Name: KEY Date:__________ PD:______

ROLE (CIRCLE ONE): CAPTAIN MANAGER RECORDER REPORTER QUALITY CONTROL

POGIL: IMPULSE

How are force, time, and momentum related?

WHY?

The next time you push a shopping cart at the grocery store, notice how long it takes to accelerate it from rest to walking speed. If you push lightly, it might take 5 seconds of pushing. If you push harder, you might speed the cart up in only 1 second. The net result is the same—that is, a small force acting for a long time has the same effect as a large force acting for a short time. In this lesson, you will learn about the effects of a force acting over a period of time.

MODEL 1: Change in Momentum of an object due to force applied

	Force (F)	Time over which force is applied (t)	Change in object's momentum (Δp)
1)	5 N	1 s	5 kgm/s
2)	5 N	2 s	10 kgm/s
3)	5 N	3 s	15 kgm/s
4)	10 N	1 s	10 kgm/s
5)	10 N	2 s	20 kgm/s
6)	10 N	3 s	30 kgm/s
7)	15 N	1 s	15 kgm/s
8)	15N	2 s	30 kgm/s
9)	15 N	3 s	45 kgm/s

1. Refer to the data in Model 1.
   a. When a force of constant magnitude is applied over increasing amounts of time, how does the change in an object's momentum change?

      Δp also increases, direct

   b. Cite evidence from Model 1 to support your claim in Part A.

      varies - ex, when force is constant @ 5N, as time increases from 1s to 3s, the change in momentum increases from 5 to 15.

   c. Using your knowledge of Newton's Second Law (F=ma) and the definitions of acceleration and velocity, explain the reasoning behind why forces applied for greater amounts of time will cause greater changes in momentum (mv).

      When you apply force to a mass, it causes acceleration. When an object accelerates for a longer time, it either gets faster or slower. When the force is in the direction of motion, velocity will increase

2. Refer to the data in Model 1.
   a. When the time over which a force is applied remains constant, what is the relationship between the amount of force applied to an object and its change in momentum?

      (which #s are we looking at?

      direct, Δp also increases

b. Cite evidence from Model 1 to support your claim in Part A. Varies - example: When time is held constant @ 1s, and Force increases from 5N to 15N, the Δp also increases from 5kgm/s to 15kgm/s

c. Using your knowledge of Newton's Second Law, explain the reasoning behind your answers in Parts A and B.

Because force and acceleration have a direct relationship - as Force increases, acceleration increases, which causes a higher velocity as well, even though the amount of time doesn't increase.

3. Refer to the data in Model 1.

a. When the change in momentum of an object is constant, what is the relationship between the force applied to an object and the time over which the force acts? Which #s are we looking at?

inverse

b. Cite **at least** two examples of evidence to support your claim in Part A.

When Δp is constant @ 30 kgm/s, a Force of 10N has a time of 3s, and when Force increases to 15N, the time decreases to 2s.

4. Using your answers to Questions 1-3 and the data in Model 1, write an equation for calculating the change in momentum of an object using force and time. Indicate what each variable represents.

F·t = Δp   Force x time = change in momentum

5. Use two examples from Model 1 to prove that your equation in Question 4 is correct (show the actual calculations.) Which #s are we looking at?

5N(2s) = 10 kg·m/s   5N(3s) = 15 kg·m/s

READ THIS!

In general, the product of a force and the time over which it acts is defined as ***impulse.*** Notice that impulse takes into account not just the force that acts on the object, but the period of time over which it acts; both quantities are important. When a force acts on an object, it changes the object's momentum. Thus, impulses cause changes of momentum in objects; specifically, the impulse that acts on an object is equal to the object's change in momentum. Impulse is a **vector** quantity, and the direction of the impulse is in the same direction as the direction of the force. The equation to calculate impulse is:

$$I = F\Delta t$$

and the units are the same as the units for momentum: kgm/s. The connection between change in momentum and impulse is represented as:

$$I = F\Delta t = \Delta p$$

Model 2: Airbags and Impulse

A person traveling at 35 mph (15.6 m/s) experiencing an offset crash test stops over a distance of 1 foot in Figure 1 and Figure 2. The dummy is the size of an average male. Table 1 shows data related to the crash.

Figure 1: Crash with airbag

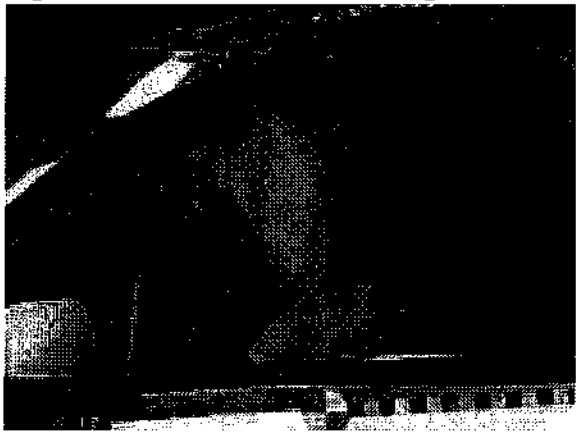

Figure 2: Crash without airbag

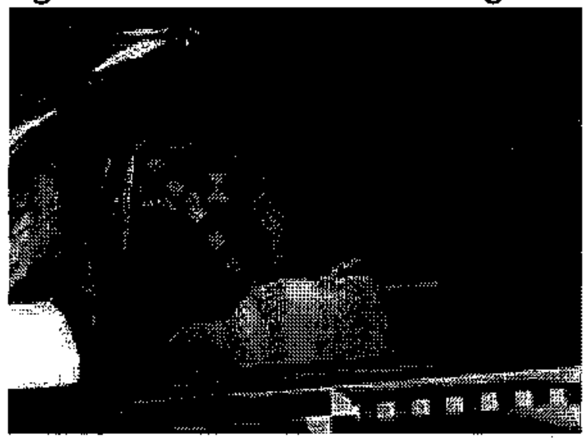

Table 1

	With an airbag (Figure 1)	**Without an airbag (Figure 2)**
Height of the dummy (in)	70	70
Mass of the dummy (kg)	80.7	80.7
Velocity at impact (m/s)	15.6	15.6
Final velocity (m/s)	0	0
Time of crash (s)	0.9	0.2
Impulse of crash	1259 kg·m/s	1259 kg·m/s

6. For the crashes represented in Figure 1 and Figure 2, what is the velocity right before impact?
   15.6
7. For the crashes represented in Figures 1 and 2, what is the mass of the dummy?
   80.7
8. Using the velocities at impact and the masses of the dummy, calculate the momentum at impact (p_i) for:
   a. Crash 1 $p = mv = (80.7)(15.6) = 1259$ kg·m/s
   b. Crash 2 $p = mv = (80.7)(15.6) = 1259$ kg·m/s
9. Using the final velocities and the masses of the dummies, calculate the momentum after the crash (p_f) for:
   a. Crash 1 $p = mv = (80.7)(0) = 0$ kg·m/s
   b. Crash 2 $p = mv = (80.7)(0) = 0$ kg·m/s
10. Using your answers to 8 and 9, calculate the change in momentum (Δp) for:
   a. Crash 1 $\Delta p = p_i - p_f = 1259 - 0 = 1259$ kg·m/s
   b. Crash 2 $\Delta p = p_i - p_f = 1259 - 0 = 1259$ kg·m/s

11. Compare the change in momentum (Δp) for Crash 1 and Crash 2. Use Evidence from Model 2 to support your answer. Same- both had Starting momentum of 1259, and both had final momentum of zero.

12. Using the knowledge you constructed in Model 1 and the "Read This" on page 2, determine the impulse for each crash and write it in the blank spaces on Table 1. Then, explain your reasoning in the space below:

Impulse is Δ in momentum. Since both crashes have the same mass, velocity, + starting + final velocities, the impulse is 1259 kg·m/s

13. Use the equation for impulse and your answers above to calculate the force exerted on the dummy with an airbag. $I = Ft$

$1259 = F(0.9)$

$F = 1399\ N$

14. Use the equation for impulse and your answers above to calculate the force exerted on the dummy without an airbag. $I = Ft$ $1259 = F(0.2)$

$F = 6299\ N$

15. From Table 1, how does an airbag change the time during which an object's momentum changes in a collision? .

The time is increased from 0.2s to 0.9s with an airbag.

16. Using your calculations above as evidence, what is the effect of using an airbag on the force applied to a person in a collision?

Using an airbag increases the time to change momentum, which decreases the Force

Model 3: Crumple Zones and Impulse

Figure 3

Figure 4

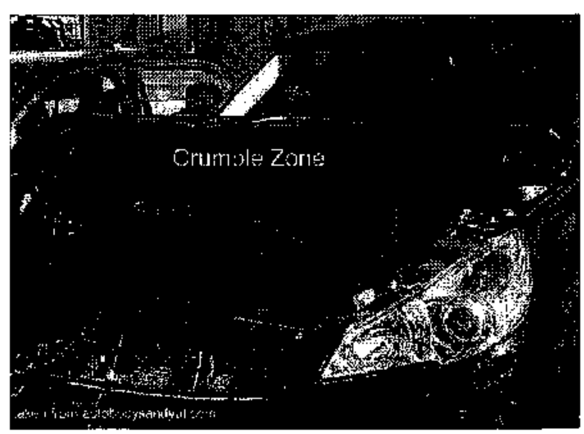

Figure 5: Crash with crumple zone

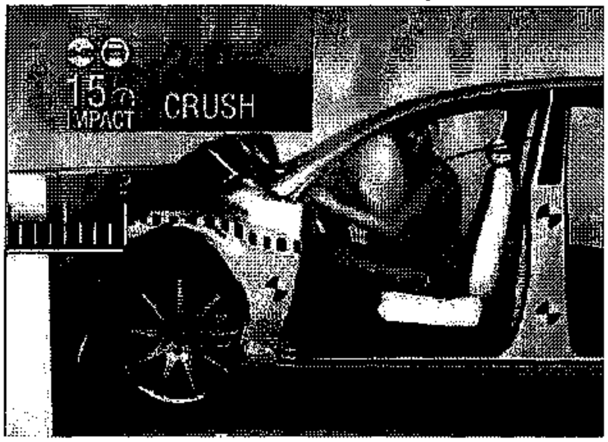

Figure 6: Crash without crumple zone

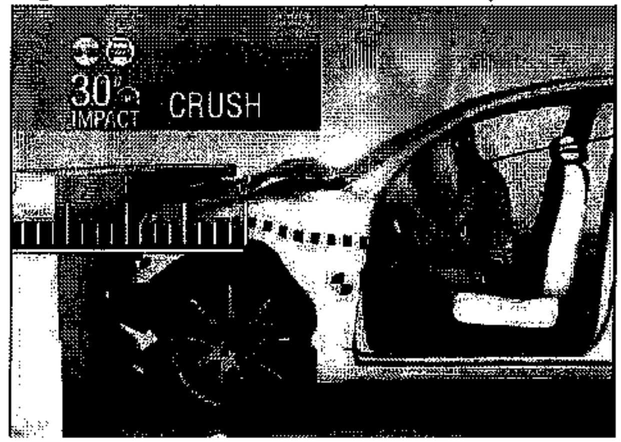

Table 2

	With a crumple zone (Figure 5)	Without a crumple zone (Figure 6)
Height of the dummy (in)	67	67
Mass of the dummy (kg)	70.5	70.5
Velocity at impact (m/s)	13.5	13.5
Final velocity (m/s)	0	0
Crush distance (ft)	2.0	1.0
Time of crash (s)	1.4	0.7
Impulse of crash		

17. From Table 2, what was the velocity at impact of both cars? 13.5

18. From Table 2, what is the mass of the dummy for both cars? 70.5

19. From Figure 5 or Table 2, what was the distance that the car crushed for the car with a crumple zone? 2.0 ft

20. From Figure 6 or Table 2, what was the distance that the car crushed for the car without a crumple zone?

1.0ft.

21. Using Figure 6 or Table 2, identify and compare the times of the crashes for both the car with a crumple zone and without a crumple zone.

CZ = 1.4s

w/a crumple zone, the time was doubled No CZ = 0.7s

22. Using the velocity at impact and the mass of the dummy, calculate the momentum at impact for:
    a. The car with a crumple zone

    $p = m \cdot v$ $p = 70.5(13.5) = 952$ kg·m/s

    b. The car without a crumple zone

    $p = 70.5(13.5) = 952$ kg·m/s

23. Using the final velocity and the mass of the dummy, calculate the final momentum for:
   a. The car with a crumple zone

   $p = m \cdot v = 70.5(0) = 0$ kg·m/s

   b. The car without a crumple zone

   $p = m \cdot v = 70.5(0) = 0$ kg·m/s

24. Calculate the change in momentum (Δp) for:
   a. The car with a crumple zone

   Starting p − final p = 952 − 0 = 952 kg·m/s

   b. The car without a crumple zone

   Same as above

25. Use the equation for impulse to calculate the force exerted on the dummy with a crumple zone.

   $I = F \cdot t$ $952 = F(1.4)$
   $t = 1.4s$ $F = 680N$

26. Use the equation for impulse to calculate the force exerted on the dummy without a crumple zone.

   $I = F \cdot t$ $952 = F(0.7)$
   $t = 0.7s$ $F = 1360N$

27. Compare the force exerted on the driver in the car with the crumple zone to the force exerted on the driver in the car without a crumple zone.

   The Force on the driver is reduced by ½ when the time of impact is doubled.

28. As a group, synthesize the knowledge you constructed while interpreting Models 2 and 3. Propose an explanation that is **supported by mathematical evidence** to explain how safety features such as airbags and crumple zones minimize the force exerted on an object during a collision. Be sure to cite your evidence.

   answers vary, but must include relevant calculations from models 2 + 3.

READ THIS!

Many safety features that are used to protect objects during collisions work by extending the time of the collision. By increasing the amount of time it takes for an object's momentum to change, the force exerted on the object decreases. This is show through simple manipulation of the impulse equation, $I = Ft$. If the equation is rearranged to solve for force, it becomes $F = \frac{I}{t}$. The larger the time for a constant I, the greater the force exerted, and vice versa.