Traffic Accident: who is to blame?

Teacher Notes

Theoretical ideas to be introduced/reinforced during the investigation

1. Friction occurs between the tyres of a car and the road surface.
2. A force is needed to allow the car to move.
3. The minimum force needed to start the car is the limiting stationary friction (often called the limiting static friction).
4. Once the car moves, a slightly smaller force is needed to keep it moving at a constant speed. This is the kinetic friction.
5. Luckily this is quite small as the amount of type surface touching the road is small and the wheel turns. But if the brakes are locked, the static friction and kinetic (or now called the sliding) friction are large.
6. When a car is moving, the brakes are applied and the wheels locked then the car slows down by sliding friction. Here the force is exerted between the car and the road and will depend on the weight of the car.
7. Investigations have showed that friction is approximately directly proportional to the normal reaction. On a level surface, the normal reaction is equal to the weight of an object.
8. The ratio of friction to normal reaction is constant and depends only on the nature of the contact surface. This is called the coefficient of friction, u,

   Thus $u = F/N$ or $F = uN$
9. u for sliding friction is slightly less than u for static friction.
10. A u value of 0.7 means that friction opposing the motion of an object on a level surface is 0.7 times the weight of the object. The u value between tyre and road surface is a key in accident investigation.
11. When a car skids, the decelerating force is the sliding friction. It is the backward push of the ground on the types. On a level road, this force is equal to the product of the coefficient of type/road friction, u, and the weight of the car

    $F = umg$ where m = mass of the car and

    g = the acceleration due to gravity.
12. Suppose a vehicle travels at a speed = v, then its K.E. = $1/2mv^2$

    When the car stops, the decelerating force is given by $F = umg$

    Work done W against friction is $W = Fs = umgs$

    When the vehicle stops, its K.E = 0.

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The change in K.E is the same as the work against friction

$1/2mv^2 = umgs$,   or $v = (2ugs)^{1/2}$

13. This shows that the skid-to-stop distance depends only on the coefficient of tyre/road friction and the speed of the vehicle prior to skidding. It is independent of the mass of the vehicle.

Calculations for the boy (time taken)

Average speed of walking (as indicated by the witness) = 5/2.9 = 1.72 m s^{-1}

Distance before impact = 4.6 m

Time taken to get to impact position = 4.6/1.72 = 2.7 s

Calculations for the van (time taken)

Assuming the final velocity was 10 km h^{-1} = 2.78 m s^{-1}

Then velocity of the van before skid marks = $(10/3.6 + 2 \times 0.76 \times g \times 19.8)^{1/2}$ = 17.4 m s^{-1} or 62.7 km h^{-1}

Skidding time = t = v-u/at = (2.78 - 17.4)/-0.76x9.81 = 2.0 s

If reaction time is taken as 0.8 s

then skidding distance + reaction distance = 19.8 + 0.8x17.4 = 33.7 m

and total time for reaction + skid = 2.0 + 0.8 = 2.8 s

When the yellow light came on, time before collision

= 2.8 + 3.0 = 5.8 s

If the van driver had applied his brakes then, his stopping distance would have avoided the accident.

Or alternatively had the van been travelling at 40 km h^{-1} as per the speed limit, the accident could also have been avoided.

Stopping distance from point of perception = skid distance + reaction time distance

= 40/3.6 x 40/3.6/2 x 0.76 x 9.81 + 40/3.6 x 0.8 = 17.2 m

(much less than the 33.7 m it took at 62.7 km h^{-1})

A Possible Conclusion

1. The least speed of the van was 62.7 km h^{-1}. This was above the speed limit.
2. The van driver did not brake when the yellow light came on: he braked only when seeing the boy stepping off the kerb.

A crucial statement in this reconstruction was that the boy started crossing the road when the 'green man' came on.

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To Determine the Coefficient of Friction

Apparatus Required; Strong elastic band (or bands joined together)

Ruler, Wooden block (about 10cm x 5cm x 5cm) with hook on one of the 5x5 faces; different surface materials length at least 20 cm and width at least 5 cm) e.g. sandpaper, wood, metal, ice?

Procedure

1. Attach the elastic band to the wooden block and determine the extension of the band when the block is lifted (i.e. determine the extension from the weight of the block),
2. Place the wooden block on each of the surfaces in turn. Determine the extension of the elastic band when, on pulling on the band in a horizontal direction, the block just begins to move.
3. Determine the ratio of the extension of the elastic band when pulling the block horizontally compared to the extension given by the weight of the block.
4. How does this ratio differ when using the different surfaces ?
5. Given that this ratio is the coefficient of friction, derive a relationship between the coefficient of friction, the weight of the block and the force need to just move the block in a horizontal direction.

Question. How many readings will you take for each measurement to maximise accuracy ?

Notes on the experiment

Instead of using an elastic band it is possible to use a spring balance when the force (in Newtons) can be directly determined.

The experiment makes use of the definition of the coefficient of friction as F/N, where F is the force needed to overcome friction and begins to move the block, and N is the normal force on the block (which in this case is the weight of the block of wood).

Thus μ (coefficient of friction) = F/N where both F and N α length of the extension of the elastic band

$$\text{Hence } \mu = \frac{\text{extension of the elastic band in pulling horizontally on the block}}{\text{extension of the elastic band by the weight of the block}}$$

Note that it is not actually necessary to know the weight of the block. The coefficient of friction does not actually depend on the weight. This also applies to the frictional force exhibited on trying to move (or stop) the movement of a car.

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For a car travelling at v km hr^{-1}, the kinetic energy changes from $\frac{1}{2}mv^2$ to O (as v = 0 when the car stops) When the car is skidding, the work done is against friction. The work done is μ. mg. s where s is the skidding distance and mg is the weight of the car.

At the end of the skidding the car has stopped. Therefore

$\frac{1}{2}mv^2 = \mu . mg . s$ and hence $v^2 = 2 \mu gs$ or $v = (2 \mu gs)^{\frac{1}{2}}$

The change in velocity from skidding is thus independent of the mass of the van.

Thus if the velocity before skidding was 30 ms^{-1}, the distance of skidding is given by

$s = 30 \times 30/2 \times \mu \times 10$ (assuming that the deacceleration against gravity is 10 ms^{-2})

If the coefficient of friction for the tyre of the van against the road surface is 0.76, then the skidding distance is 900/15.2 metres = 59.2 metres.

On the other hand, if the skidding distance was 15 metres, then the velocity of the van just before the skidding began is given by $(2 \times 0.76 \times 10 \times 15)^{\frac{1}{2}}$

$= \text{approx } 15 \text{ ms}^{-1}$

This experiment ignores the concept of static friction and kinetic friction as separate entities (the difference is very small)

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