Southern New Hampshire University

PHY-150 Project 5-2:
Assessment of cell phone case durability

Prepared on: June 5, 2022

Prepared for: Prof. Bruce Brazell

Prepared by: Alexander Ahmann

Contents

1 Newton's Laws (Question 1)

Prompt: To begin your evaluation of different case materials, you must first define Newton's laws of motion and then describe how each of Newton's laws applies to the motion you will be analyzing.

As you will be presenting this report to various stakeholders, you have been asked to write your definitions and descriptions with a nontechnical audience in mind.

My answer: Newton's laws are:

1. Anything that is in motion will stay in motion until acted on by another force.[a]
2. $F = ma$
3. For every action, there is an equal and opposite reaction.[b]

The product of the phone's mass and its acceleration directly influence its force. With Newtons laws, the second and third ones in particular, I can work out the acceleration of a falling phone and the impact of it falling on the ground.

[a] Or,

$$(\forall \rho)\ \neg \vec{F}_{ext} \Rightarrow \left[\frac{d\vec{v}_\rho(t)}{dt} = 0 \right]$$

[b] Or,

$$(\forall \vec{F}, \rho)\ \vec{F}_{\rho x, \rho y} \Rightarrow (\exists \vec{F}_{\rho y, \rho x} = -\vec{F}_{\rho x, \rho y})$$

2 Force diagrams (Question 2)

Prompt: Once you have described the relevant laws of motion, create force diagrams to model the motion for a phone dropped from a set height. You should include diagrams, with their respective force vectors, for each phone drop. In your diagrams, address the following:

1. Define the height you will be using for each phone drop. As the researcher, you will choose a drop height of between 1 and 2 meters.
2. Using the provided mass of 6.2 oz., or by measuring the mass of a personal cell phone, determine the mass you will be using for your calculations. Remember to add the mass of the case material.
3. In your diagram, show the direction and name of each force on the cell phone both at the drop point and at the point of collision with the ground.

My answer: First, I will need a list of the phones, their respective cases, and their respective masses and collision times. The following is a table of them[a]

Test material	Mass (converted)	Collision time
Phone only (no case)	0.1704 kg.	0.01 s.
Silicone	0.0483 kg.	0.05 s.
Hard plastic	0.0312 kg.	0.03 s.
Rubber	0.0909 kg.	0.08 s.

I will define the height by which to drop the phone as being two (2) metres and use provided mass of 6.2 oz., or $\sim$ 0.1704 kg., as the mass of the base phone without the casing. Fig. 1 depicts a free-body diagram of what I intend to analyse.

[a] I converted the mass from ounces to kilograms with the following formula:

$$f(x)\ [\text{kg}] = x\ [\text{oz}] \cdot \left(\frac{0.0284\ [\text{kg}]}{1\ [\text{oz}]} \right)$$

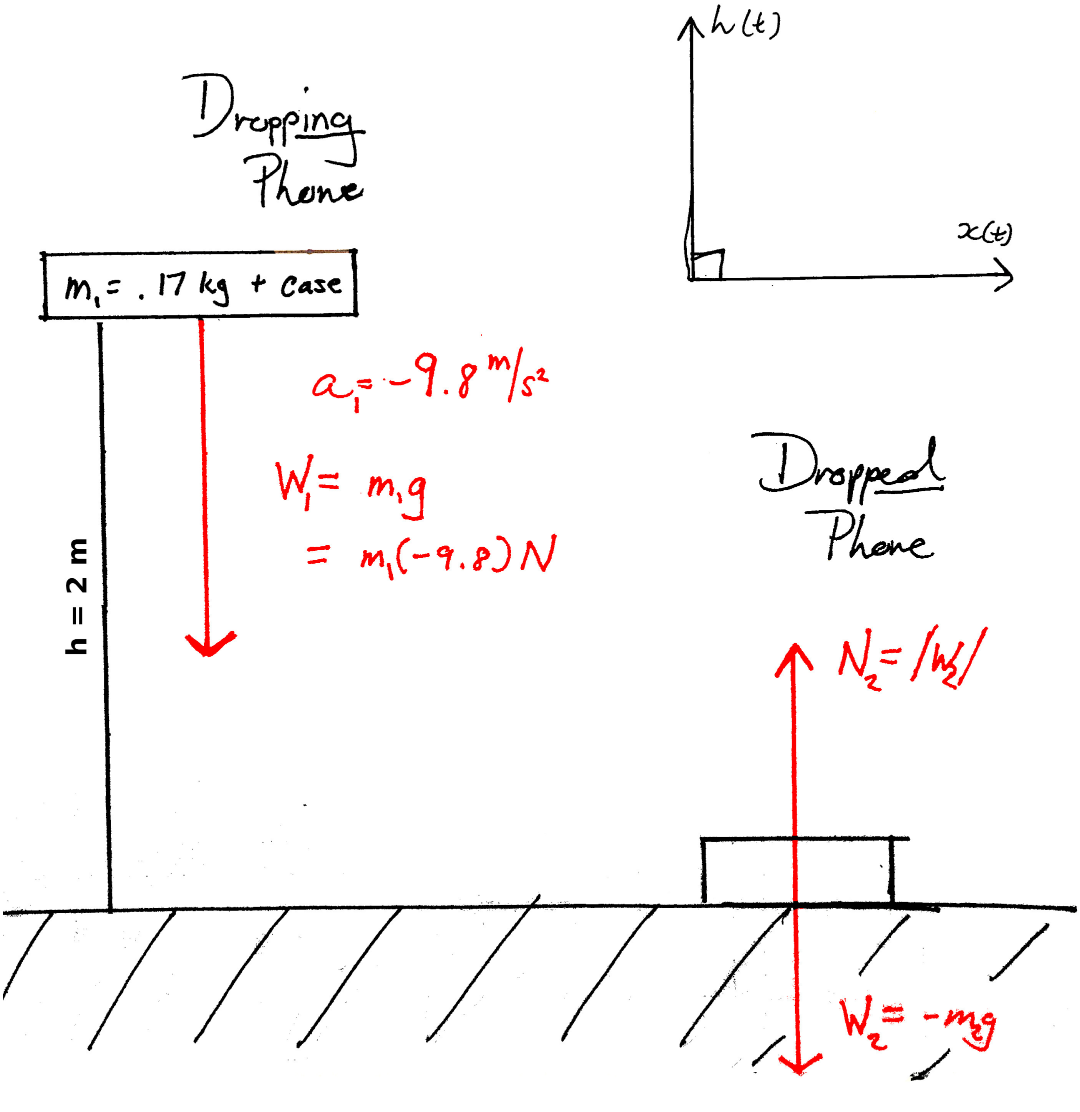

Figure 1: **Free-body diagram for hypothetical phone in free fall and impacting with the ground.**

3 Motion before and during impact (Question 3)

Prompt: Following the creation of the force diagram, use the information provided in your case specification document to calculate the velocity before impact and deceleration at impact. Remember that deceleration is represented as negative acceleration in force equations.

In your calculations, assume a standard free-fall acceleration during the fall, and a velocity of 0 m/s after the impact. You should include calculations for the following scenarios: *a phone without a case*, *a phone with a silicone case*, *a phone with a hard plastic case* and *a phone with a rubber case*.

My answer: Regarding the velocity before impact, the formula[a] to work this out is:

$$v_h = \sqrt{2gh_i}$$

The height is constant and set to $h = h_i = 2\ m$ and that $g = 9.80\ m/s^2$, this can be worked out as $v_h = 39.2\ m/s$.

Regarding the deceleration of the falling phone, this can be worked out from Newton's second law[b] and the notions of mechanical work and potential energy.[c]

[a]Derived by Dr. Bruce Brazell.

[b]Knowing that $F_w = ma_h$, one can conclude with a bit of algebra that:

$$a_h = \frac{F_N}{m}$$

[c]Without going into the derivations regarding mechanical work, potential energy and their relationship with mechanical work, it can be shown that:

$$F_N = mgh_i$$

My answer (question 3 cont.): The initial height of the falling phone is at a constant two metres, or $h_i = 2\ m$. The mass of the falling phone is dependent on its casing[a] and the following table shows the decleration for each phone.[b]

Casing type	Mass (kg)	Deceleration
No casing	0.1704 kg.	$\sim +3.340\ m/s^2$
Silicone	0.0483 kg.	$\sim +4.290\ m/s^2$
Hard plastic	0.0312 kg.	$\sim +3.951\ m/s^2$
Rubber	0.0909 kg.	$\sim +5.122\ m/s^2$

[a]Or lack of casing; the $\sum$ mass = phone mass + casing mass.

[b]The decelerations are *positive* because it is opposite to gravity, which is negative in my defined coordinate system, and a double negative evaluates to a positive.

4 The force of impact (Question 4)

Prompt: Using Newton's second law, calculate the force of impact for each scenario.

My answer: To "keep things simple," I will skip the derivations and just use the following formula to calculate the force at impact for each of the cell phones and their respective casings:

$$F_N = mgh_i$$

where m is the mass of the phone in kilograms,[a] $g = 9.8\ m/s^2$ and h is the initial height, which is $h = 2\ m$. The following table shows my calculations of the mechanical force at impact for each respective phone:

Casing type	Mass (kg)	Force at impact
No casing	0.1704 kg.	$\sim +3.340\ N$
Silicone	0.0483 kg.	$\sim +4.287\ N$
Hard plastic	0.0312 kg.	$\sim +3.951\ N$
Rubber	0.0909 kg.	$\sim +5.122\ N$

[a]Like in the previous question, I started with the phone's mass and added the size fo the case onto it.

5 Force Equations (Question 5)

Prompt: After you have completed your calculations, describe how force equations model the given scenario. In your description, address the following elements: *velocity before impact*, *acceleration* and *force*.

My answer: Regarding the *velocity on impact*, this is a kinematics equation that describes the speed of the falling phone as it hits the ground.

Regarding acceleration, this is the change in the speed, which is "increasing" as the height of the cell phone's initial drop point increases.

Finally, regarding the mechanical forces, they identify and quantify the external influences on the phone's motion.

6 Recommendations (Question 6)

Prompt: Finally, using data from your analysis, recommend the best material for a cell phone case. In your recommendations, address the following elements:

1. Which of the trials results in the lowest force of impact on the phone?
2. What considerations, in physics or otherwise, might you have in recommending a material for a cell phone case?

My answer: Regarding the casing, perhaps the best kind would be the "hard plastic" one as it has the least amount of mechanical force acting on it— which in turn would imply the least amount of damage. Perhaps adding a soft "pillow-like" substance inside the casing could mitigate the damage.