11-14 Momentum and Force

Prerequisites

Students should have already completed the **Calculating Speed, Weight, Forces** and **Momentum** sheets. While not essential, it will help if they have also studied the **Force & Motion** sheet. A momentum approach can be a simpler approach to understanding how force affects motion than the conventionally taught F=ma, and therefore the students do not need to have prior knowledge of acceleration.

This builds on the momentum sheet applying the principle to situations where there is more than one force, the object does not start or end at rest and where the direction of motion changes. It is advanced for KS3 but some students may well enjoy it and find it gives a very firm foundation for their subsequent learning at GCSE and beyond.

The Main Points

- We recap:
    - **Momentum** = mass x velocity and is measured in kg m/s
    - The more momentum something has, the harder it is to stop it.
    - Momentum as a number tells you the size of [resultant] force (in newtons) needed to stop the object in one second.
    - If there is **no force** on an object (or balanced forces) the **momentum does not change**
    - If an **unbalanced force** pushes an object, the **momentum will change**.
    - A 14N force (for example) will change an object's momentum by 14 units every second.
    - As an equation: Force x Time = Momentum change
        - Force needed = Momentum change / Time taken
        - Time taken = Momentum change / Force
        - If there is more than one force, then the ‘Force’ in these equations is the Resultant Force (see the Force and Motion sheet for an explanation).
- New ideas
    - If momentum = mass x velocity, the mass will not change, so
        - change in momentum = mass x change in velocity
    - Depending on whether the change is in the direction of the original motion, the new momentum will either be
        - New momentum = Old momentum + Change if change is in the original direction
        - New momentum = Old momentum - Change if change is in the opposite direction.
    - If something reverses direction, we need to use ideas from our velocity sheet to work out the change in velocity. Therefore something which hits a wall at 2m/s and bounces off the other way at 1m/s has
        - a velocity which changes from 2m/s one way to 1m/s the other
        - this is therefore a change of 3m/s in the direction away from the wall

Teacher Quarter Briefing

- Introduction: https://youtu.be/ifjFAJOJC4A
- Practice: class https://isaacphysics.org/gameboards#itsp_teach_forcemom
- Review: https://youtu.be/OD-IEwP4bho
- If you want to go further: https://isaacphysics.org/gameboards?stage=all#phys_book_gcse_ch_2_19

Class Question Notes

The worksheet can be printed either in full, or in cloze text form (where the red text is missing, and students can complete these blank spaces after class discussion). The online version of the notes requires the appropriate text to be dragged to the right place in the sentences.

Shallow learning gradient online assignment - q1,2,3,6,7,8,9
Steeper learning gradient online assignment - q1,3,4,5,7,8,10,11

1. With scaffolded support and an example, the student works out that mass x velocity change = momentum change.
2. A lamb slows down from 4m/s to 1m/s. The change in velocity is 3m/s, so using the lamb's mass of 25kg, the change in momentum can be worked out as 25kg x 3m/s = 75 kg m/s. The original momentum is 25kg x 4m/s = 100 kg m/s. The new momentum can be worked out in two ways
    a. mass x new velocity = 25kg x 1m/s = 25 kg m/s
    b. old momentum - change = 100 kg m/s - 75 kg m/s = 25 kg m/s We subtract because the change of momentum is opposite to the original direction of motion (reducing it).
3. In this question, students work out momentum changes from masses and velocity information. The easiest way is first to work out the velocity changes (2.5m/s, 15m/s and 1.2m/s respectively) and then multiply them by the mass. However if students wish, they can work out the momentum before and after and subtract to get the change.
4. After an example, students work out a momentum change for a netball which reverses in direction (3.5m/s changing to 2.5m/s the other way means that there is a 6.0m/s velocity change). The question is done in stages working out the momentum change when it is stopped, and then the change which happens when it speeds up during the bounce.
5. In this question, students repeat the logic of Q4 but without the scaffolded support.
6. In this question, using scaffolded reasoning, students first work out a starting momentum (2kg x 0.5m/s), then work out the change in momentum (from force x time, which is given: 1.5N x 2s), and then add these to get the final momentum.
7. In this question, with scaffolded support, students work out the force needed to change a trolley's momentum from 2.5 kg m/s to 1.0 kg m/s. Change in momentum = 1.5 kg m/s (albeit backwards). This is equal to force x time, and the time is 3s, so the force in newtons is 1.5 / 3.
8. Students work out the speed change of an aircraft accelerating using momentum information, with scaffolded support (the question is broken into stages).
9. This is similar to Q8, but students are not given scaffolded support.
10. Students work out the force needed to slow a car down in two different times.
11. Students write word equations linking mass, resultant force, time and velocity change. (Resultant force x time = mass x velocity change)

Homework Question Notes

These questions have a very similar form to the questions in the class task, so students can refer back to their earlier answers to help

Shallow learning gradient online assignment - q1,2,3,4,7,8,9,10,12
Steeper learning gradient online assignment - q1,3,4,5,6,8,10,11,13,14

1. Students complete sentences to describe the link between momentum and force.
2. With scaffolded support and an example, the student works out that mass x velocity change = momentum change.
3. A cat slows down. In the first part of the question, the change in velocity is 2m/s backwards, so using the cat's mass of 4kg, the change in momentum can be worked out as 4kg x 2 m/s = 8 kg m/s backwards.
4. In this question, students work out momentum changes from masses and velocity information. The easiest way is first to work out the velocity changes (2.5m/s, 15m/s and 1.2m/s respectively) and then multiply them by the mass. However if students wish, they can work out the momentum before and after and subtract to get the change.
5. Students work out a momentum change for a cricket ball which reverses in direction (35m/s changing to 45m/s the other way means that there is a 80m/s velocity change). The question is done in stages working out the momentum change when it is stopped, and then the change which happens when it speeds up during the bounce.
6. In this question, students repeat the logic of Q5 but without the scaffolded support.
7. Students complete a sentence linking force to the change of momentum each second (a 4N resultant force changes the momentum by 4 kg m/s each second).
8. In this question, using scaffolded reasoning, students first work out a starting momentum (2kg x 1.0m/s), then work out the change in momentum (from force x time, which is given: 4N x 0.5s), and then add these to get the final momentum.
9. In this question, with scaffolded support, students work out the force needed to change a badger's momentum from 10 kg m/s to 0 kg m/s. Change in momentum = 10 kg m/s. This is equal to force x time, and the time is 0.2s, so the force in newtons is 10 / 0.2.
10. Students work out the speed change of a train accelerating using momentum information, with scaffolded support (the question is broken into stages).
11. This is similar to Q9, but students are not given scaffolded support.
12. Students write a word equation for resultant force in terms of mass, time and velocity change. (Resultant force = mass x velocity change / time) Note that as velocity change / time is the same as acceleration, they have shown that F=ma.
13. Students work out the force needed to slow a coach passenger down in two different times. You can use the answers to discuss the importance of avoiding rapid velocity changes if you want to keep people safe on the road (e.g. seat belts, padding, crumple zones etc.)
14. Students extend Q13 to work out the force on the coach as a whole.

Extension questions from 'Step Up to GCSE Physics':
https://isaacphysics.org/gameboards#step_up_phys_13_b1
https://isaacphysics.org/gameboards#step_up_phys_14_b1
https://isaacphysics.org/gameboards#step_up_phys_15_b1