name: SOLUTIONS

group members:

SCIENCE ONE PHYSICS WORKSHEET 2: MOMENTUM

In this worksheet, we'll discover some very useful results by thinking about momentum.

We saw last time that Newton's First Law is equivalent to saying that the momentum $\vec{p} = m\vec{v}$ of an isolated object is unchanging in time. This LAW OF CONSERVATION OF MOMENTUM doesn't just apply to single objects. More generally:

good approximation for ordinary speeds.

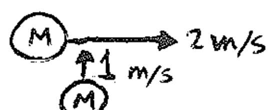
For any physical system with translational symmetry in direction x, the total x momentum p_x in the system is unchanging in time.

The same goes for y and z, so if there is complete translational symmetry (e.g. in outer space), the total p_x, p_y, and p_z are each constant in time.

For now, let's take our physical system to be one with multiple objects that may interact with one another. In this case, the total momentum is just the sum of the momenta for each of the objects.

Let's start with an example to see how Conservation of Momentum can help predict the future in a more interesting example than just an isolated object floating through space:

Question 1



Suppose there is a collision between two blobs of space-goo, each with mass M and velocities as shown. If the blobs stick together, what is the final *velocity* of the resulting blob (give x and y components)?

see sample solution. [redacted]

more space on next page.

Question 2

Somewhere in outer space, two identical space-rocks each collide (at identical velocity) with two different asteroids, one twice as heavy as the other. If the rocks bounce off at the same speed in each case, which asteroid has a larger change in momentum? Use your clicker to select one of the answers on the board, and use the space below to write an argument based on momentum conservation.

Momentum is conserved in each collision.

So: Δp (asteroid) $= -\Delta p$ (rock) ← same for both.

Thus, each asteroid experiences the same change in momentum.

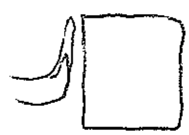
Hopefully, you have just discovered the following important result: **two objects that experience the same external influence will experience the same change in momentum.**

Different external influences can have smaller or larger effects on an object. We'd now like to come up with a quantitative measure of how strong such an influence (e.g. a push or a pull) is.

Question 3

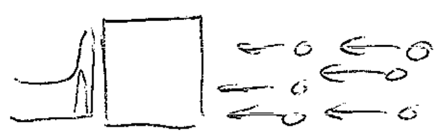
Suppose you are in outer space. You want to come up with a standard way to measure the strength of a push (e.g. to tell whether). What should you do?

example:



stronger push: momentum changes faster

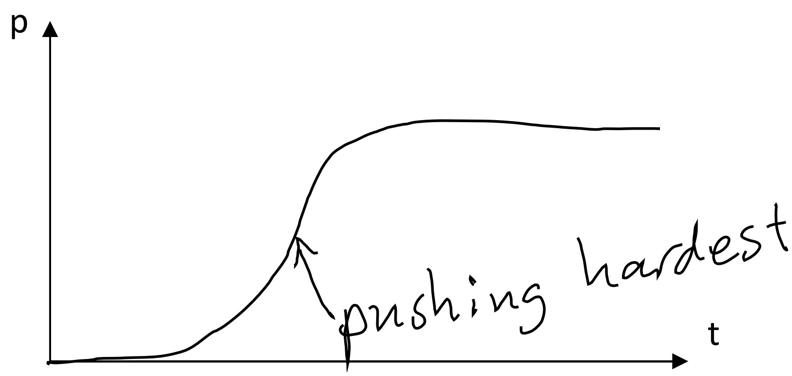
or



measure strength of push
by # of peas per second
that it takes to counteract push.

Question 4

a) Imagine giving something a push (in outer space). On the axes below, make a sketch where the horizontal axis is time and the vertical axis is the momentum of the object



b) Indicate on your graph where you were pushing the hardest. What specific feature of your graph tells you this?

largest slope

c) In physics-speak, we would use the term FORCE to indicate how hard we are pushing at a particular time. Based on your previous answer, come up with a definition of force in terms of some property of the momentum versus time graph. (Check your answer with an instructor).

$$F = \frac{dp}{dt}$$

d) Rewrite your answer to c) using the formula for momentum in terms of mass and velocity. You may use the fact that mass doesn't change with time.

$$F = \frac{d}{dt}(mv) = m\frac{dv}{dt} = ma$$

e) If we applied the same force to a more massive object, how would the momentum versus time graph differ? same.

f) Apart from your definition in part c), can you think of another way to define force?

Question 5

Suppose two objects are interacting (e.g. during a collision when they are in contact with each other). In a certain small time interval Δt, the change in momentum of the first object is Δp_1.

(*answer all questions in terms of Δt and Δp_1*)

a) What is the change in momentum of the second object during the same amount of time?

$-\Delta p_1$ since total p constant.

b) What is the force on the first object?

$$F_1 = \frac{\Delta p_1}{\Delta t}$$

c) What is the force on the second object?

$$F_2 = -\frac{\Delta p_1}{\Delta t} = -F_1$$

Question 6

A small car pushes a large truck that has broken down. They are stuck together, so they have the same acceleration. Is the force of the car on the truck larger or smaller than the force of the truck on the car? Explain why your answer is consistent with Newton's second law.

Same by Newton's 3rd Law.

BUT F_{NET} on truck $= M_{TRUCK}\, a$ has greater magnitude than F_{NET} on car $= M_{CAR}\, a$.

This is consistent, since F_{NET} includes force of road.