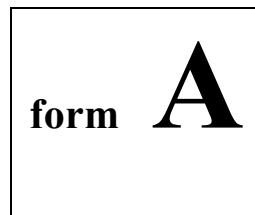


Physics 2211M
Summer 2018
Test 3



Instructions:

- 1) Please use **dark-colored ink** or **heavy pencil strokes**; this test will be scanned and graded electronically, and it is important for your work to be legible on the scanned page.
- 2) **DO NOT ERASE** any of your work and overwrite it with new work—this will interfere with the legibility of your scanned test. Please draw a line through invalid work that you wish us to disregard.
- 3) Do not include any loose scratch work on a separate page along with your test—extra pages are not scanable. If you need additional workspace, please use the provided blank space on pages 2 or 9. Be sure to point out, on the main problem, when you have additional work on the scratch page(s).
- 4) For each free response question, show all work necessary to support your answer. Clearly indicate your final answer by underlining it, or boxing it in.
- 5) For each multiple-choice question, select the answer most nearly correct, **circle this answer on your test**, and bubble it in on your answer card. **Show all relevant work on your quiz.**
- 6) You may use a simple scientific calculator capable of logarithms, exponentials, and trigonometric functions. **Programmable engineering calculators with text or graphical capabilities are not allowed. Wireless devices are prohibited.**

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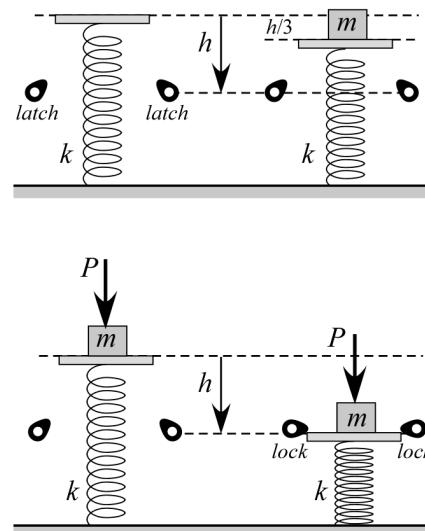
The following problem will be hand-graded. Show all supporting work for this problem.

- I]** (20 points) A spring-launched cannon consists of a massless platform atop a vertical spring of elastic constant k (top left). The spring must be compressed a distance h (from its neutral position) to engage a latch mechanism that holds the platform in place until launch.

A block of mass m is gently placed on the platform, but the spring only compresses a distance $h/3$ before coming to equilibrium, and thus cannot lock into place (top right). To fully compress the spring and lock the mechanism, you must therefore push the block down with an external applied force of magnitude P . Assume that you start pushing the moment you place the block (bottom left) and continue with a constant force until the latch engages (bottom right).

What is the smallest value for P that will allow the lock to engage? Express your answer as a multiple of the block's true weight, mg .

Hint: you may assume the block ends at rest, at the moment the latch engages.

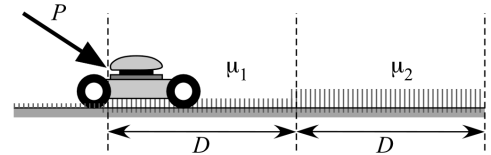


Form A

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The following problem will be hand-graded. Show all supporting work for this problem.

- [II]** (20 points) A lawn mower of mass m is pushed through heavy grass, which causes a resistive force behaving just like kinetic friction, with a resistive coefficient μ . Starting from rest in short grass ($\mu_1 = 0.20$), the mower is pushed by a constant force P , directed at an angle 35° below the horizontal. The mower picks up speed as it travels a distance D , at which point it hits taller grass ($\mu_2 = 0.30$). Although the same pushing force is maintained, the extra resistance of this grass causes the mower to slow back down, bringing it to halt after an additional distance D .



Identify all forces acting on the mower, and determine expressions for the work done by each force during the time it is acting on the mower.

Use your expressions, and the Work-Energy Principle, to find the magnitude of the pushing force, P . Express your answer for P as a multiple of mg .

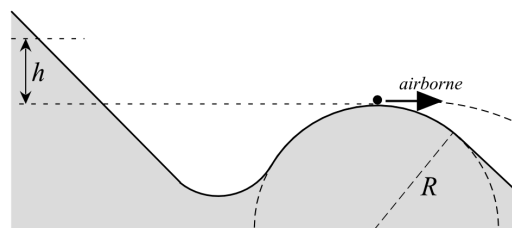
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The following problem will be hand-graded. Show all supporting work for this problem.

- [III]** (20 points) A skateboard park has a large hemispherical hill of radius R in a low-lying area. From a higher nearby slope, a boy sets off from rest and passes over the lower hill. From what maximum height can the boy start, without losing contact with the ground as he passes over the highest point of the hill? (That is, the goal is for the boy NOT to become airborne, as shown in the figure!)

Treat the boy and skateboard as a single particle, and assume negligible friction between the skateboard and the ground.

Give your answer as a height h above the apex of the lower hill, expressed as a multiple of the hill's radius of curvature R .

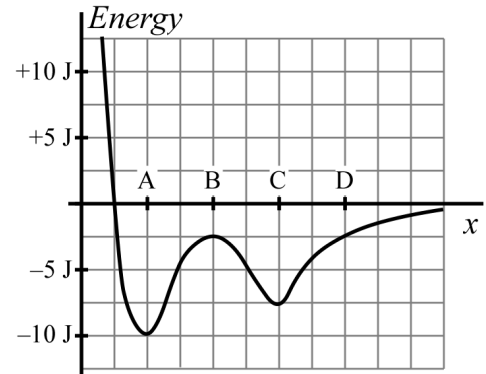


Form A

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The next two questions involve the following situation:

The figure at right displays the potential energy curve for an object that moves along the x -axis. There are no other forces acting on the object, apart from the conservative force that gives rise to this PE curve.



- Question value 4 points*
- (1) If the object begins at rest at position A, how much external work must be done on the system in order for the object to reach position C?
- (a) No amount of work will allow the object to reach position C.
 - (b) $W_{ext} = -2.5 \text{ J}$
 - (c) $W_{ext} = +2.5 \text{ J}$
 - (d) $W_{ext} = -7.5 \text{ J}$
 - (e) $W_{ext} = +7.5 \text{ J}$

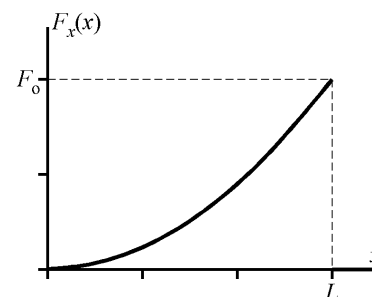
- Question value 4 points*
- (2) How many stable equilibrium positions does this system have?
- (a) Three.
 - (b) Four.
 - (c) Two.
 - (d) Zero.
 - (e) One.

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- (3) A variable conservative force acts on an object that moves along the x -axis, given by the functional expression:

$$F_x(x) = F_0 \frac{x^2}{L^2} \text{ for } 0 \leq x \leq L,$$

where F_0 and L are constants. What is the change in the object's potential energy, as it moves from $x = 0$ to $x = L$?



- (a) $\Delta U = +F_0L$
(b) $\Delta U = +\frac{F_0L}{3}$
(c) $\Delta U = -\frac{F_0L}{3}$
(d) $\Delta U = 0$ because the force is conservative.
(e) $\Delta U = -F_0L$

Question value 8 points

- (4) A construction worker drops a 2.0 kg hammer while standing on a girder that is 25 m above the ground. The hammer strikes the ground moving at 18 m/s. How much work was done on the hammer by aerodynamic drag?
- (a) +324 J
(b) -490 J
(c) -166 J
(d) zero J, because energy was conserved
(e) +490 J

Form A

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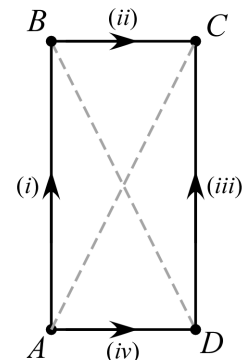
Question value 8 points

- (5) A block moves in the xy plane, subject to a single conservative force. Points A – D are located at the corners of a rectangle of dimension $d \times 2d$. Paths (i) through (iv) connect these points as shown. The work done by the conservative force, along each path, are given by:

$$\begin{array}{ll} W_i = +5 \text{ J} & W_{ii} = -4 \text{ J} \\ W_{iii} = +4 \text{ J} & W_{iv} = -3 \text{ J} \end{array}$$

If the object moves directly across the diagonal, from D to B , how much work is done by the force?

- (a) $W_{D \rightarrow B} = -2 \text{ J}$
(b) $W_{D \rightarrow B} = -8 \text{ J}$
(c) $W_{D \rightarrow B}$ cannot be computed from the information given.
(d) $W_{D \rightarrow B} = +8 \text{ J}$
(e) $W_{D \rightarrow B} = +2 \text{ J}$



Question value 8 points

- (6) You are standing around talking to your friends, when your bookbag slips off your shoulder at falls to the ground, where it comes to rest. Considering the system consisting of just your bookbag, starting from the moment it starts to slip, what work is done on the bag?
- (a) Friction with your shoulder does negative work, gravity does positive work, and the normal force with the ground does negative work. The total work done is negative.
(b) Friction with your shoulder does negative work, gravity does positive work, and the normal force with the ground does negative work. The total work done is zero.
(c) Friction with your shoulder does negative work and the normal force with the ground does negative work. The total work done is negative.
(d) Friction with your shoulder does negative work, gravity does negative work, and the normal force with the ground does positive work. The total work done is negative.
(e) Friction with your shoulder does positive work and the normal force with the ground does negative work. The total work done is zero.

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