When you are told to begin, check that this examination booklet contains all the numbered pages from 2 through 10.

The exam contains three problems that count equally although some problems may be harder than others.

Do not panic or be discouraged if you cannot do every problem; there are both easy and hard parts in this exam. **Keep moving and finish as much as you can!**

Read each problem carefully. You must show your work—the grade you get depends on how well I can understand your solution even when you write down the correct answer. Please **BOX** your answers.

**DO ALL THE WORK YOU WANT GRADED IN THIS EXAMINATION BOOKLET!**

Rewrite and sign the Honor Pledge: *I pledge my honor that I have not violated the Honor Code during this examination.*
This page intentionally left almost blank.
Problem 1. Gravity Launcher. The diagram shows a launcher that we might have used in lab instead of the ones we actually used. It makes use of gravity rather than a spring to launch a projectile towards the target. The projectile has mass $m$ and slides on the launcher which is a frictionless track. The projectile starts from rest at height $h$ above the launch point. The launch direction is an angle $\theta$ above the horizontal and the launch point is a height $H$ above the target and a horizontal distance $D$ from the target. Just as in lab, ignore air resistance.

(a) Assume the projectile leaves the launch point with speed $v_0$. How long does its flight last before it hits the target? Your answer may include any or all of $m$, $v_0$, $\theta$, $g$, $D$, and $H$. (5 points)
Problem 1. Continued.

(b) Find an expression for $D$ in terms of any or all of $m$, $v_0$, $\theta$, $g$, and $H$. (4 points)

(c) Recall that in lab we calculated how far to compress the spring so that the projectile would hit the target. In this case, the parameter we can adjust is the height $h$ at which the projectile is released on the launcher. Find $h$ so that the projectile hits the target. Your answer may include any or all of $m$, $\theta$, $g$, $D$, and $H$. Note that $v_0$ is not allowed in the answer! (6 points)
Problem 1. Continued.

(d) (You should be able to do this part even if you didn’t get the previous parts.) At the lowest point of the launcher track, the radius of curvature is \( R = 0.2 \) m. The projectile, with mass \( m = 0.1 \) kg, is released from a height \( y = 1.0 \) m above the bottom (lowest point) of the track. Use \( g = 9.8 \) m s\(^{-2}\). What are the magnitude, direction, and units of the force exerted on the projectile by the track at this point? (5 points)
Problem 2. Stepladder. A stepladder consists of two legs hinged together at the top by a frictionless hinge. The ladder rests on a smooth (frictionless) floor and the legs are kept from spreading apart by a horizontal cable connecting the two legs. You are standing on the top of the ladder (violating a whole bunch of CPSC warning labels!). Some data: the left leg rests on the floor a distance $a = 0.5$ m to the left of the point directly below the hinge and the right leg rests $b = 0.25$ m to the right of that point. The ladder is $H = 2$ m tall and the cable connecting the legs is $h = 1.5$ m above the floor. The acceleration of gravity is $g = 9.8 \text{ m s}^{-2}$. The stepladder is a lightweight aluminum ladder so its mass may be ignored. Finally, you have put on some weight since quiz 5 and your mass is now $M = 90$ kg. (Note that the figure is not to scale!)

(a) Draw a free body diagram showing all the external forces on the ladder. (4 points)
Problem 2. Continued.

(b) Determine the magnitude and direction of the force the floor exerts on each leg of the ladder. (5 points)

(c) Determine the tension in the cable. Hint: isolate one leg and take the origin for torques at the top hinge. (6 points)
Problem 2. Continued.

(d) Suppose the cable breaks, the legs fly out, and you come crashing down. Where do you hit the floor and why? (State your answer relative the spot directly below you when you are standing on the ladder.) (5 points)
Problem 3. World’s Fastest Man in 1996. At the Atlanta Olympics in 1996, Donovan Bailey won the 100 meters in a World Record time of 9.84 s. Michael Johnson won the 200 meters in a World Record time of 19.32 s. A certain NBC announcer (can you guess which one?) started to say things like Johnson should have the title of the World’s fastest man since his time was less than twice Bailey’s time. Of course, the announcer forgot about the need to accelerate from rest! Johnson’s “splits” (times to run each half of the 200 m race) were 10.12 s for the first 100 m and 9.20 s for the second 100 m.

Let’s consider a simple model in which a sprinter accelerates with constant acceleration until he reaches his top speed and then runs with constant speed to the end of the race. (This ignores things like running on the curve and fatigue of the sprinter, but it might still give us a handle on what happens in a sprint.) We’ll use the data for Michael Johnson. The top speed is reached well within the first 100 meters of the race. You might want to consider the plots you are asked to draw in part (f) as you do parts (a)–(e).

(a) Using data for the second split, determine Johnson’s top speed, \( v_m \). (2 points)

(b) In the first half of the race, suppose Johnson accelerated with constant acceleration from rest to speed \( v_m \) in time \( t_a \) and then ran at constant speed \( v_m \) for time \( t_v \). What was Johnson’s average velocity in the constant acceleration portion of the first half of the race? (3 points) (Hint: a formula is desired.)
Problem 3. Continued.

(c) In terms of \( v_m, t_a, \) and \( t_v, \) give expressions (not numbers!) for the distance covered and the time elapsed in the first half of the race. (3 points)

(d) Using the fact that the distance and time for the first half of the race are 100 m and 10.12 s, determine numerical values for \( t_a \) and \( t_v. \) (3 points)

(e) What is the magnitude of the constant acceleration at the start of the race? (3 points)
Problem 3. Continued.

(f) On the diagram below make reasonably accurate sketches of Michael Johnson’s position, velocity and acceleration as functions of time according to the model we’ve worked out. Be sure to indicate the scale for the velocity and acceleration graphs. (6 points)
This page intentionally left almost blank.