Name: _____ Date: _____ Period: _____

Seat Belt Engineering — Regents Practice

Practice cluster in the format of the NYS Regents Examination in Physical Science: Physics. Companion to the reading passage "The Physics of Survival".
Base your answers to questions 1 through 6 on the information below and on your knowledge of Physical Science: Physics. Some questions may require the use of the 2025 Edition Reference Tables for Physical Science: Physics.
Seat Belt Engineering

Block 1: The Locking Sensor

A seat belt retractor normally lets the belt slide in and out freely. To lock the belt in a crash, many retractors use an inertia sensor. Model 1 (described in words): a small steel ball rests in a shallow cup fixed to the car's frame. A lever sits on top of the ball. When the ball rolls up the side of the cup, it lifts the lever into the teeth of a gear on the belt spool, and the spool can no longer turn. During normal driving at constant velocity, the ball stays at the bottom of the cup.
1. The car is moving forward and the driver brakes hard. Which statement best explains why the ball rolls toward the front of the cup?
(1) The braking car exerts a forward force on the ball.
(2) The ball tends to keep moving forward at its original velocity while the cup slows down.
(3) The gravitational force on the ball increases while the car slows down.
(4) The ball's mass increases when the car decelerates.

Block 2: The Load-Limiting Belt

A belt that locks completely rigid can stop the occupant very quickly. Many modern belts include a torsion bar, a metal rod that twists at a set load and lets out a few centimeters of belt. Engineers compared a rigid belt with a load-limiting belt in sled tests. A 75-kg crash-test dummy slowed from 15 m/s to 0 m/s in each test. Table 1 shows the time each dummy took to stop and how far the dummy's chest moved forward while stopping.
Table 1: Sled Tests of Two Belt Designs (75-kg dummy, 15 m/s to 0 m/s)

Belt Design	Time for Dummy to Stop (s)	Forward Distance Moved by Chest While Stopping (m)
Rigid belt	0.060	0.45
Load-limiting belt	0.090	0.68

Data are representative values for practice.
2. Which mathematical representation can be used to determine the magnitude of the average force on the dummy wearing the load-limiting belt?
(1) F = (75 kg)(15 m/s)(0.090 s)
(2) F = (75 kg)(15 m/s) / (0.090 s)

(3) $F = (75\ kg)(9.8\ m/s^2)$
(4) $F = (75\ kg)(0.090\ s) / (15\ m/s)$
3. An engineer claims, "The load-limiting belt lowers the average force on the dummy because it reduces the dummy's change in momentum." Place a check mark (✓) in either the Support or Refute box below to indicate if the given information supports or refutes the engineer's claim. Justify your response using a mathematical relationship. [1]
☐ Support ☐ Refute
Justification:

_____
_____
_____

4. Based on Table 1, describe one trade-off engineers must consider when deciding how much belt the torsion bar should let out. [1]

_____
_____
_____

Block 3: Pre-tensioners and Slack

Passengers often leave slack in their belts. With slack, the occupant keeps moving forward for a moment after the car begins to slow, and the belt then catches the occupant suddenly. A pre-tensioner removes the slack a few milliseconds before impact so the belt holds the occupant snugly against the seat from the start. Consider an occupant whose speed decreases from the same initial value to zero in both cases. During the crash, the car is moving toward the right of the page and slowing down.
5. In the space below, draw a free-body diagram of the belted occupant while the car is slowing down. Represent the occupant as a dot. Draw and label arrows for the force of the belt on the occupant, the gravitational force on the occupant, and the upward force of the seat on the occupant. Arrow lengths should show the relative sizes of the forces. [1]

6. Which row in the table below correctly compares an occupant whose belt has slack with an occupant whose belt was pulled snug by a pre-tensioner?

Row	Change in Momentum of Occupant with Slack	Time for Occupant with Slack to Stop	Average Force on Occupant with Slack
(1)	the same	shorter	greater
(2)	greater	the same	greater
(3)	the same	longer	smaller

Row	Change in Momentum of Occupant with Slack	Time for Occupant with Slack to Stop	Average Force on Occupant with Slack
(4)	smaller	shorter	the same