F_{net} = 0$, so $a = 0$. The diagram must be for the book, since the carton has only two forces on it. On the given diagram, one downward force is the gravitational force on the book; the other is the normal force by the carton. So, the normal force by the book on the carton is either 1 or 2 units upward. Thus, the carton has an upward normal force on it by the book that is two units in length or one unit. The carton thus has a downward gravitational force on it by the Earth that is two (or one) unit in length.

+2 pts correct number of forces (2)
+1 pt both forces have same magnitude
+1 pt correct magnitudes of forces
+1 pt for each force correctly labeled