

CfE Higher 2016

6. A website states “*Atoms are like tiny solar systems with electrons orbiting a nucleus like the planets orbit the Sun*”.

Use your knowledge of physics to comment on this statement.

3

There are similarities to the solar system in that;

- there is a large mass at the centre
- electrons ‘orbit’ the central mass (nucleus)
- relative distances between them are large

The differences between solar system and atom include

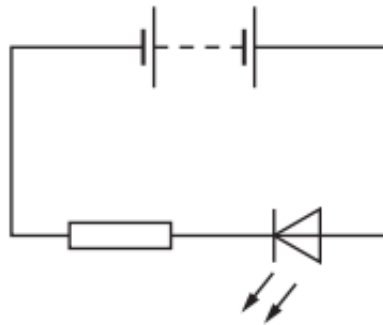
Gravity is the main force in the solar system. This force is only attractive and the exchange particle is thought to be the graviton, which has not yet been detected. Planet positions are determined by their relative masses, whereas in the atom all electrons are identical. They have the same mass, but occupy different energy levels.

However, **in the atom electromagnetism is the fundamental force** (the photon is the exchange boson). This force can be attractive (opposite charges) and repulsive (like charges).

The centre is also made up of smaller particles, protons and neutrons which are in turn made up of quarks. The strong nuclear force holds the nucleus together.

CfE Higher 2016

11. A student is describing how the following circuit works.



The student states:

“The electricity comes out of the battery with energy and flows through the resistor using up some of the energy, it then goes through the LED and the rest of the energy is changed into light waves.”

Use your knowledge of physics to comment on this statement.

3

Battery is a source of emf, in which each coulomb of charge is given energy. Energy is changed into heat energy in the resistor and light energy in the LED. The energy given up by each coulomb of charge is known as the potential difference. The emf is equal to the sum of potential differences in the circuit.

The LED is a forward biased p-n junction. Electrons in the conduction band of the n type material jump down into holes in the valence band of the p type material. On account of this coming together, the change in energy levels, photons are released.

CfE Higher 2017

4. Some motorways have variable speed limits, with overhead information boards displaying the maximum speed allowed. This system is designed to keep the traffic flowing and to avoid congestion.



In this system, the flow of traffic is observed and the maximum speed to be displayed is determined using

$$\text{speed} = \text{frequency} \times \text{wavelength}$$

Use your knowledge of physics to comment on this system for determining the maximum speed to be displayed.

3

We have to decide how to measure v (velocity), f (frequency) and λ (wavelength) in these equations and define

f – number of cars per second

λ – space between cars

v – not the vehicle speed but the rate at which the spaces are moving

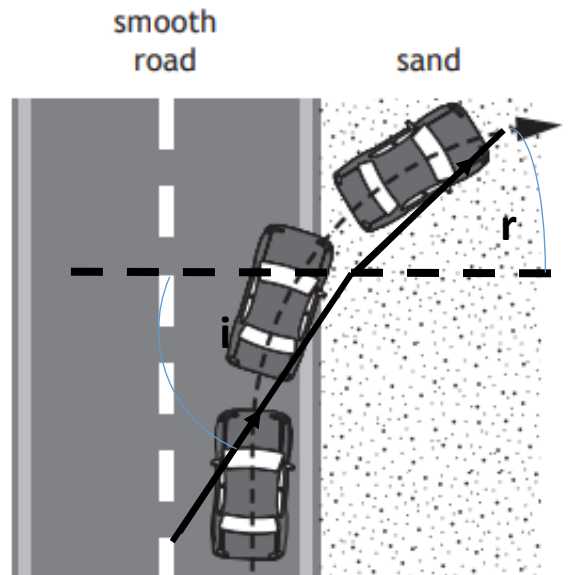
If a vehicle's speed increases, stopping distance increases and we need more time to stop safely.

The benefits of using this system could be that, as the wavelength gets larger, we could allow a larger vehicle speed limit, $\lambda = v/f$ we limit this to keep a safe stopping distance between cars.

However there are also limitations to this system because as frequency increases, in theory we should allow speed to increase ($v = f \lambda$).

BUT this leads to an increasing speed limit which means more cars per second, decreasing the space between cars, which would not be safe.

11. The use of analogies from everyday life can help better understanding of physics concepts. A car moving from a smooth surface to a rough surface, eg from a road to sand, can be used as an analogy for the refraction of light.



Use your knowledge of physics to comment on this analogy.

3

Refraction is the change in speed of light as it passes from one material to another. The smooth road, perhaps represents air, and the sand is another material, which is optically more dense i.e. has a greater refractive index.

The car will slow down on the rougher surface just as light slows as it passes into the material with a greater refractive index.

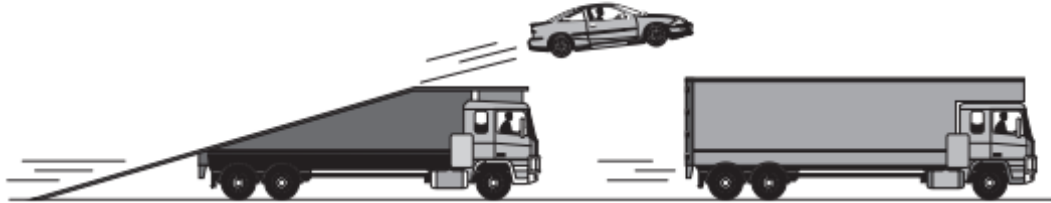
Sometimes that change in speed is accompanied by a change in direction. The annotations on the diagram show the angles of incidence and refraction and the normal and how the angle of refraction is smaller than the angle of incidence. The refractive index can be calculated by using $n = \sin i / \sin r$.

The car appears to follow a curved path but light always travels in straight lines

CfE Higher 2018

4. A stunt is being carried out during the making of a film.

A car is to be driven up a ramp on a moving lorry by a stunt driver, who will attempt to land the car safely on the roof of a second moving lorry. The car is to stop on the roof of the second lorry while this lorry is still moving.



Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully.

3

The speeds of the lorries relative to one another are important. If both lorries are travelling at the same speed it is as if both are stationary. The relative speed of the car has to be greater than the speed of the lorries.

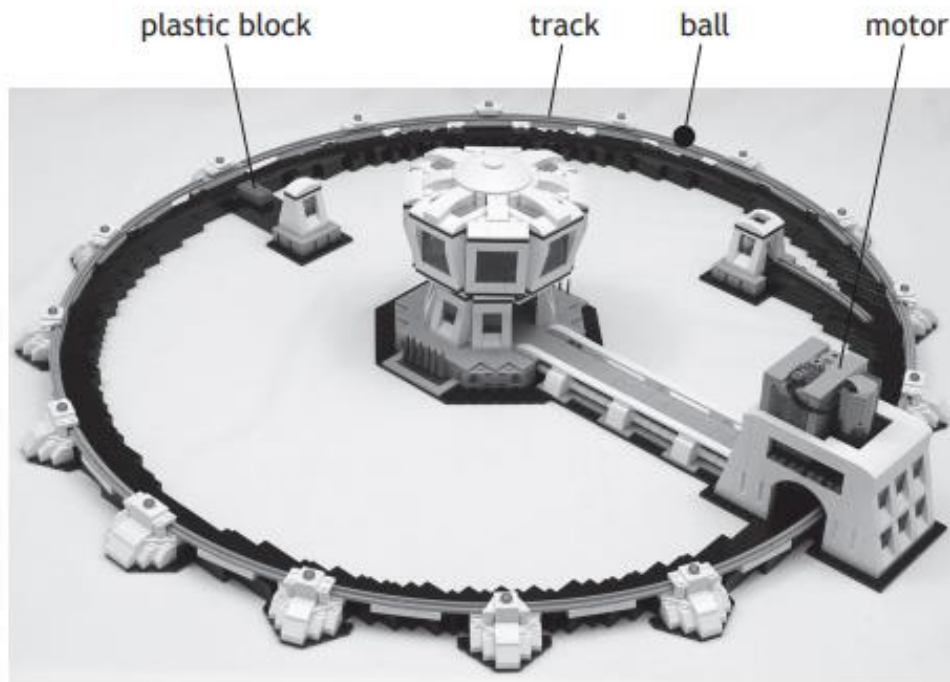
The collision between the car and lorry needs to ensure that the car stops in a short distance and therefore a short time. So for the momentum to change the force must be big according to $Ft = \Delta mv$.

The resultant speed of the car on collision is determined by both the horizontal velocity and the vertical velocity so the planning of the stunt will need to consider the angle of the ramp and the speed of the vehicle on the ramp.

The deceleration of the car on the ramp will come about due to an unbalanced force acting upon the car. During this deceleration the kinetic energy of the car will convert to work done against friction (heat).

6. (continued)

- (c) A student builds a model of a particle accelerator. The model accelerates a small ball on a circular track. A battery-operated motor accelerates the ball each time it passes the motor. To cause a collision a plastic block is pushed onto the track. The ball then hits the block.



Using your knowledge of physics comment on the model compared to a real particle accelerator, such as the large hadron collider at CERN.

3

The similarities to CERN are

The circular shape is the same as the synchrotron at CERN

The ball requires energy from a motor. At CERN energy is given to the particles by an electric field causing them to accelerate.

The ball is kept on track by the rails. In the LHC, the particles are made to follow a circular path because of the electromagnetic field surrounding the beam.

The ball collides with a target at a particular point, which is where the particle detectors would be (ATLAS, LHC-B and ALICE)

The differences between the two models are

The relative scale. The diameter of the LHC is kilometres across

The velocity of the ball is very small compared to the particles in the accelerator. These can reach velocities close to the speed of light.

For the collisions at CERN to have enough energy, the particles collide head on so particles are accelerated in both directions, the target isn't a solid, sitting still.

The total energy before the collision is much greater if both objects are moving

Total $E_k = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$ which is less if v_2 is zero.

CfE Higher 2019

3. A footballer tells teammates that a football can be kicked a much greater distance when the ball is initially travelling towards them, compared to kicking a stationary ball.



Use your knowledge of physics to comment on this statement.

3

To cover a greater distance the ball must leave the foot at a greater velocity.

(distance = velocity x time as the ball obeys Newton's first law when it is no longer in contact with the foot)

The question is related to conservation of momentum and the fact that

Impulse = Change in momentum

$$Ft = mv - mu$$

Ball initially at rest

If the ball leaves the foot at 5ms^{-1} and has an initial velocity of 0ms^{-1} .

We assume that the ball has a mass of 0.4kg and contact is for 0.1 s . How much force is needed?

$$Ft = mv - mu$$

$$F = 0.4 (5 - 0) \times 0.1 = 0.2 \text{ N}$$

Ball travelling towards player

If the initial velocity is 4ms^{-1} towards you and we kick with the same force, 0.2N , then what would be the velocity of the ball

$$0.2 = 0.4 (v - (-4)) \times 0.1$$

$$0.2 = 0.04 (v + 4)$$

$$v + 4 = 0.2/0.04$$

$$v + 4 = 5$$

$$v = 1 \text{ ms}^{-1}$$

The ball leaves the foot at 1ms^{-1} which is less.

To get the ball to move off at 5ms^{-1} how much force would it take?

$$F = 0.4 (5 - (-4)) \times 0.1$$

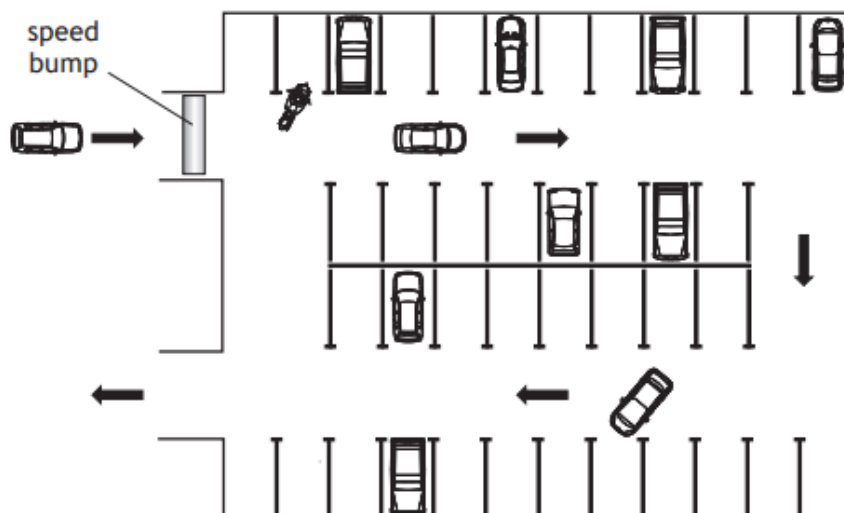
$$= 3.6\text{N} - \text{a much greater force is needed.}$$

To get the ball to travel further needs more force if it is initially travelling towards you.

13. (continued)

- (d) The use of analogies from everyday life can help improve the understanding of physics concepts.

Vehicles using a car park may be taken as an analogy for the charging of a capacitor.



Use your knowledge of physics to comment on this analogy.

3

The car park is a capacitor, the cars are electrons and the speed bump is a resistor. The number of cars in the car park represent the charge on the capacitor. The greater the number of cars in the car park, the more difficult it is to find a space. This slows up the filling of the car park just as charge on the capacitor makes it more difficult for charge to flow around a circuit. When the car park is full no more cars will find a spot just as no more charges will build up on the capacitor when it is fully charged.

Cars exit the car park quicker than they enter. This can be attributed to the speed bump. In a circuit with a resistor a capacitor will charge or discharge slower than one without a resistor. The speed bump at the entrance acts like a resistor in the charging circuit whereas the discharging circuit has no resistor just as the exit has no speed bump.