Force of Impact

This exercise challenges the student to consider the effect on a body when it hits another edge on. Newton's second law is tested. Results can be compared to a car hitting an electric light pole, tree, guardrail etc.

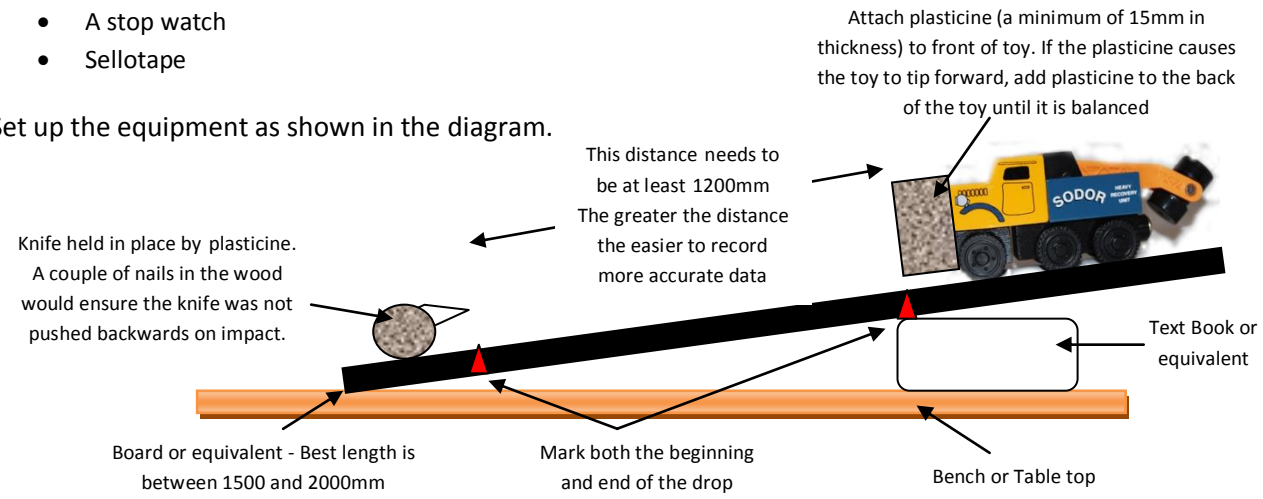
Guard Rails[1] are engineered to absorb the kinetic energy of an impacting vehicle. This is accomplished by deforming (flattening) the guardrail. End terminals are designed to reduce the problems associated with impacting vehicles, such as spearing, vaulting and rollover. Images 1 and 3 are two designs to absorb the impact. Image 2 is a slightly curved end of a straight guardrail (fishtail model) – 2a shows the knife edge end close up from image 2. All photos taken in Australia.

There are three parts to this exercise. Depending on the age bracket being taught, the user might wish to limit the parts used.

Equipment required: see suggestions made by teachers on page 4

- A free wheeling toy car
- A solid lump of plasticine
- A board of approximately 1500 to 2000mm in length and wide enough to run a toy car without falling off an edge
- Text books or eqivalent to act as spacers 50mm in thickness
- Solid weights (Science Lab 10g or 50g weights or 50 cent coins) you will need about 5 identical in mass weights
- A bread knife
- A stop watch
- Sellotape

Set up the equipment as shown in the diagram.



Method: **(each of the following steps should be repeated three times to avoid any major error)**

Part A

1. Place the text books etc under one end as shown lifting the end 50mm. Allow the toy to roll down a distance of say 1200mm. Mark the toys plasticine front and knife edge as the distance travelled e.g. 1200mm. Allow the toy to roll down the board recording the
    a. time it took to reach the knife.
    b. indent measurement into the plasticine on the front of the toy.
2. Return the plasticine on the toy to its original shape and reposition the knife ensuring both toy's plasticine and knife's edge are in the same position as in step 1. Increase the text book height by another 50mm. Allow the toy to roll down the board and record all details as before.
3. Keep repeating steps 1 and 2 until the toy's plasticine is close to being cut in two.
4. Enter your data in Table 1.

[1]Further information on types of guardrails can be gained from Australian Companies:
Ingal Civil - http://www.ingalcivil.com.au/guardrail.html
Guardrail Installations Australia Pty Ltd - http://www.guardrailinstallations.com/Guardrail-Installations-contacts.htm

Table 1 – knife edge

Text Book Height		Length of Slope (mm)	Plasticine Indent (mm)	Average indent (mm)	Time (seconds)	Average Time (seconds)
50mm	1	1200				
	2	1200				
	3	1200				
100mm	4	1200				
	5	1200				
	6	1200				
150mm	7	1200				
	8	1200				
	9	1200				
200mm	10	1200				
	11	1200				
	12	1200				

5. Calculate the AVERAGE SPEED for each roll down.

AVERAGE SPEED = Distance Travelled divided by **Time Taken**

6. What did you learn?
   From your results, did the indent in the plasticine
   a. Increase with each increase in text book height?
   b. Stay the same?
   c. Decrease the indent with each added height? Explain you findings!

Part B

7. Now repeat the prac but this time turn the knife blade so the flat side faces the toy and plasticine.
8. Enter your results in Table 2.

Table 2 – Flat side of knife

Text Book Height		Length of Slope (mm)	Plasticine Indent (mm)	Average indent (mm)	Time (seconds)	Average Time (seconds)
50mm	13	1200				
	14	1200				
	15	1200				
100mm	16	1200				
	17	1200				
	18	1200				
150mm	19	1200				
	20	1200				
	21	1200				
200mm	22	1200				
	23	1200				
	24	1200				

9. What did you learn?
   From your results, did the indent in the plasticine
   a. Increase with each increase in text book height?
   b. Stay the same?
   c. Decrease the indent with each added height? Explain you findings!
   d. How do these results differ to when the knife edge was facing the toy and plasticine? Explain!

Part C

10. To confirm what you have learnt, this time weigh the toy and plasticine and repeat steps 1 and 2 explained on page 1.
11. Instead of increasing the text book height, increase the mass of the toy and plasticine by using sellotape to hold in place a single weight. Allow the toy to roll down the board, timing how long it takes to hit the knife. Measure the indent.
12. Repeat steps 7 and 8 three times before adding an additional weight and testing for indent and time.
13. Complete Table 3.
14. Calculate the speed for each drop.

Table 3

Text Book Height (mm)		Mass of Toy, Plasticine & additional weight (grams)	Length of slope recorded in (metres)	Plasticine Indent recorded in (metres)	Average indent recorded in (metres)	Time (seconds)	Average Time (seconds)	Calculated ACCELERATION metres/second^2 (m/s^2)	Calculated FORCE Newtons (N)
50	25		1.2						
50	26		1.2						
50	27		1.2						
50	28		1.2						
50	29		1.2						
50	30		1.2						
50	31		1.2						
50	32		1.2						
50	33		1.2						
50	34		1.2						
50	35		1.2						
50	36		1.2						

Where Force is not being measure in Newtons (N) and assistance is required, visit
http://en.wikipedia.org/wiki/Pound-force#Conversion_to_other_units OR
http://en.wikipedia.org/w/index.php?title=Special%3ASearch&search=Newton+unit

15. Using the formula **$s = \frac{1}{2} at^2$** where **s** is distance travelled; **a** is the acceleration and **t** is time we can rearrange the formula algebraically to read **acceleration** = **2 X distance travelled** divided by **time X time** – enter your calculated acceleration in the table.
16. Sir Isaac Newton stated in his Second Law of motion that **Force = Mass X Acceleration** or simply put **F=ma.** Calculate the **FORCE** exerted on the plasticine each time the plasticine hit the knife using the **Total Mass** (toy, additional weight and plasticine) and the calculated **Acceleration** for each **Mass.** Record this calculation in Table 3.

    Wikipedia description: http://en.wikipedia.org/wiki/Newton_(unit)
    The newton is the unit of force derived in the SI system; it is equal to the amount of net force required to **accelerate** a **mass** of one **kilogram** at a rate of one **meter per second per second**. In **dimensional analysis**, F=ma, multiplying m (kg) by a (m/s^2), the dimension for 1 newton unit is therefore:

$$1\text{N} = 1\frac{\text{Kg X metres}}{\text{Seconds}^2}$$

    On the same graph plot your results from the three tables showing speed on one axis and mass on the other.

17. From the graph, what stands out as the major factor of doing the most damage if the toy car was a car you were driving? Explain your findings.

Key to terms:
accelerate – http://en.wikipedia.org/wiki/Accelerate
mass – http://en.wikipedia.org/wiki/Mass
kilogram – http://en.wikipedia.org/wiki/Kilogram
meter per second per second – http://en.wikipedia.org/wiki/Meter_per_second_squared
dimensional analysis – http://en.wikipedia.org/wiki/Dimensional_analysis

Suggestions for the various Parts of this practical.

18. The preferred board is one of the following:
    a. Hot wheels track
    b. Laminated surface (desk top that seats two students is usually 1200mm long – the desk can be lifted one end with equal spacers under each of the two legs and use a second desk in place of the listed nails to stop the knife from being forced backwards.
    c. MBF where no grain or knots can alter the direction of the toy car – it has been found that timber with knots and or grain (that can be felt) can make the car change direction at times where the car can swerve away from hitting the knife edge at all.

    NB: For all surfaces ensure that no sticky surface areas are present. Sticky surface areas will cause greater friction and slow the vehicle down.

19. The car:
    a. must have some mass or if too light will not give an indent reading that is noticable.
    b. The toys axles must allow the car to travel in a straight line. Some toys have very light wire as the axle and under a heavy handed student the axle will bend. It was found that wheels can rub on other parts of the car etc all causing retardation to the speed of the car down the board.
    c. Plasticine pushed to far into the car at the front has also fouled the front wheels of the car. Ensure that students attach the plasticine to the bonnet of the car rather than to the wheel area.
20. The knife edge:
    a. If using a wide board, it was found that
        i. a piece of thin sheet metal or
        ii. a plastic ruler with a thin edge,

    close to the width of the board, was better than using a bread knife whose blade length was not as wide as the board.