Crash Helmet – Define Phase
Kinematics and Impulse Computations Practice
+ Problem Statement Writeup

On a separate sheet of paper, solve Questions 1-10 (7 pts each). Show all work. Then write your problem statement in Question 11 (30 pts).

DROP PHASE: Dropping a Raw, Unprotected Egg

Compute Final Velocity when a = g

$v_f^2 = v_0^2 + 2ad$

1. Drop the egg from an altitude of 0.5 m.
   Compute its final velocity at the moment of impact with the ground. Respond in m/s and mph.

2. Drop the egg from a balcony, approximately 13 ft above the ground. *(Caution: convert your units!)*
   Compute its final velocity at the moment of impact with the ground. Respond in both m/s and mph.

3. From what altitude must the egg drop for it to hit the ground with a final velocity of 7 m/s?

DROP PHASE: Dropping an Egg Wearing a Protective Device which Creates Drag

Compute Net Acceleration and Final Velocity when a ≠ g

$d = v_0 t + \frac{1}{2} a t^2$

4. Drop the egg, in its protective device, from an altitude of 4.0 m.
   Compute its net acceleration if it takes 1.0 s from release to impact. Respond in m/s^2.

5. How does the acceleration you computed in Question #4 compare with the value of g?

6. Why do you want to create drag? How effective is the protective device in Questions #4 and #5 in creating drag?

7. Using the acceleration you found in Question #4, compute the final velocity of the egg, in its protective device, at the moment of impact with the ground. Respond in both m/s and mph.

CRASH PHASE: Role of Cushioning when Computing F from Impulse

Compute F for various values of Δt

Impulse Equation: $F\Delta t = m\Delta v$

8. Consider a 50 g egg, in its protective device (ignore the mass of the device), as it crashes on the ground. The egg is moving downwards at 7 m/s as it begins the crash. How much force does the egg experience during the crash (from the moment of impact until the egg comes to rest with a velocity of 0 m /s) if device cushioning results in a crash time of Δt = 0.01 s?
   Respond in N.

9. Repeat Question #8, but provide extra cushioning so that Δt = 0.1 s. How much force does the egg experience now during the crash (from the moment of impact until the egg comes to rest with a velocity of 0 m /s)? Respond in N.

10. What is the relationship between F and Δt in the Impulse equation, and what does this tell you about the role of cushioning in your egg protection device?

COMPOSE YOUR PROBLEM STATEMENT

The following is a sample problem statement addressing protection of an egg head during a crash:

Design a personal protective device which will safeguard a boiled egg head of median mass 55g from impact injury (cracking) when falling onto a hard surface from altitudes up to 2m. The device must be reusable (unless damaged); sized to fit a median egg of 55mm (height) and 44mm (width); compact with regard to dimensions and mass; provide easy ingress and egress; and must not interfere with user mobility and sensory functions.

11. Write your own problem statement addressing protection of an egg head during a crash, using your own data (from your egg measurements) and your own specifications (see below):

    ….. For example, if you found that an unprotected egg typically survives a crash of no more than 150 mm, do you want to design a helmet which improves survival by a factor of ten (which is 1.5 m)? or a factor of twenty (which is 3 m)?

    ….. What about ingress and egress? Can you quantify these? Should it be, for example, that it takes less than ten seconds for the egg to put on its helmet? Less than five seconds? What is a reasonable specification for this component of the protective device?

    ….. And what about overall size? If the helmet is enormous in size, it may protect the egg, but be impractical with regard to the egg's ability to wear the device and retain its mobility. How will you address this in your problem statement?