SENIOR SECONDARY INTERVENTION PROGRAMME 2013

education

Department: Education

GAUTENG PROVINCE

GRADE 12

PHYSICAL SCIENCES

LEARNER NOTES

The SSIP is supported by

TABLE OF CONTENTS

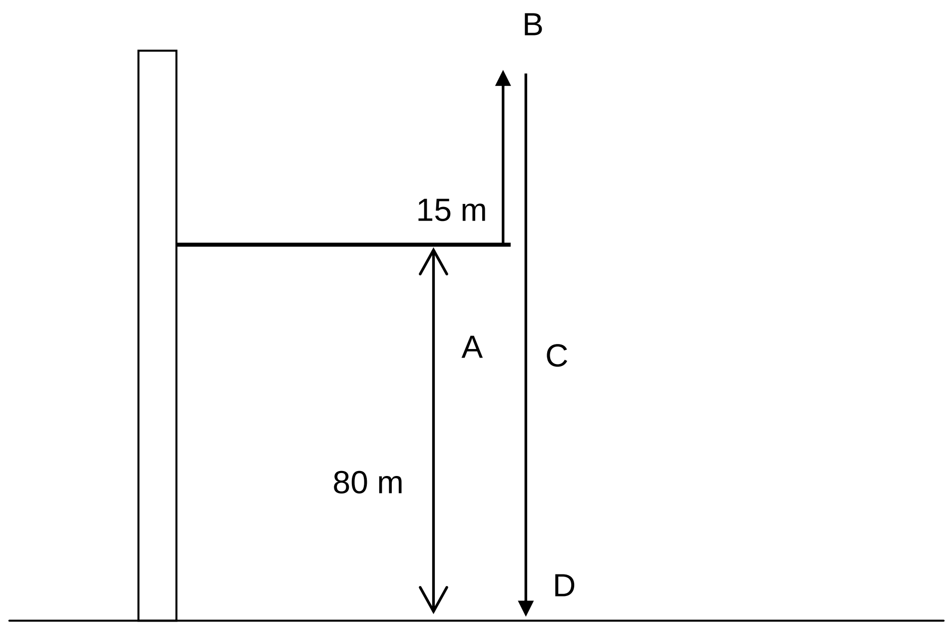
TOPIC 1: MECHANICS – PROJECTILE MOTION

Learner Note: Always draw a diagram of the situation and enter all the numerical values onto your diagram. Remember to SELECT A DIRECTION AS POSITIVE OR NEGATIVE.

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 6 minutes *(Taken from the WC Prelim. paper 2008)*

A cross-bow (bow and arrow) is used to shoot an arrow vertically upwards into the air from the top of an 80 m high platform. The arrow reaches a height of 15 m above the platform and then falls to the ground below. Ignore the effects of air friction.



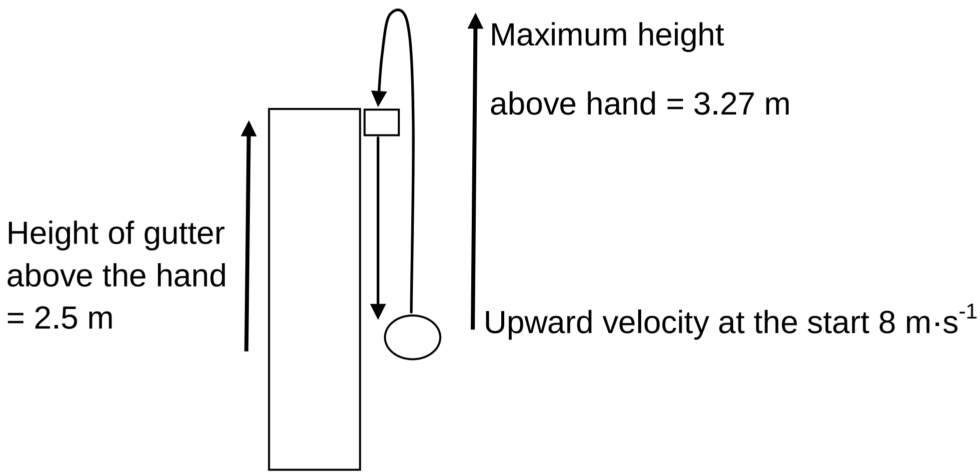
1.1 Calculate the magnitude of the velocity of the arrow at the instant it is shot up into the air from the top of the platform. (4)

1.2 Calculate the time it takes for the arrow to reach the ground from the moment it is shot upwards (4)

[8]

QUESTION 2: **4 minutes** (*Taken from Gauteng Prelim paper 2009)*

Sandile throws a small metal ball of mass 10 g vertically up into the air. The ball accidentally lands in the gutter of a building. It remains in the gutter for 0.5 s during which time it rolls a few centimetres in the gutter, and then falls through a hole in the gutter back to the original position in Sandile's hand. The upward velocity with which the ball left Sandile's hand was 8 $m{\cdot}s^{-1}$. When the ball finally falls back into his hand, the velocity is 7 $m{\cdot}s^{-1}$ downward. Ignore friction as well as all horizontal movement and answer the following questions:.



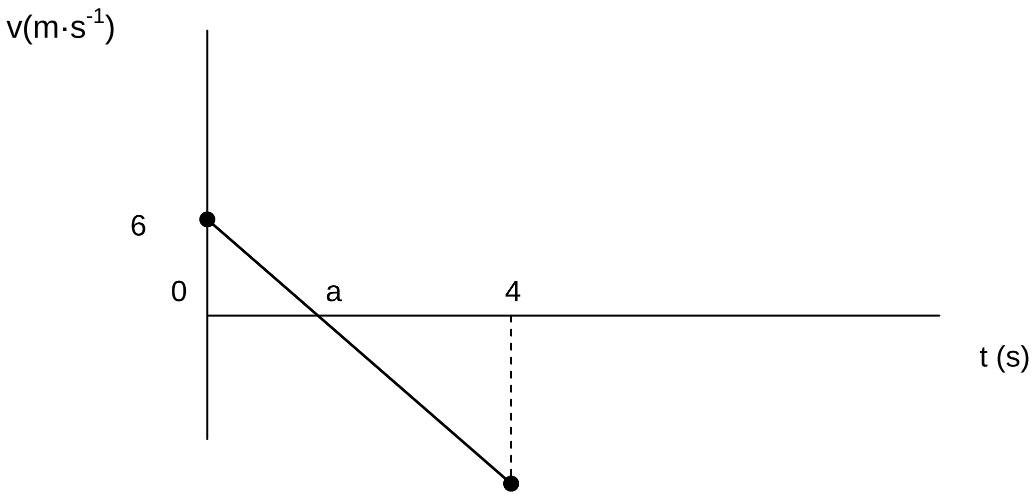
2.1 At what speed would the ball have fallen into Sandile's hand if the ball had not fallen into the gutter? (1)

2.2 The maximum height that the ball reaches above Sandile's hand is 3.27 m. Prove that this is correct by using an equation of motion and not energy principles. (4)

[5]

QUESTION 3: 20 minutes

A helicopter is rising vertically at constant velocity. When the helicopter is at a height of 100 m above the ground, a girl accidentally drops her camera out of the window of the helicopter. The velocity-time graph below represents the motion of the camera from the moment it is released from the helicopter until it strikes the ground. Ignore air-resistance.



3.1 What is the **value** of the slope (gradient) of the graph? (2)

3.2 Use the gradient to calculate the time *a* on the time axis. (5)

3.3 Which point on the path of the camera corresponds to time *a*? (1)

3.4 **Use an equation of motion** to calculate the magnitude of the velocity of the camera as it reaches the ground at 4 s. (4)

3.5 **Use the graph** to calculate the maximum height reached by the camera. (5)

3.6 Draw a rough displacement-time graph **and** an acceleration-time graph to represent the motion of the camera from the moment it was released until it hit the ground. Time values must be shown but y-axis values need not be shown. (8)

[25]

SECTION B: ADDITIONAL CONTENT NOTES

Equations of motion are equations that are used to describe the motion of a body while experiencing a force as a function of time. These equations apply only to bodies moving linearly (unilaterally) i.e. in one direction with a constant acceleration. The body's motion is considered between two time points: that is, from one initial time point and its final point in time.
Motion can be described in different ways.

Words: When your friend explains his first experience in driving a car and tells you in detail how he struggles to pull off and stop.

Diagrams: When you draw a sketch to explain a specific movement.

Graphs: We use three different graphs.

1. velocity – time graph
2. acceleration – time graph
3. position – time graph.

METHOD FOR ANSWERING THESE QUESTIONS:

STEP 1: Write down all the information given from the question

STEP 2: Identify which formula to use, i.e. identify the known and unknown quantities

STEP 3: Substitute into the equation

STEP 4: Interpret the answer

EXAMPLE 1:
A car is travelling at 5 m·s^{-1} and it starts to accelerate at 2 m·s^{-2} for 3 s. What distance will the car cover in the 3 s?

ANSWER:

STEP 1: $v_i = 5$ m·s^{-1}
$a = 2$ m·s^{-2}
$t = 3$ s
$x = ?$

STEP 2: $\Delta x = v_i\Delta t + ½ a\Delta t^2$

STEP 3: $\Delta x = (5)(3) + ½ (2)(3)^2$
$= 135$ m

STEP 4: The car will travel 135 m in the direction of the motion.

Introduction to the use of equations of motion in the vertical direction

A projectile is an object that is given an initial velocity by shooting or throwing etc, and once launched, the only force acting on it is the force due to gravity. In the absence of air resistance, the object is free falling.

Terminal velocity is reached when the downward force of gravity and the upward force of air resistance are equal, and now the object falls at a constant velocity as a result of there being no resultant force acting in on the object.

The Equations of Motion for Vertical Projectile Motion

LINEAR MOTION	***VERTICAL PROJECTILE MOTION***
$v_f = v_i + a\Delta t$	$v_f = v_i + g\Delta t$
$\Delta x = v_i \Delta t + \frac{1}{2} a\Delta t^2$	$\Delta y = v_i \Delta t + \frac{1}{2} g\Delta t^2$
$v_f^2 = v_i^2 + 2a\Delta x$	$v_f^2 = v_i^2 + 2g\Delta y$

substitute 'g' for 'a' and 'Δy' for 'Δx' in vertical projectile motion problems

All objects are attracted to the earth with a gravitational force called WEIGHT.

All objects will accelerate towards the earth with a constant acceleration called the **gravitational acceleration (g)** which has a value of 9,8 $m \cdot s^{-2}$.

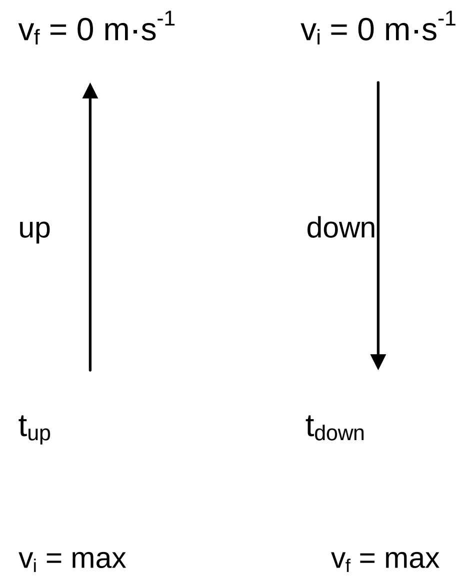
g = 9,8 $m \cdot s^{-2}$ which is found on the information sheet.

Gravitational acceleration (g) is ALWAYS downwards no matter whether the object is being thrown up or falling down.

Important facts concerning Vertical Projectile Motion:

- At the greatest height of the upward motion, $v_f = 0\ m{\cdot}s^{-1}$
- The object will take the same time to reach its greatest height from point of upwards launch as the time taken to fall back to point of launch

  ($t_{up} = t_{down}$)



- Can have motion described by a single set of equations of motion for the upward and downward motion.
- If the object is being released from rest or being dropped, its initial velocity is $0\ m{\cdot}s^{-1}$.
- If the object is being thrown upwards, it must start with a maximum velocity and as it moves up, the velocity decreases until it stops.
- These are vectors thus direction is important.

SECTION C: HOMEWORK

QUESTION 1

A hot-air balloon is rising upwards at a constant velocity of 5 m·s^{-1}. When the balloon is 100 m above the ground, a sandbag is dropped from it (see FIGURE 1). FIGURE 2 shows the path of the sandbag as it falls to the ground. Ignore air resistance.

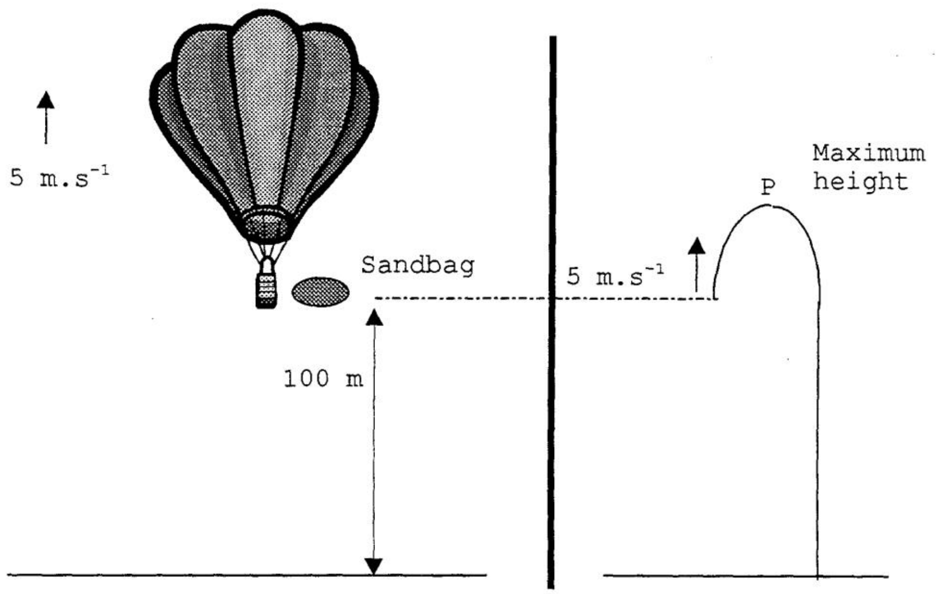


FIGURE 1 **FIGURE 2** Motion of sandbag

1.1 What is the acceleration of:

1.1.1 The hot-air balloon while the sandbag is in it? (1)

1.1.2 The sandbag the moment it is dropped from the hot-air balloon? (2)

1.2 Determine the maximum height P, **above the ground**, reached by the sandbag after it is released from the hot-air balloon. (3)

1.3 Calculate the time taken for the sandbag to reach this maximum height after it has been released. (3)

1.4 Calculate the total time taken for the sandbag to reach the ground after it has been released. (4)

1.5 Will the velocity of the hot-air balloon **INCREASE**, **DECREASE** or **REMAIN THE SAME** immediately after the sandbag has been released? Explain fully. (4)

[17]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 Take downwards as the positive direction / upward is negative (4)

$v_f = 0$

$g = 9{,}8\ m\cdot s^{-2}$

$\Delta y = -15\ m$

$$v_f^2 = v_i^2 + 2a\Delta y \ \checkmark$$

$$0^2 = v_i^2 + 2(9{,}8)(-15) \ \checkmark \checkmark$$

$$\therefore v_i = -17{,}15\,m\cdot s^{-1} = 17{,}15\,m\cdot s^{-1} \ \checkmark$$

1.2

$\Delta x = 95\ m$

$g = 9{,}8\ m\cdot s^{-2}$

$v_i = -\ 17{,}15\ m\cdot s^{-1}$

$\Delta t = ?$

$$\Delta y = v_i\Delta t + \tfrac{1}{2} g\Delta t^2 \ \checkmark$$

$$80 \ \checkmark = (-17{,}15)\Delta t + \tfrac{1}{2}(9{,}8)\Delta t^2 \ \checkmark$$

$$4{,}9\Delta t^2 - 17{,}15\Delta t - 80 = 0$$

$$\Delta t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{17{,}15 + \sqrt{17{,}15^2 - 4\times 4{,}9 \times -80}}{9{,}8} = 6{,}15\ s \ \checkmark$$

OR (4)

AB

$v_f = -17{,}15 s$

$v_i = 0$

$a = 9{,}8\,m\cdot s^{-2}$

$\Delta y = ??$

$\Delta t = ??$

$v_f = v_i + a\Delta t$

$0 = (-17{,}15) + (9{,}8)\Delta t \ \checkmark$

$\Delta t = 1{,}75\,s$

BCD

$v_f = 0$

$v_i =$

$a = 9{,}8\,m\cdot s^{-1}$

$\Delta y = 95\,m$

$\Delta t = ??$

$\Delta y = v_i\Delta t + \tfrac{1}{2}a\Delta t^2$

$95 \checkmark = 0 \checkmark + \tfrac{1}{2}(9{,}8)\Delta t^2$

$\Delta t = 4{,}40\,s$

$\therefore t_{total} = 1{,}75 + 4{,}40 = 6{,}15\,s \ \checkmark$

[8]

QUESTION 2

2.1 8 m·s^{-1} ✓ (1)

2.2 $v_f^2 = v_i^2 + 2a\Delta y$ ✓

$\Delta y = \frac{0^2 + (-8)^2}{2(9.8)} = 3.27 m$ ✓ ✓ ✓ (4)

[5]

QUESTION 3

3.1 9.8 m·s^{-2} down ✓✓ (2)

3.2 g = gradient = change in velocity /change in time = $\frac{0 - 6}{a - 0} = \frac{-6}{a} = -9,8$ ✓ ✓ ✓ ✓

Therefore a = 0,61 s ✓ (5)

3.3 At the point of maximum height reached where v = 0 i.e. point at the top of the motion. ✓ (1)

3.4

$v_f = v_i + g\Delta t$ ✓

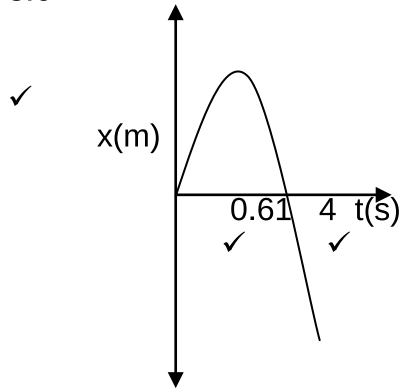
= 0 + (-9,8)(3,39) ✓ ✓

= 33,22 m·s^{-1} down ✓ (4)

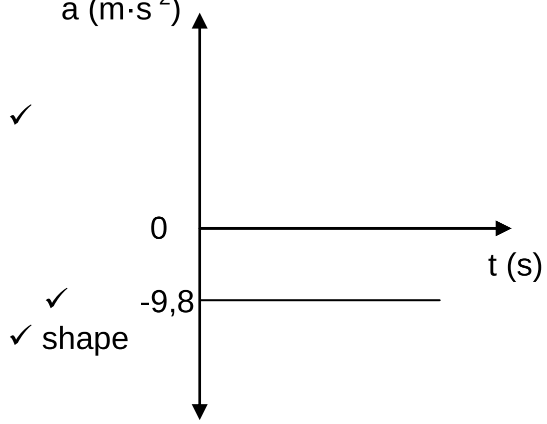
3.5 x = area under graph = ½ b h = ½ (0,61)(6) = 1,8 m ✓ ✓ ✓ ✓

Maximum height reached = 100 + 1,8 = 101,8 m ✓ (5)

3.6



✓ ✓ shape



(8)

[25]

Learner Note: Copy the equation off the information sheet as given. Only then substitute into the equation, and then manipulate the equation to make the unknown the subject of the formula.

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TOPIC 2: CONSERVATION OF MOMENTUM

Learner Note: Always draw a diagram of the situation before and after the collision. Place all the numerical values on the diagram and remember to SELECT A DIRECTION AS POSITIVE OR NEGATIVE.

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes *(Taken from DoE Paper 1 Additional Exemplar 2008)*

New cars have a crumple zone to help minimise injuries during accidents. In addition seat belts, air bags and padded interiors can reduce the chance of death or serious injury.

1.1 Use principles in physics to explain how air bags can reduce the chance of death or injury. (3)

1.2 In a crash test, a car of mass 1,2 x 10^3 kg collides with a wall and rebounds as illustrated below. The initial and final velocities of the car are 12 m·s^{-1} to the left and 2 m·s^{-1} to the right respectively. The collision lasts 0,1 s.

Calculate the:
1.2.1 Impulse of the car during the accident (4)
1.2.2 Average force exerted on the car (3)

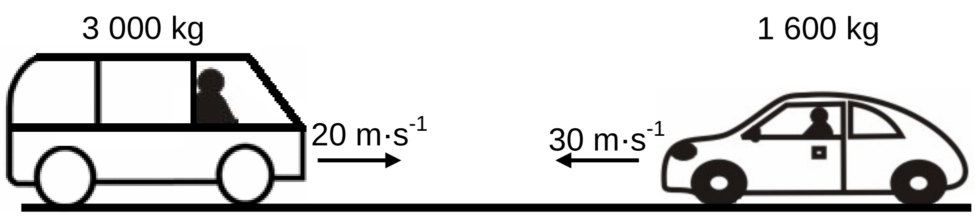
1.3 How will the magnitude of the force exerted on the car be affected if the time interval of the collision remains 0,1 s, but the car does not bounce off the wall? Write down only INCREASES, DECREASES or REMAINS THE SAME. Explain your answer. (2)

HINT: Remember that impulse is equal to the change in momentum. If you use the change in momentum to work out the impulse, the units must be N·s even though you used mass and the change in the velocity.

[12]

QUESTION 2: 15 minutes *(Taken from DoE Paper 1 Exemplar 2008)*

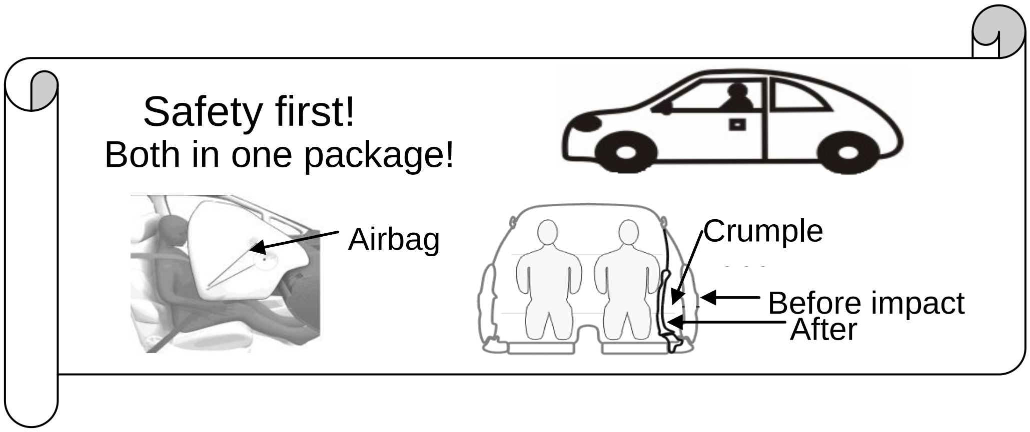
Collisions happen on the roads in our country daily. In one of these collisions, a car of mass 1 600 kg, travelling at a speed of 30 m·s^{-1} to the left, collides head-on with a minibus of mass 3 000 kg, travelling at 20 m·s^{-1} to the right. The two vehicles move together as a unit in a straight line after the collision.



2.1 Calculate the velocity of the two vehicles after the collision. (6)

2.2 Do the necessary calculations to show that the collision was inelastic. (6)

2.3 The billboard below advertises a car from a certain manufacturer.



Use your knowledge of momentum and impulse to justify how the safety features mentioned in the advertisement contribute to the safety of passengers. (3)

[15]

SECTION B: ADDITIONAL CONTENT NOTES

Momentum and Impulse

Momentum is a vector quantity and has the unit: $kg \cdot m \cdot s^{-1}$.

$$p = mv$$

The principle of conservation of linear momentum:

The total linear momentum of an isolated system remains constant in magnitude and direction.

E.g. If these two balls have exploded apart from rest

$v_1 = -2 m \cdot s^{-1}$ $v_2 = ?$

$m_1 = 2$ kg $m_2 = 2,2$ kg

$$
\begin{aligned}
p_{\text{before collision}} &= p_{\text{after collision}} \\
0 &= m_1v_1 + m_2v_2 \\
0 &= 2(-2) + 2,2 \cdot v_2 \\
4 &= 2,2 \cdot v_2 \\
v_2 &= 1,82 \ m \cdot s^{-1}
\end{aligned}
$$

Impulse:

The applied resultant force is equal to the rate of change of momentum (impulse), and this change is in the direction of the force applied.

Therefore

$$F_{res}\Delta t = m\Delta v$$

Be very careful of sign conventions!

We need to know the difference between elastic and inelastic collisions.

In an *elastic collision* kinetic energy and momentum are conserved.

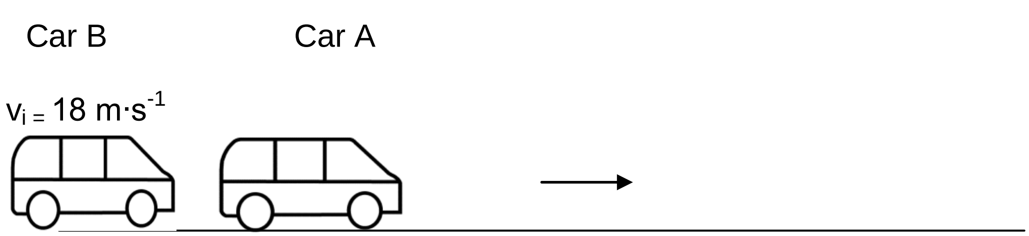
In an *inelastic collision*, momentum is conserved, but not kinetic energy.

The conservation of kinetic energy is determined by calculating the total kinetic energy of all parts of the closed system before the collision and comparing that to the total kinetic energy of all the parts of the closed system after the collision.

SECTION C: HOMEWORK

QUESTION 1: **13 minutes** *(Taken from DoE Paper I Nov 2008)*

The most common reasons for rear-end collisions are too short a following distance, speeding and failing brakes. The sketch below represents one such collision. Car A of mass 1 000 kg, stationary at a traffic light, is hit from behind by Car B of mass 1 200 kg, travelling at 18 m·s^{-1}. Immediately after the collision Car A moves forward at 12 m·s^{-1}.



1.1 Assume that linear momentum is conserved during this collision. Calculate the speed of Car B immediately after the collision. (4)

1.2 Modern cars are designed to crumple partially on impact. Explain why the assumption made in QUESTION 1.1 may NOT be valid in this case. (2)

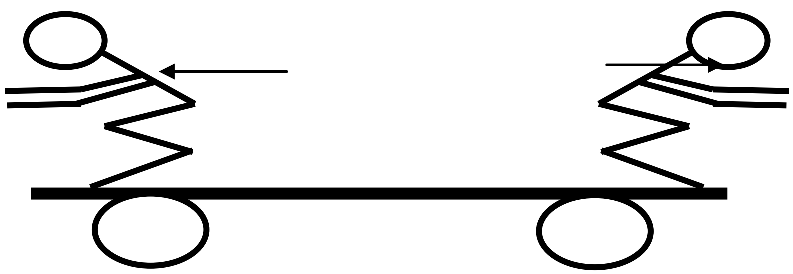
1.3 A traffic officer appears at the scene of the accident and mentions the dangers of a head-on collision. He mentions that for cars involved in a head-on collision, the risk of injury for passengers in a heavier car would be less than for passengers in a lighter car. Use principles of physics to explain why the statement made by the traffic officer is correct. (3)

[9]

QUESTION 2: 17 minutes *(Taken from Gauteng Prelim Paper Paper I 2009)*

Two boys, Franck and Mandla, have masses of 50 kg and 80 kg respectively. They stand on a stationary trolley of mass 180 kg. The trolley is free to move in a horizontal plane either to the left or to the right. The boys simultaneously jump off the trolley in opposite directions from each end of the trolley. Both the boys leave the trolley with an initial speed of 3 m·s^{-1} relative to the ground.

Franck	Mandla
Mass: 50 kg	Mass: 80 kg
Speed before jump: 0 m·s^{-1}	Speed before jump: 0 m·s^{-1}
Speed after jump: 3 m·s^{-1}	Speed after jump: 3 m·s^{-1}



Calculate the magnitude and direction of the velocity at which the trolley starts to move immediately after the boys have jumped off the trolley. (6)

2.2 Give a reason why the velocity of the trolley calculated in 2.1 does not remain constant after the boys have jumped off. (2)

2.3 Explain, using Newton's second Law, why the trolley moves in the direction as calculated in question 2.1 as above. (4)

2.4 The time it takes for Mandla to push against the trolley with his legs is 0.2 s. During this time the trolley exerts a force on Mandla. Calculate the magnitude of the force the trolley exerts on Mandla during the time it takes for Mandla to push against the trolley. (3)

2.5 Explain why Mandla accelerates towards the right if the force exerted on Mandla by the trolley and the force Mandla exerts on the trolley has the same magnitude but act in opposite directions to each other. (2)

[17]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 When the airbag inflates during a collision, the contact time of a passenger/driver with an air bag is longer than without an airbag ✓and thus the force on the passenger/driver is reduced ✓according to Fnet =Δp/Δt ✓. (3)

1.2.1 Take to the right as negative:
$F_{net} \Delta t = \Delta p = mv_f - mv_i$ ✓
$F_{net} \Delta t = 1,2 \times 10^3 (-2 - 12)$ ✓
$= -1,68 \times 10^4$

Impulse = $1,68 \times 10^4$ N·s ✓to the right or away from wall✓

OR

$v_f = v_i + a \Delta t$
$-2 = 12 + a(0,1)$
$a = -140$ m·s^{-2}
$= 140$ m·s^{-2} to the right
$F_{net} = ma$
$= (1,2 \times 10^3)(-140)$ ✓
$= -1,68 \times 10^5$
$F_{net} = 1,68 \times 10^5$ N to the right
Impulse = $F_{net} \Delta t$ ✓
$= (1,68 \times 10^5)(0,1)$ ✓
$= 1,68 \times 10^4$ N·s✓ to the right or away from wall
(4)

1.2.2 $F_{net} \Delta t = \Delta p = -1,68 \times 10^4$
$F_{net}(0,1) = -1,68 \times 10^4$ ✓
$F_{net} = -1,68 \times 10^5$ N
$F_{net} = 1,68 \times 10^5$ N to✓ the right ✓

OR

Take to the right as negative:
$v_f = v_i + a \Delta t$
$-2 = 12 + a(0,1)$
$a = -140$ m·s^{-2}
$F_{net} = ma$
$= (1,2 \times 10^3)(-140)$ ✓
$= -1,68 \times 10^5$
$F_{net} = 1,68 \times 10^5$ N ✓to the right or away from the wall✓ (3)

1.3 Decreases ✓
The final velocity of the car is zero and thus Δ p decreases✓ (2)
[12]

(Remember the selection of a direction and the integration of equations of motion in this section.)

! **Learner Note:** Copy the equation off the information sheet as given. Only then substitute into the equation, and then manipulate the equation to make the unknown the subject of the formula.

2.1 Consider motion to the right as positive:

$p_{before} = p_{after}$ ✓

$m_1v_{i1} + m_2v_{i2} = (m_1 + m_2)v_f$

(1 600)(30) ✓+ (3 000)(-20) ✓ = (1 600 + 3 000) v_f✓

48 000 – 60 000 = (4 600)v_f

v_f = - 2,6 m·s^{-1} ∴ v_f = 2,6 m·s^{-1} ✓ to the right✓ (6)

2.2 Before collision:

$E_k = \frac{1}{2}m_1v_{i1}^2 + \frac{1}{2}m_2v_{i2}^2$ ✓= $\frac{1}{2}$ (1 600)(30)^2 + $\frac{1}{2}$(3 000)(16)^2 ✓

= 720 000 + 384 000 = 1,104 x 10^6 J✓

After collision:

$E_k = \frac{1}{2}m_1v_{f1}^2 + \frac{1}{2}m_2v_{f2}^2$ = $\frac{1}{2}$ (1 600 + 3 000)(2,6)^2 ✓= 384 000

= 5 980 J ✓

E_k before collision not equal to E_k after collision – thus the collision is inelastic ✓ (6)

2.3 During a collision, the crumple zone/ airbag increases the time during which momentum changes ✓ and according to the equation

$F_{net} = \frac{\Delta p}{\Delta t}$ ✓ the force during impact will decrease. ✓ (3)

[15]

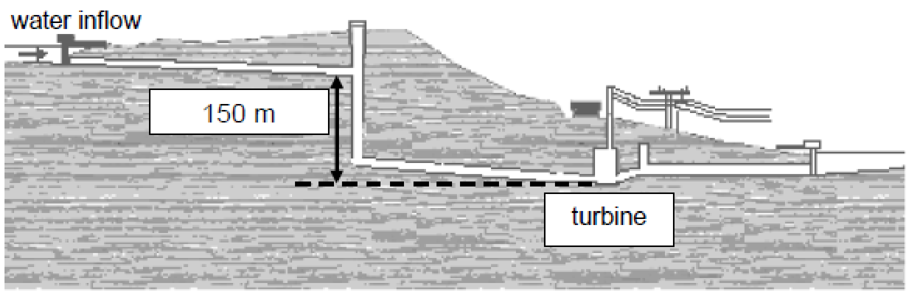
WORK, ENERGY AND POWER

Learner Note: Make sure you know what can be calculated from each of the equations, what each physical quantity stands for, and what the units are for each physical quantity.

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes *(Taken from DoE Paper 1 Nov. 2008)*

The diagram below represents how water is funnelled into a pipe and directed to a turbine at a hydro-electric power plant. The force of the falling water rotates the turbine. Each second, 200 m^3 of water is funnelled down a vertical shaft to the turbine below. The vertical height through which the water falls upon reaching the turbine is 150 m.
Ignore the effects of friction.
NOTE: One m^3 of water has a mass of 1 000 kg.



1.1 Calculate the mass of water that enters the turbine each second. (1)

1.2 Calculate the kinetic energy of this mass of water when entering the turbine. Use energy principles. (4)

1.3 Calculate the maximum speed at which this mass of water enters the turbine. (3)

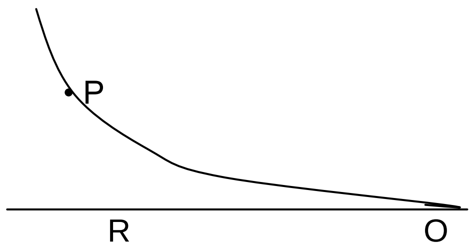
1.4 Assume that a generator converts 85% of this maximum kinetic energy gained by the water into hydro-electricity. Calculate the electrical power output of the generator. (2)

1.5 Explain what happens to the 15% of the kinetic energy that is NOT converted into electrical energy. (1)
[11]

HINT: Ensure that you know the different forms of energy and what a renewable and non-renewable energy source is.

QUESTION 2: 15 minutes *(Taken from GDE District D9 Paper 1 June 2009)*

A toy train of mass 2 kg moves down an inclined track and has a speed of 0,8 m·s^{-1} at point P which is 2 m above the ground level of 0R. The bent part of the track, PO, is 2,5 m long. When the truck reaches point O, it has a speed of 3 m·s^{-1}.



There is friction between the track and the toy train.

2.1 Is mechanical energy conserved? Explain. (2)

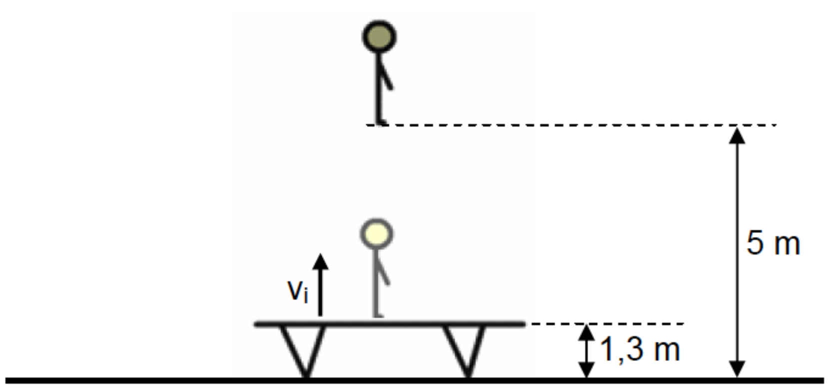
2.2 Determine the work done by friction on the train as it moves from P to O. (8)

2.3 Accept that the average friction force between the train and the train is constant between P and O. Determine the average frictional force that the train experiences as it moves along PO. (3)

[13]

QUESTION 3: 7 minutes *(Taken from DoE Additional Exemplar Paper 1 2008)*

A gymnast jumps vertically upward from a trampoline as illustrated below.



The gymnast leaves the trampoline at a height of 1,3 m and reaches a maximum height of 5 m. Ignore the effects of friction.

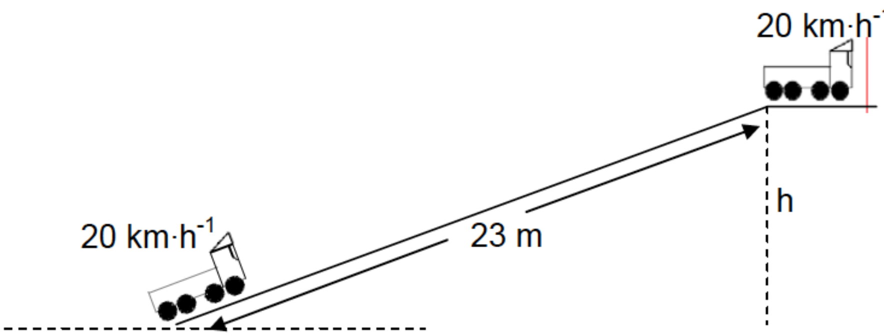
3.1 Write down the work-energy theorem. (2)

3.2 Use energy principles to calculate the initial speed *vi* with which the gymnast leaves the trampoline. (5)

[7]

QUESTION 4: 16 minutes *(Taken from DoE Paper 1 Feb/March 2009)*

In South Africa the transportation of goods by trucks adds to the traffic problems on our roads. A 10 000 kg truck travels up a straight inclined road of length 23 m at a constant speed of 20 km·h^{-1}. The total work done by the engine of the truck to get there is 7 x 10^{5} J. The work done to overcome friction is 8,5 x 10^{4} J.



4.1 Calculate:

4.1.1 The height, h, reached by the truck at the top of the road. (6)

4.1.2 The instantaneous power delivered by the engine of truck. (6)

4.2 Arrestor beds are constructed as a safety measure to allow trucks to come to rest when their brakes fail whilst going downhill. Write down TWO design features of such arrestor beds. (2)

[14]

QUESTION 5: 7 minutes

A child pushes a wooden box of weight 80 N along a 15 m horizontal surface, with a horizontal force of 20 N. This effort took the child 2 minutes. Calculate the child's power. [6]

SECTION B: ADDITIONAL NOTES

WORK

Work done is energy transferred and it is measured in the unit of Joules.

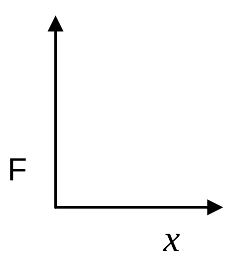
Work is a scalar quantity. It is the product of two vector quantities which must be acting in the same direction.

Work = force x displacement

$$\boxed{W = F \cdot \Delta x \cdot \cos\theta}$$

- In order for work to be done, the force must be acting in the same direction as the movement.
- If this is not the case, calculate the component of the force that is in the same direction as the movement, in order to calculate the work.
- If the movement and the force are perpendicular to one another, then no work is done.

Direction of displacement



is horizontal.

But F has no horizontal

component.

So $W = F \cdot \Delta x$

$= 0 \cdot (x)$

$= 0$ J

ENERGY

Energy is also a scalar quantity. Energy is the ability to do work and is also measured in Joules

Energy = force x displacement $E = F \cdot x$

Kinetic energy is the energy as a result of movement

$$E_k = \frac{1}{2} mv^2$$

Gravitational Potential Energy is the energy possessed as a result of position

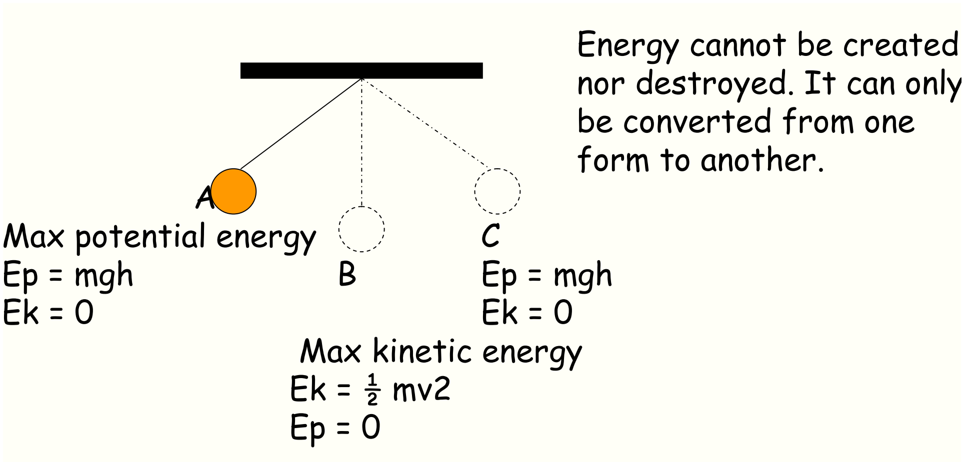
$$E_p = mgh$$

Mechanical Energy is a combination of kinetic and potential energies.

Mechanical Energy = Potential Energy + Kinetic Energy

$$E_m = E_p + E_k$$

During <u>free fall</u>, total mechanical energy remains <u>constant</u>, since the potential energy lost is gained in the form of kinetic energy.



At A and C the sphere is at rest

- At B the sphere is at its lowest point and moving fastest
- The height at A and C is equal. This shows that E_m is conserved
- At B all potential energy is converted into kinetic energy
- At A and C all kinetic energy has been converted into potential energy

c. $E_m = E_p + E_k$

Total mechanical energy = Max E_p *= Max* E_k *= 4J*

$4 = \frac{1}{2} mv^2 + mgh$

$h = 0{,}3m$

$4 = \frac{1}{2} (0{,}8)v^2 + (0{,}8)(10)(0{,}3)$

$v = \pm 2 m\cdot s^{-1}$

WORK- ENERGY THEOREM

The work done by a constant net force in displacing an object is equal to the change in kinetic energy of the object.

$$W_{net} = \Delta Ek = F \cdot \Delta x$$

POWER

Power is also a scalar quantity. It is measured in the unit of Watts.

Power = work done ÷time = energy transferred÷time

$$P = \frac{W}{t}$$

Also $P = Fv$ when v is constant

SECTION C: HOMEWORK

QUESTION 1: 10 minutes

A motor pumps water from a well 10 m deep, and projects it at a speed of 15 $m \cdot s^{-1}$. The water pours from the pipe at the rate of 1 200 $kg \cdot min^{-1}$. Find the power of the motor. [7]

QUESTION 2: 4 minutes

A rope is used to pull a box on a frictionless surface through a distance of 3 m. If the angle that the rope makes with the horizontal is 48°, and the force exerted on the rope is 50 N, calculate the work done on the box. [3]

QUESTION 3: 16 minutes

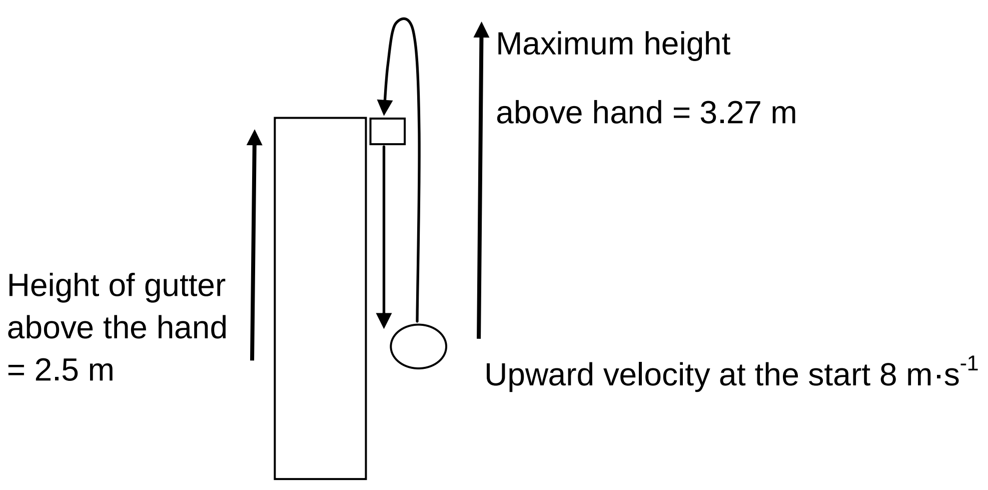
A bricklayer (mass = 88 kg) climbs a ladder until he is standing on a beam 7 m above the ground.

3.1. What is his potential energy once he is on the beam? (3)

3.2. If he climbs the ladder carrying a 20 kg bucket of cement, how much work does he do? (3)

QUESTION 4: 20 minutes *(Taken from Gauteng Paper 1 Prelim 2009)*

Sandile throws a small metal ball of mass 10 g vertically up into the air. The ball accidentally lands in the gutter of a building. It remains in the gutter for 0.5 s during which time it rolls a few centimeters in the gutter and then falls through a hole in the gutter back to the original position in Sandile's hand. The upward velocity with which the ball left Sandile's hand was 8 $m \cdot s^{-1}$. When the ball finally falls back into his hand the velocity is 7 $m \cdot s^{-1}$ downward. <u>Ignore friction as well as all horizontal movement and answer the following questions</u>



4.1 At what speed would the ball have fallen into Sandile's hand if the ball had not fallen into the gutter? (2)

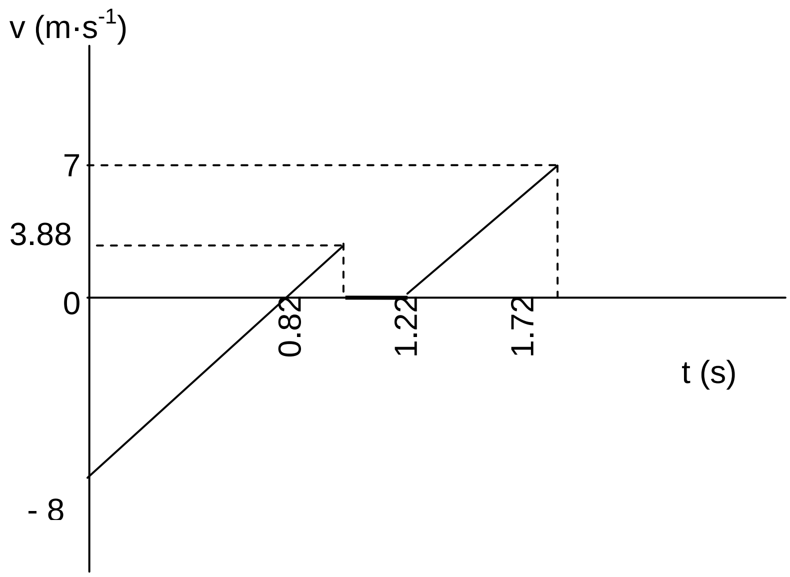
4.2 The maximum height that the ball reaches above Sandile's hand is 3.27 m. Prove that this is correct by using an equation of motion and not energy principles.(4)

4.3 If the gutter is at a height of 2.5 m above Sandile's hand,
1.4.1 Explain by using energy principles, why the kinetic energy at the end of the ball's motion is less than at the start of its motion. (2)
1.4.2 Explain what happened to this energy. (1)

4.4 Using energy equations only calculate the amount of work done on the ball by the gutter. (5)

4.5 The velocity – time graph of the ball for the ball's motion is given below.

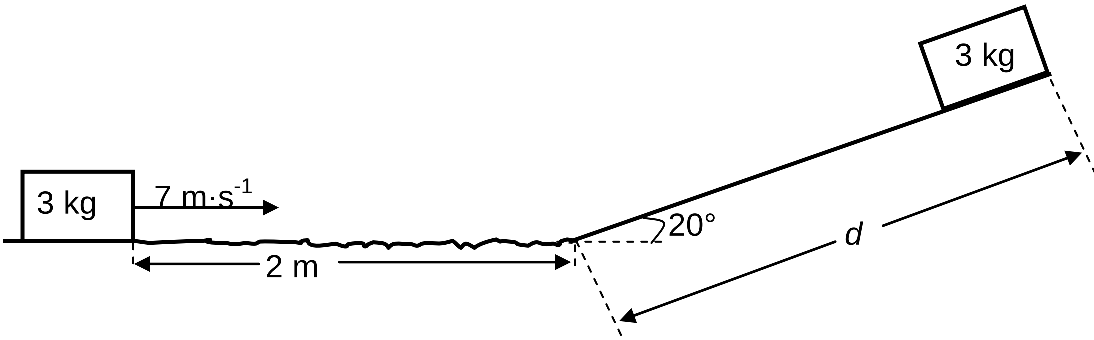
VELOCITY – TIME GRAPH FOR THE MOTION OF THE BALL



Use the above graph to sketch the displacement – time graph for the ball's motion for the time interval 1.22 s to 2.43 s. In other words from the moment the ball falls into the gutter until Sandile catches it again. The sketch graph must be done in your answer book and it is not necessary to draw it to scale. Show the appropriate time and displacement values on the axes. (4)
[18]

QUESTION 5: **10 minutes** *(Taken from DoE Paper 1 Nov. 2009)*

A 3 kg block slides at a constant velocity of 7 m·s^{-1} along a horizontal surface. It then strikes a rough surface, causing it to experience a constant frictional force of 30 N. The block slides 2 m under the influence of this frictional force before it moves up a frictionless ramp inclined at an angle of 20° to the horizontal, as shown in the diagram below.



5.1 Show by calculation that the speed of the block at the bottom of the ramp is 3 m·s^{-1}. (5)

5.2 Draw a free-body diagram to show all the forces acting on the block in a direction parallel to the incline, whilst the block is sliding up the ramp. (2)

5.3 Calculate the distance, *d*, the block slides up the ramp. (5)
[12]

QUESTION 6

A bricklayer (mass = 88 kg) climbs a ladder until he is standing on a beam 7 m above the ground.

6.1. What is his potential energy once he is on the beam? (3)
6.2. If he climbs the ladder carrying a 20 kg bucket of cement, how much work does he do? (3)

The bricklayer's assistant then throws bricks, each of mass 2 kg, up to him where he is standing on the beam.

6.3. What is the minimum velocity with which a brick must leave the assistant's hand? (4)
6.4. Calculate the gain in potential energy of each brick as it reaches the builder's hand. (3)
6.5. If it takes 1 minute to throw 12 bricks up to the bricklayer, find the average power that the assistant generates per brick thrown. (4)

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 200 x 1 000 = 2 x 10^5 kg ✓ (1)

1.2 Initial Mechanical Energy = Final Mechanical Energy

Eki + Epi = Ekf + Epf ✓

$\frac{1}{2}mv^2$ + mghi = Ekf + mgh_f

$\frac{1}{2}(2\times10^5)0^2 + (2 \times 10^5)(9,8)(150)$ ✓= Ekf + $(2\times10^5)(9,8)(0)$ ✓

∴ Ekf = 2,94 x 108 J✓

OR

Wnet = ΔEk

Fcos θ x Δy = Ekf - Eki ✓

(200 000)(9,8)(cos 0^o)(150) =✓ Ekf – 0 ✓

∴ Ekf = 2,94 x 10^8 J ✓ (4)

1.3 Ekf = $\frac{1}{2}mv^2_f$ ✓

2,94 x 10^8 J = ½(2 x 105)vf^2 ✓

vf = 54,22 $m \cdot s^{-1}$ ✓ (3)

1.4 $P = \frac{85}{100} \times \frac{W}{\Delta t} = \frac{85}{100} \times \frac{2,94 \times 10^8}{1}$ ✓

$= 2,94 \times 10^8$ W✓ (2)

1.5 Converted to sound / heat in turbine / other forms of energy. ✓ (1)

[11]

QUESTION 2

2.1 Mechanical energy is not conserved because there is friction. **OR** mechanical energy is not conserved because it is only conserved when there is no friction. ✓✓ (2)

2.2 Mechanical energy at P = $(E_p + E_k)_P$ = $(mgh + ½ mv^2)_P$ ✓

= (2 x 9,8 x 2 + ½ x 2 x $0,8^2$) ✓✓

= 39,84 J✓

Mechanical energy at O = = $(E_p + E_k)_O$ = $(mgh + ½ mv^2)_O$

= (2 x 9,8 x 0 + ½ x 2 x 3^2) ✓✓

= 9 J✓

Work done by friction = 39,84 – 9 = 30,84 J ✓ (8)

2.3 $W_{friction} = F_{friction}$ x Δx x cos ✓

$F_{friction}$ = 30,84/2,5 x cos 180°✓= - 12,34 N = 12,34 N in opposite direction to motion.✓ (3)

[13]

QUESTION 3

3.1 The net work done on an object is equal to the change in the object's kinetic energy.
OR
The work done on an object by a net force is equal to the change in the object's kinetic energy. ✓✓ (2)

3.2 $(E_p + E_k)_f = (E_p + E_k)_i$

$mgh_f + ½mv_f^2 = mgh_i + ½mv_i^2$ ✓

m(9,8)(5) ✓+ 0✓ = m(9,8)(1,3) ✓ + $½mv_i^2$

v_i = 8,52 m·s^{-1} ✓ (5)

OR

$W_{net} = \Delta E_k = E_{kf} - E_{ki}$✓

$W_{net} = F\cos\theta \; \Delta y = ½mv_f^2 - ½mv_i^2$

mgcos180°(hf – hi) ✓ = 0 $- ½mv_i^2$✓

m(9,8)cos180°(5 – 1,3) = $- ½mv_i^2$✓

m(9,8)(-1)(3,7) = $- ½mv_i^2$

v_i = 8,52 m·s^{-1}✓ (5)

[7]

QUESTION 4

4.1.1 $W_{net} = \Delta E_p + \Delta E_k$ ✓

$W_{net} = (mgh_f – mgh_i) + (½mv_f^2 - ½mv_i^2)$

7×10^5 ✓ $– 8,5 \times 10^4$ ✓ $= 10\ 000(9,8)(h_f – 0)$ ✓ $+ 0$ ✓

$6,15 \times 10^5 = 10\ 000(9,8)h_f$

$h_f = 6,28$ m ✓ (6)

Alternative Solution

Useful work done = gain in Ep ✓ = mgh ✓

7×10^5 ✓ $– 8,5 \times 10^4$ ✓ $= 10\ 000(9,8)h$ ✓

h = 6,28m (6)

4.1.2 $W = F \cdot \Delta x \cos \theta$ ✓

7 x 105 = F(23)(1) ✓

F = 3,04 x 104 N ✓

P = Fv ✓

= (3,04 x 104)(60x6000020) ✓

= 1,6 x 105 W ✓ (6)

4.2 **Any TWO*:***

Surface must provide sufficient friction like sand. ✓

Must be long enough for vehicle to stop. ✓ (2)

[14]

QUESTION 5

$F_V = 80$ N $F_H = 20$ N

$x_H = 15$ m t = 2 min = 120 s

W = F·x·cosθ✓

= (20)(15) ✓Use the horizontal force since the displacement is horizontal

= 300 J✓

P = W÷ t✓

= 300÷120✓

= 2,5 W✓

[6]

TOPIC 1: PHOTOELECTRIC EFFECT

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes (Taken from the DoE Additional Exemplar P1 2008)

A learner wants to demonstrate the photoelectric effect. He uses a disk of zinc placed on an electroscope. The work function of zinc is 6,9 x 10-19 J.

1.1 Define the concept *work function*. (2)

1.2 Calculate the maximum wavelength of light that will eject electrons from the zinc. (4)

1.3 The electroscope is negatively charged and then exposed to ultraviolet light from a mercury discharge lamp. One of the wavelengths of the light is 260 nm. Calculate the kinetic energy of an electron emitted from the zinc disk by a photon of this light. (4)

1.4 When the student attempts the experiment with a positively charged electroscope, he finds that the ultraviolet light has no apparent effect. Explain this observation. (2)

[12]

QUESTION 2: 15 minutes *(Taken from DoE Physical Sciences Paper 1 Nov. 2008)*

A fully automatic camera has a built-in light meter. When light enters the light meter, it strikes a metal object that releases electrons and creates a current.

2.1 What phenomenon is described by the underlined sentence? (1)

2.2 A metal plate is irradiated with electromagnetic radiation of wavelength 200 nm. The metal has a work function of 7,57 x 10-19 J. Show by calculation that the metal plate will emit photo-electrons when irradiated with radiation of this wavelength. (6)

2.3 The intensity of the incident radiation on the metal plate is increased while maintaining a constant wavelength of 200 nm. State and explain what effect this change has on the following:

2.3.1 Energy of the emitted photo-electrons (2)

2.3.2 Number of emitted photo-electrons (2)

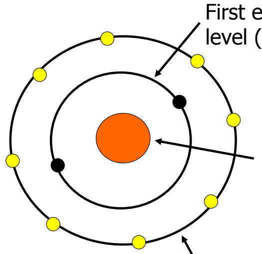
[11]

education
Department: Education
GAUTENG PROVINCE

SECTION B: ADDITIONAL NOTES

The Photoelectric Effect

In order to understand the photoelectric effect and spectra, we need to remind ourselves of Bohr's atomic model.



He believed that more than 1 electron could move in each orbit. Electrons release and absorb energy as they move between energy levels.
Electrons move as waves within the orbitals.

Light has a wave nature and a particle nature. The particles in light are called photons.

When a photon of high enough energy collides with an electron near the surface of a metal, it transfers all its energy to the electron. If there is enough energy for that particular metal, then the electron that was collided with, is knocked out of the metal.

If there is not quite enough energy to remove the electron from the metal, then the energy excites electrons into the next energy level, which then fall back emitting energy (shiny). Metal energy levels are close together and metal electrons are delocalised and can, therefore, be relatively easily removed from the lattice.

Non metals have large gaps between energy levels so some frequencies are absorbed and others reflected giving the object its colour .

Work is done in removing an electron from the surface of a metal. The minimum amount of energy needed to remove an electron from the metal is called the Work Function.

Work function = h x threshold frequency Where h is Plank's constant

The Threshold Frequency is the minimum frequency of the light that can eject an electron from a certain metal. The kinetic energy of an electron that has been ejected can be found using the following equation:

energy of the photon = work function + kinetic energy

Energy of the photon = hf

- where f is the actual frequency of the light shone on the metal.

SECTION C: HOMEWORK

QUESTION 1: 10 minutes *(Taken from DoE Feb/March Physical Sciences P1 2009)*

The work function of three metals is shown in the table below.

Metal	Work function (W_o) in J
Aluminium	$6,54 \times 10^{-19}$
Zinc	$6,89 \times 10^{-19}$
Silver	$7,58 \times 10^{-19}$

1.1 Give a reason why different metals have different work functions. (1)

1.2 Light of wavelength $2,3 \times 10^{-7}$ m is shone onto a metal X. The average speed of the emitted electrons is $4,78 \times 10^{5}$ $m \cdot s^{-1}$. Identify metal X by performing a relevant calculation (6)

1.3 What conclusion about the nature of light is drawn from the photo-electric effect? (1)

[8]

QUESTION 2: 10 minutes *(Taken from the GDE Preliminary Examination 2009)*

The light reaching the earth from the sun is regarded as white light. The sky, however, appears to be blue during the day.

2.1 Using scientific terminology explain why the sky appears to be blue during the day. (3)

2.2 The photoelectric work function of potassium is 3.204×10^{-19} J. Light with a wavelength of 360 nm falls onto the surface of the potassium.

2.2.1 Calculate the energy of the photons. (3)

2.2.2 Calculate the velocity of the electrons ejected from the surface of the potassium under these circumstances. (4)

[10]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 Minimum energy needed to eject electrons from a certain material/metal. ✓✓ (2)

1.2 $E = hc/\lambda$ ✓

$\therefore 6{,}9 \times 10^{-19}$ ✓ $= (6{,}63 \times 10^{-34})(3 \times 10^{8})/\lambda$ ✓

$\therefore \lambda = 288{,}26 \times 10^{-9}$ m ✓ $= 288{,}26$ nm (4)

1.3 $E_k = \frac{hc}{\lambda} - W$ ✓

$= \frac{(6{,}63 \times 10^{-34})(3 \times 10^{8})}{260 \times 10^{-9}}$ ✓ $- 6{,}9 \times 10^{-19}$ ✓

$= 7{,}65 \times 10^{-19} - 6{,}9 \times 10^{-19}$

$= 7{,}5 \times 10^{-20}$ J ✓ (4)

1.4 The positively charged zinc plate will attract electrons ✓preventing them from being emitted. ✓ (2)

[12]

QUESTION 2

2.1 Photo-electric effect ✓ (1)

2.2 $c = f\lambda$ ✓

$\therefore 3 \times 10^{8} = f(200 \times 10^{-9})$ ✓

$\therefore f = 1{,}5 \times 10^{15}$ Hz

$f_0 = W_o/h$ ✓

$= \frac{7{,}57 \times 10^{-19}}{6{,}63 \times 10^{-34}}$ ✓ $= 1{,}14 \times 10^{15}$ Hz ✓

Frequency ($1{,}5 \times 10^{15}$ Hz) greater than threshold frequency ($1{,}14 \times 10^{15}$ Hz) ✓ (6)

2.3.1 The energy of the photo-electrons remains unchanged ✓ as the frequency / wavelength of the photons did not change. ✓ (2)

2.3.2 Number of photo-electrons (per second) is increased ✓. When the intensity is increased the number of photons will increase, releasing an increased number of electrons. ✓ (2)

\- **[11]**

TOPIC 2: ELECTROMAGNETIC RADIATION AND SPECTRA

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes

The electromagnetic spectrum includes microwaves, ultraviolet light, gamma rays, and visible light.

1.1 Briefly describe the propagation of electromagnetic radiation through space. (4)

1.2 Arrange the four types of EM radiation listed above in order of increasing wavelength. (4)

1.3 Which of the types of EM radiation listed above has the greatest penetrating power? (1)

1.4 Name 3 other types of EM radiation. (3)
[12]

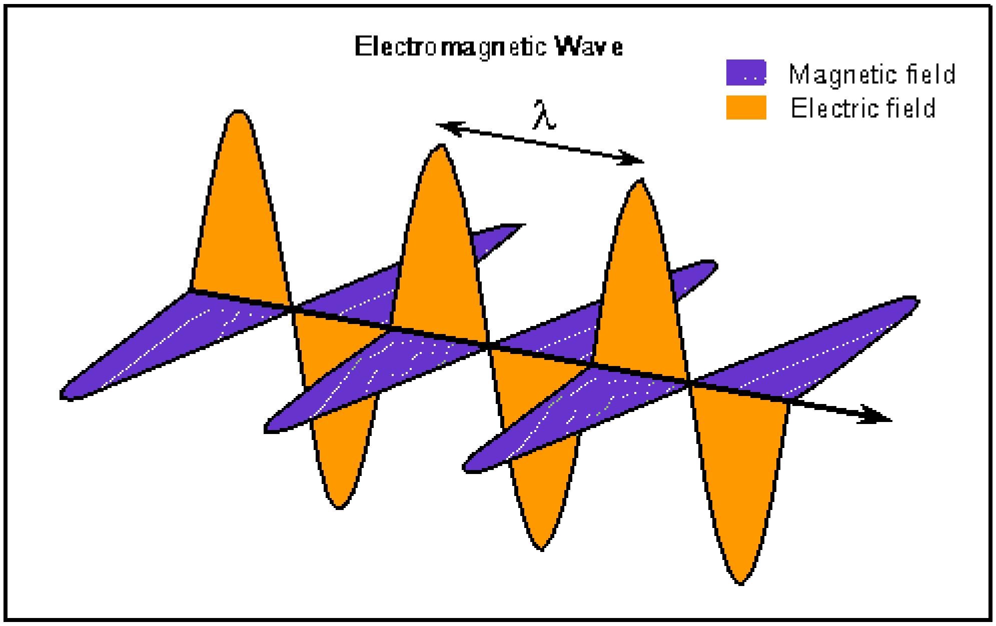
QUESTION 2: 10 minutes

2.1 In a helium-neon laser, the electrons in the neon atoms drop down from their excited state at -4.026 eV to -5.990 eV. What is the frequency of the light emitted? (4)

2.2 Explain briefly how scientists can use emission line spectra? (2)
[6]

SECTION B: ADDITIONAL NOTES

INTRODUCTION TO ELECTROMAGNETIC WAVES



Source: http://www.warren-wilson.edu

Electromagnetic waves can be set up by charges that oscillate backwards and forwards. (accelerating charged particles)

The oscillation causes a vibration which in turn causes a wave shaped electric field.

As the electric field changes it induces (creates) a changing magnetic field at right angles to it.

As the magnetic field changes, it induces a changing electric field at right angles to it.

It this way the wave self propagates (keeps on going).

The magnetic and electric fields are in phase with one another.

Electromagnetic waves are transverse waves.

Electromagnetic waves do not need a physical medium to travel in. They can travel through a vacuum.

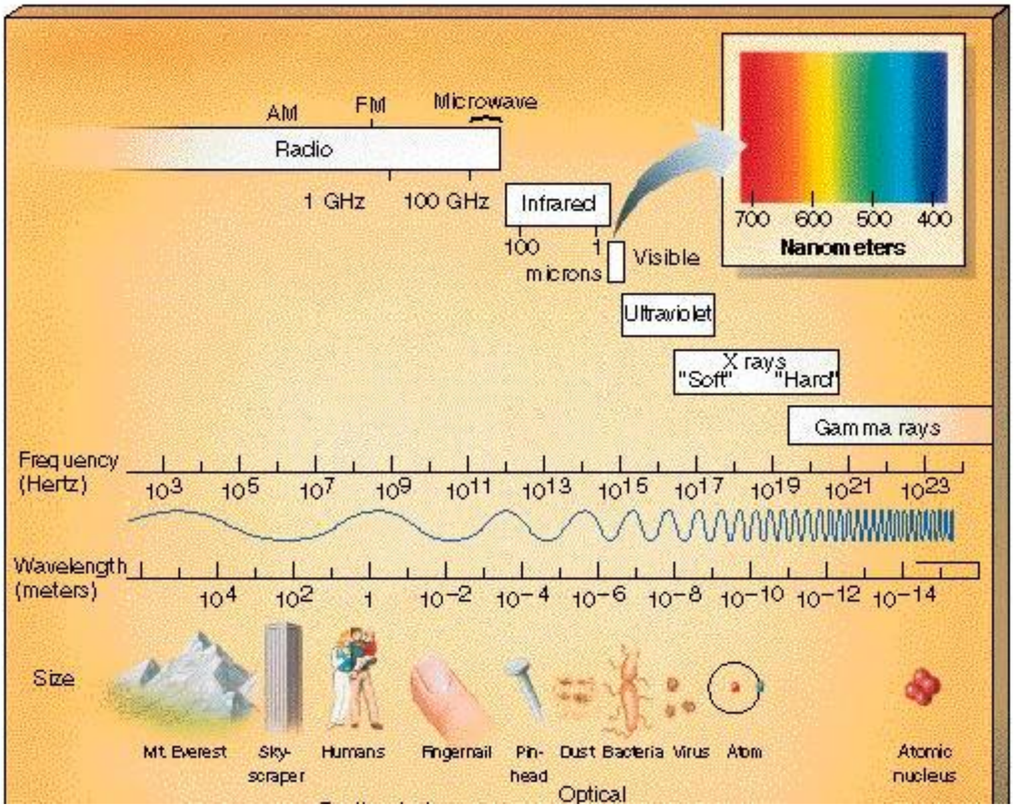
All electromagnetic waves travel at a speed of 3×10^8 $m.s^{-1}$ (c).

$$\boxed{v = c = f \times \lambda}$$

Electromagnetic waves also have a particle nature. The energy of the photons

$$\boxed{E = h \times f}$$

THE ELECTROMAGNETIC SPECTRUM



Source: http://www.astro.princeton.edu

RADIO WAVES

Radio waves are produced by vibrating electric currents in a transmitting aerial.

Radio waves can be easily diffracted because they have long wavelengths.

Medium wave radio is easily transmitted over long distances.

Radio 702 transmits on a frequency of 702kHz (λ = 427m).

TV WAVES

VHF (very high frequency) and UHF (ultra high frequency) waves are used for television.

VHF and UHF waves are not as easily diffracted as radio waves, so they cast shadows behind buildings. For this reason, televisions usually need relatively large and exterior aerials.

MICROWAVES

The wavelength of microwaves is a few centimetres.

Microwaves are used for satellite communication, for telephone and television.

Satellite dishes are parabolic in shape and reflect the waves to a focal point receiver.

Microwaves are also used to cook food in microwave ovens. Water molecules absorb the energy from these wavelengths. This causes the water molecules to vibrate, thereby heating the water and cooking the food.

INFRARED RADIATION

The particles of all objects vibrate and as a result emit radiation in the infrared region of the spectrum. We can often detect this radiation in the form of heat.

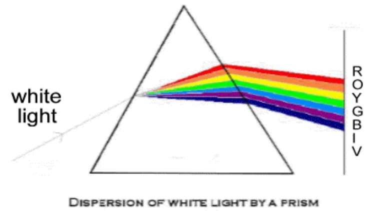
Infrared radiation can affect some photographic film. Infrared photographs can be taken in the absence of light.

Infrared binoculars allow us to view objects, like animals, at night.

VISIBLE LIGHT

Visible light is referred to as white light.

White light is made up of the seven colours of the spectrum.



Source: www.ectc.org.uk

ULTRAVIOLET RADIATION

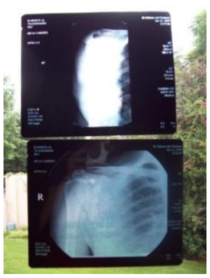
Ultraviolet rays are emitted by very hot objects, like the sun and electric arc welders.

Ultraviolet light causes some chemicals to glow or fluoresce. These chemicals are sometimes added to washing powders where they absorb ultraviolet rays and release them as visible light. Washing then appears to be “whiter than white.”

The ultraviolet rays of the sun can cause skin cancer. The ozone layer of our atmosphere protects us from these rays by absorbing them before they reach us. The hole in the ozone layer means that more ultraviolet radiation reaches our earth and this is damaging to animals and plants.

Ultraviolet rays can kill harmful bacteria and are used for this purpose in sterilization units in doctors’ rooms and hospitals.

X RAYS



X rays are emitted when high-speed electrons bombard a metal plate. The electrons slow down and their energy is transferred as high energy electromagnetic radiation. X rays can penetrate many solid objects because of their high frequency.

X rays can pass through soft tissue but not bones. For this reason they can be used to photograph bones.

X rays do not penetrate lead so radiographers wear thin lead aprons to protect themselves from the radiation.

GAMMA RAYS

Gamma rays are emitted by naturally occurring radioactive materials and are a by-product of nuclear reactions.

Gamma rays have the greatest penetrating ability of all electromagnetic radiation, have the greatest energy and are the most dangerous to man.

CONTINUOUS EMISSION SPECTRUM

This spectrum is obtained when pure white light is passed through a triangular glass prism. This is the full visible spectrum which we often refer to as the rainbow.

LINE EMISSION SPECTRUM

The line spectrum of an element is characteristic of that element and can be used to identify that element. It is almost like a 'fingerprint' for the element.

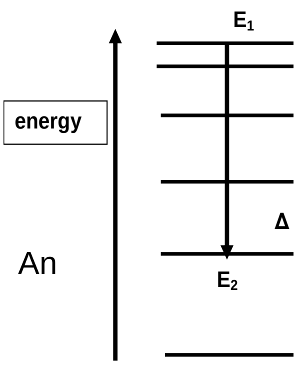
Only certain colours which correspond to specific frequencies of light are present in a line emission spectrum.

Each colour in the line emission spectrum results from the emission of an electromagnetic wave of a particular frequency.

So using E = hf we can deduce that each line represents photons of a different energy.

The energy is released as electrons fall from a high energy level to a lower energy level.

Diagram showing the energy levels in an atom

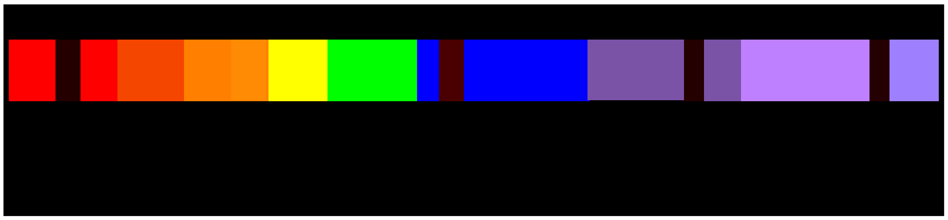


When the electron in a hydrogen atom is in the orbital closest to the nucleus, it possesses the least amount of energy. This is called the "ground state".

An electron in an energy level further from the nucleus than it normally occupies, is said to be in the 'excited state'.

Movement between orbitals causes energy to be released and absorbed. We see this as absorption and emission spectra

LINE ABSORPTION SPECTRA



A line absorption spectrum is formed when white light is passed through a cold gas before being shone through a prism or a diffraction grating.
The black lines represent wavelengths of light that have been absorbed by the gas.
The frequency of the lines in the emission spectrum of an element is exactly the same as those of the missing lines in the absorption spectrum.

Notice that the energy released and absorbed is at distinct positions. This means that they have distinct energies. The energy released an absorbed is not continuous but rather is emitted in small packages called quanta. Quanta are indivisible ‘packages’ of energy.

SECTION C: HOMEWORK

QUESTION 1: 5 minutes

Absorption lines are the reverse of emission lines. Comment on this statement. [6]

QUESTION 2: 5 minutes

A certain electromagnetic wave has a photon energy of 1,89 x 10^{-24} J. What kind of electromagnetic wave is this [5]

QUESTION 3: 10 minutes

An electromagnetic wave of frequency 405 MHz is travelling through space.

3.1 What is the wavelength of the wave? (4)

3.2 What type of electromagnetic radiation is this? (1)

3.3 How much energy does each photon have? (4)

[9]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 A changing/ oscillating ✓electric field induces a changing magnetic field ✓in the perpendicular plane✓, which induces a changing electric field. ✓ (4)

1.2 Gamma rays✓, UV✓, visible light✓, microwaves✓ (4)

1.3 Gamma rays ✓ (1)

1.4 X-rays✓, Infra-red✓, radio waves✓ (3)

[12]

QUESTION 2

2.1 $\Delta E = -4.026 - (-5.990)$
$= 1.964 \text{ eV}$ ✓

$\Delta E = (1.964)(1.6\times10^{-19})$

$= 3.142\times10^{-19} \text{ J}$ ✓

$\Delta E = hf$

$3.142\times10^{-19} = 6.6\times10^{-34} f$ ✓

$f = 4.74\times10^{14} \text{ Hz}$ ✓ (4)

2.2 Each element has its own unique energy levels✓ and so has its own unique spectra that can be used to identify the element✓ (2)

[6]

TOPIC 1: ORGANIC MOLECULES: STRUCTURES AND PHYSICAL PROPERTIES

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes *(Taken from the DoE Exemplar 2008)*

Alcohols are used in a variety of chemical reactions and as preservatives in certain medicines. All alcohols are toxic. Although **ethanol** is the least toxic of all alcohols, it is still a poisonous substance. It is rapidly absorbed into the blood. High blood alcohol levels can cause brain poisoning. The body can reduce high blood alcohol levels by oxidising the alcohol. Contrary to what people believe, alcohol is a depressant and not a stimulant.

The following table indicates the effects of various blood alcohol levels:

The effects of blood alcohol levels	
% per volume	**Effect**
0,005 – 0,15	Loss of coordination
0,15 – 0,20	Severe intoxication
0,20 – 0,40	Loss of consciousness
0,50	Death

The liver enzyme, ADH, catalyses the oxidation of ethanol to **ethanal** and then to non-toxic **ethanoic acid**. The liver is able to remove only 28 grams of pure alcohol per hour.

1.1 Write down the NAMES of the homologous series to which the compounds ethanal and ethanoic acid respectively belong (2)

1.2 Write down the structural formula of ethanal. (2)

1.3 Alcohols are prepared by the **hydration** of alkenes. Use structural formulae to write down the equation which represents the formation of ethanol. (4)

1.4 The warning on the labels of certain medicines reads as follows: *The effect of this medicine is aggravated by the simultaneous intake of alcohol.*

Use the information in the passage above to justify this warning. (4)

[12]

QUESTION 2: 15 minutes

The first six members of the alkanes occur as gases and liquids at normal temperatures. Alkanes are currently our most important fuels, but the use of alcohols as renewable energy source is becoming more and more important. Alcohols are liquids that might be a solution to the energy crisis.

2.1 Which chemical property of alkanes and alcohols make them suitable to be used as fuels? (2)

2.2 The table shows the boiling points of the first six alkanes and the first six alcohols:

Alkane	Boiling point (°C)	Alcohol	Boiling point (°C)
methane	- 164	methanol	65
ethane	- 89	ethanol	79
propane	- 42	1-propanol	97
butane	- 0,5	1-butanol	117
pentane	36	1-pentanol	138
hexane	69	1-hexanol	156

Draw a graph of boiling points versus number of carbon atoms for the first six ALCOHOLS. Choose 50 °C and 1 carbon atom as origin and use an appropriate scale. Plot the points and draw the best curve through the points. (6)

2.3 What trend in boiling point can be observed from the graph? (2)

2.4 Provide a reason for the trend mentioned in QUESTION 2.3 by referring to the type of intermolecular forces. (2)

2.5 Explain, referring to the type of intermolecular forces, why the boiling points of alcohols are higher than the boiling points of alkanes. (2)

2.6 People are always cautioned to keep liquids such as petrol (a mixture of alkanes) out of reach of children. Use the boiling points of alkanes and justify this precaution. (2)

2.7 Briefly explain why ethanol is a renewable energy source, while the alkanes are non-renewable. (2)
[18]

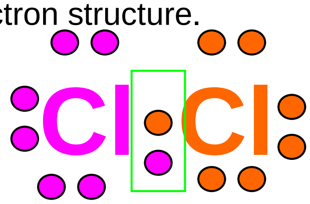
SECTION B: ADDITIONAL NOTES

COVALENT BONDING AND INTERMOLECULAR FORCES

COVALENT BONDS

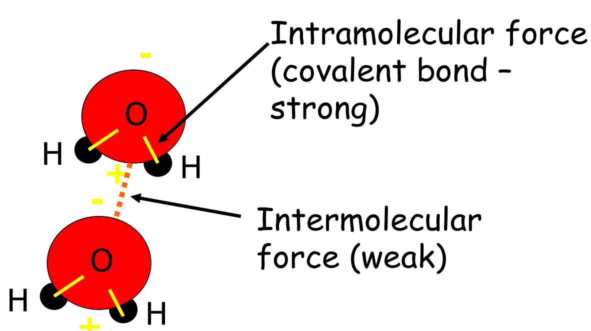
- Covalent bonds occur between two non metals
- Electronegativity difference of 0 non polar covalent
- Electronegativity difference of 0,1 – 1,6 polar covalent
- Electrons are shared in a covalent bond

- Forming a Chlorine molecule
    - Each atom has 7 ē in the outer energy level.
    - The only way that each can achieve the octet structure, is for a pair of ē's to be shared equally between them:
    - Each F atom now shares 1 ē with the other therefore each has the noble gas electron structure.



INTERMOLECULAR FORCES

- Weak electrostatic forces (Coulombic forces)
- Holds together molecules (covalently bonded units)
- Between non polar molecules – London forces or instantaneous dipoles
- Between polar covalent molecules – dipole dipole van der Waals forces. Dipole-dipole is an attraction between slightly positive and slightly negative sides (poles) of the molecule.
- Hydrogen bonding between NOF (Nitrogen, Oxygen and Fluorine) bonded to hydrogen.



CARBON STRUCTURES

Important features of Carbon

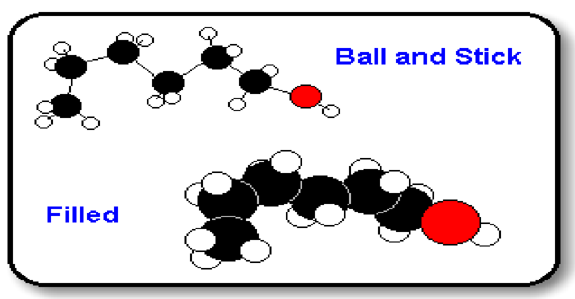
- There are different allotropes (same element, same phase, different atomic arrangement) of C – graphite, coal & diamond.
- Carbon has a valency of 4 (can form 4 bonds), & has 4 valence electrons (outermost energy level).
- In the *excited state*, valence electrons are unpaired i.e. one 2s electron moves to higher 2p orbital. i.e. $1s^2 2s^1 2p^3$
- Carbon has the ability to form long chains with other C atoms – called Catenation.
- Graphite is a non-metal that conducts electricity.

Alternative representations of organic molecules

- Molecular formula: $C_6H_{13}OH$
- Condensed formula: $CH_3CH_2CH_2CH_2CH_2CH_2OH$
- Structural formula:

$$\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & H & \\ & & | & & | & & | & & | & & | & & | & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - OH \\ & & | & & | & & | & & | & & | & & | & \\ & & H & & H & & H & & H & & H & & H & \end{array}$$

- Ball + stick & space filled:



HYDROCARBONS

- Saturated – single bonds only
- Unsaturated – double and triple bonds

Alkanes

Single covalent bonds

CH_3 - CH_2-CH_2-CH_3

butane

- SATURATED molecule.
- General formula: C_nH_{2n+2}

Alkenes

CH_2=CH-CH_2-CH_3

but-1-ene

- have one or more C=C double bonds
- The general formula: C_nH_{2n}.
- UNSATURATED molecule

Alkynes

CH≡C-CH_2-CH_3

but-1-yne

- One or more triple bonds
- General formula: C_nH_{2n-2}
- UNSATURATED molecule

Naming alkyl groups

Alkyl group structure	Alkyl name
CH_3 -	methyl
CH_3CH_2-	ethyl
$CH_3CH_2CH_2$ -	propyl
CH_3CH_2 CH_2CH_2 -	butyl

FUNCTIONAL GROUPS

RULES FOR NAMING ORGANIC COMPOUNDS (IUPAC RULES)

- Identify the functional group of the molecule – this determines the ending of the name.
- Find the longest continuous carbon chain and allocate its prefix according to the number of carbon atoms in the chain (see table for prefixes).

Name prefixes

No of C atoms	Prefix
1	meth
2	eth -
3	prop -
4	but -
5	pent -
6	hex -
7	hept -
8	oct -
9	non -
10	dec -

- Number the carbon atoms in the chain. Number them so that the functional group is on the carbon of lowest possible number. Double and triple bonds take preference over side chains.
- Name the branched group according to the number of carbon atoms it has and give it a number according to the carbon atom it is attached to.
- If there is more than one branched group of the same kind, use the Greek prefixes di, tri, tetra, penta and so on to indicate this.
- If a halogen atom is attached to the carbon chain, it is treated as an alkyl group, then the prefixes: fluoro-, chloro-, bromo -, and iodo – are used.

E.g. Write down the IUPAC name of each one of the following compounds:

H — C ≡ C — H

Ethyne (two carbons and a triple bond)

```
      H    H    H    H
      |    |    |    |
Br — C — C — C = C — H
      |    |
      H    H
```

4-bromo- but-1-ene (four carbons in main chain, double bond on first carbon, bromine on fourth carbon)

Homologous Series

/ As their molecular mass increases the intermolecular forces become stronger; therefore, they have a higher boiling point.

Alcohols

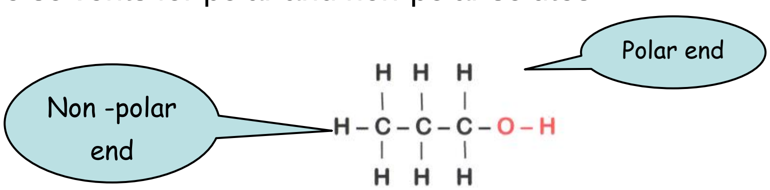
m -OH (hydroxyl) NOT hydroxide (OH^-) functional group.

m Named using the ending –ol. –O-H group gets the lowest possible number:

m Alcohols are oxidized to carboxylic acids when treated with strong oxidizing agents.

m Alcohol molecules have a non-polar hydrocarbon end and a polar –O-H section.

m Alcohols are solvents for polar and non-polar solutes.



Carboxylic Acids

m Compounds that have the carboxyl, -COOH functional group

m The ending -oic acid denotes that we are dealing with a carboxylic acid.

☺ Are relatively weak acids.

```
         O
         ||
CH3  -  C-O-H
```

Esters

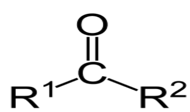
- These are compounds that have the CO-O-C functional group.
- Pleasant smelling substances which are responsible for fragrance of fruit & flowers.
- Esters arise by the reaction between a carboxylic acid and an alcohol:

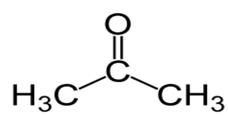
$$CH_3\overset{O}{\overset{\|}{C}}\boxed{OH + H}OCH_2CH_3 \rightleftharpoons CH_3\overset{O}{\overset{\|}{C}}OCH_2CH_3 + H_2O$$

- Water is also formed as a result of the reaction.
- All esters consist of two parts;
  - an alkyl derived from an alcohol,
  - anoate derived from a carboxylic acid (has the double bond O)
- In the example above, ethanoic acid and ethanol react to form the ester, ethyl ethanoate.
- NB. Use the oxygen atom as a divider to name the molecule.

Ketones

- Structure:

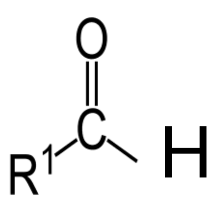


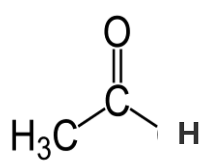


- A carbonyl group (C=O) is polar.

Aldehydes

- Structure:





- A carbonyl group (C=O) is polar.

ISOMERS

- Examine the two structural formulae shown below. Both are structural formulae with molecular formulae C_4H_8.

  $CH_2{=}CH{-}CH_2{-}CH_3$

  but-1-ene

  $CH_2{-}CH{=}CH_2{-}CH_3$

  but-2-ene

- These two molecules are said to be ISOMERS.
- Isomers are compounds which have the same molecular formula, but different structural formulae.

PHYSICAL PROPERTIES

Molecules are held together by intermolecular forces. In order to separate these molecules from each other requires energy. The stronger the intermolecular forces, the more energy that is required to separate or break these bonds. This will lead to a higher melting point, boiling point, etc.

Boiling and melting points

As the strength of the intermolecular forces increase, the boiling point and melting point will increase. Thus molecules where there are hydrogen bonds present, will have a higher melting point and boiling point than those molecules where there are weaker London forces or Van der Waals forces present.

Vapour pressure

Vapour pressure is the amount of pressure that the gaseous molecules exert above the surface of the liquid phase. The vapour pressure will decrease as the size of the molecule increases (chain length).

Vapour pressure is an indication that there are weak intermolecular forces present in the liquid phase.

Viscosity

A liquid that has a low viscosity will be able to flow more easily. Thus, where hydrogen bonds are present, there will be a much higher degree of viscosity. The opposite is true for the weak Van der Waals forces. Viscosity will also increase as the length of the carbon chain increases.

Density

The density of organic molecules will increase as the length of the chain increases.

Surface area

As the surface area of the molecule decreases, there will be lower boiling and melting points as the intermolecular forces will be weaker.

Phases

As you go down a group, either alkanes, alkenes etc, as the chain length increases, the melting and boiling points will increase. The smaller molecules will then be gases at room temperature and the longer chain lengths will be liquids or solids at room temperature

SECTION C: HOMEWORK

QUESTION 1: 20 minutes *(Taken from DoE Physical Sciences Feb-March Paper 2 2009)*

There are two structural isomers for the organic compound with molecular formula $C_2H_4O_2$.

1.1 Define the term *structural isomer*. (2)

1.2 Write down the structural formula of these two isomers and next to each its IUPAC name. (3 x 2) (6)

1.3 State with reason which ONE of these isomers:

1.3.1 Has the higher boiling point (3)

1.3.2 Has the higher vapour pressure (3)

1.4 Will the vapour pressure of carboxylic acids increase or decrease if the number of carbon atoms in the chain increases? Give a reason for your answer. (3)

[17]

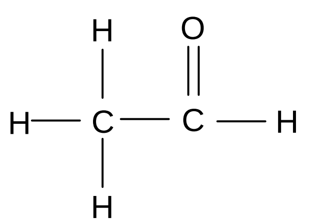
SECTION D: SOLUTION AND HINTS TO SECTION A

QUESTION 1

1.1 ethanal – aldehydes ✓

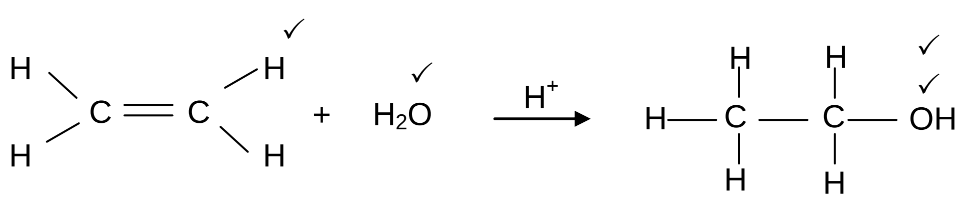
ethanoic acid – carboxylic acids ✓ (2)

1.2



✓✓ (2)

1.3



(4)

1.4 Any additional intake of alcohol will increase the blood alcohol level ✓✓which may then lead to either loss of coordination / severe poisoning / damage to organs e.g. the liver.✓✓ (4)

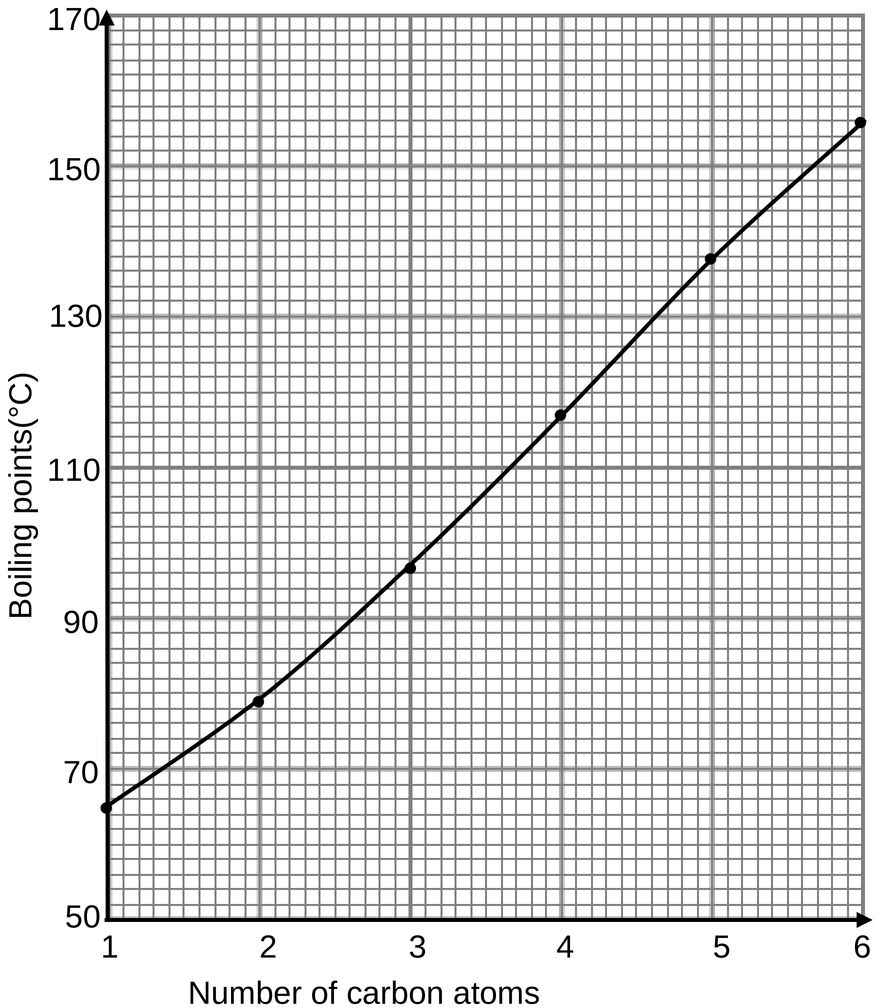
[12]

QUESTION 2

2.1 High energy of combustion/Combustion releases huge amounts of energy/highly exothermic. ✓✓ (2)

2.2

Graph of boiling points versus number of carbon atoms



Criteria for graph	
Appropriate heading	✓
Appropriate scale on both axes	✓
Both axes labelled correctly	✓✓
Points correctly plotted	✓
Best curve drawn through points	✓
Total	(6)

2.3 Boiling point increases with number of carbon atoms✓✓ (2)

2.4 Van der Waals forces between alcohol molecules ✓
increase with increase in molecular size ✓ (2)

2.5 Hydrogen bonds between alcohol molecules are stronger ✓
than Van der Waals forces between molecules of alkanes✓ (2)

2.6 Petrol has a low boiling point ✓, vapourises easily / is volatile / explosive /
flammable / easily combustible / vapours have a higher density than oxygen ✓
and when swallowed, vapours can cause suffocation. (2)

2.7 Ethanol can be produced by fermentation of plant material, e.g. maize and sugar cane. ✓
Alkanes are fossil fuels ✓which are non-renewable. (2)

[18]

TOPIC 2: ORGANIC MOLECULES: REACTIONS

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 17 minutes

(Taken from the DoE Physical Sciences Feb-March Paper 2 2009)

Most organic compounds can undergo substitution or addition or elimination reactions to produce a variety of organic compounds. Some incomplete organic reactions are represented below.

Reaction

$$CH_3 - CH_2 - CH = CH_2 + H_2O \longrightarrow$$

Reaction II

$$\begin{array}{l} CH_3CH_2\,CH_2 - \underset{\displaystyle CH_3}{\underset{|}{C}} = CH_2 + HBr \longrightarrow \end{array}$$

Reaction III

$$CH_3\underset{\displaystyle OH}{\underset{|}{C}}H\,CH_2CH_3 \xrightarrow[\text{heat}]{H_2SO_4}$$

1.1 Name the type of reaction represented by reaction III. (1)

1.2 Both reactions I and II are examples of addition reactions. Name the type of addition that is represented by each reaction. (2)

1.3 Write down the structural formula and IUPAC name of the major product formed in reaction I. (3)

1.4 Reaction I only takes place in the presence of a catalyst. Write down the formula of the catalyst used in reaction I. (1)

1.5 Write down the structural formula and IUPAC name of the major product formed in reaction II. (3)

1.6 To which homologous series does the organic product formed in reaction III belong? (2)

[12]

QUESTION 2: 13 minutes

(Taken from the DoE Physical Sciences Feb–March Paper 2 2010)

Consider the following terms/compounds in organic chemistry.

aldehydes	ketones	oxidation	haloalkane	hydrolysis
ethyne	hydrohalogenation	but-1-ene	water	amines
hydration	chlorine	butane	potassium hydroxide	alkynes

Choose from the above terms/compounds: (Write down the question number only and next to each the correct term/compound.)

2.1 The homologous series that has a carbonyl group as functional group (1)

2.2 A saturated hydrocarbon (1)

2.3 The product formed when an alkane reacts with a halogen (1)

2.4 The homologous series to which propanal belongs (1)

2.5 The homologous series to which 2-bromobutane belongs (1)

2.6 The reaction of 2-bromobutane with water (1)

2.7 The homologous series with a $-NH_2$ group as functional group (1)

2.8 An unsaturated compound that has isomers (1)

2.9 A compound which belongs to the homologous series with the general formula C_nH_{2n-2} (1)

2.10 The type of organic reaction during which hydrogen chloride reacts with ethene. (1)

[10]

SECTION B: ADDITIONAL NOTES

ORGANIC REACTIONS

Combustion reactions:

- Hydrocarbons react with oxygen to form water and carbon dioxide and energy.
- Alkane example:

$$2\,C_8H_{18} + 25\,O_2 \longrightarrow 16\,CO_2 + 18\,H_2O$$

- Alkenes & Alkynes undergo similar reactions to form the same products.

Substitution reactions

An atom or group of atoms in a molecule is substituted by another.

- One atom or group is removed and another takes it's place.

E.g.1 $CH_{4(g)} + Br_{2(g)} \rightarrow CH_3Br_{(g)} + HBr_{(g)}$ Halogenation

E.g. 2 $CH_3Cl_{(g)} + H_2O_{(l)} \rightarrow CH_3OH_{(aq)} + HCl_{(aq)}$

Addition reactions

- Reverse of elimination reactions.
- The number of molecules decreases in addition reaction (on product side).
- High T favour elimination reactions & low T favour addition reactions.
- Therefore, we can drive reactions in opposite paths.
- Addition reactions generally occur faster than substitutions reactions.

E.g. $C_2H_{4(g)} + H_2O_{(l)} \rightarrow C_2H_5OH_{(g)}$

C=C (unsaturated) becomes C-C bond → saturated molecule (has full complement of H atoms). When the chains get longer, then the addition reaction obeys **Markovnikov's** rule i.e. *The positive part of the molecule added to the bonds to the carbon already bonded to the most hydrogen atoms and the negative part bonds to the carbon atom bonded to the most carbon atoms.*

```
  H  H                      Br Br
  |  |                      |  |
H—C=C—H + Br—Br  →        H—C—C—H
                            |  |
                            H  H
```

Elimination reactions

- molecule of a reactant breaks up to form 2 or more new molecules – similar to decomposition.
- Opposite of addition reactions.
- Number of molecules greater on product side.
- Single bond is ELIMINATED and double bond forms!

E.g. 1 $C_2H_5OH_{(g)}$ + --(conc. acid + heat)→ $C_2H_{4(g)} + H_2O_{(l)} + H^+$

Dehydration is the elimination of the hydroxyl (-OH) and the H atom from the alcohol.

E.g. 2 $C_2H_5Cl_{(aq)} + NaOH_{(aq)} \rightarrow C_2H_{4(g)} + NaCl_{(aq)} + H_2O_{(l)}$

Dehydrohalogenation is the elimination of the halogen atom (Cl) and an H atom leaving a carbon = carbon bond – strong base is used.

Cracking

- Heating to a high temperature
- Produces unsaturated products

E.g. $CH_3CH_3 \rightarrow CH_2 = CH_2 + H_2$

Oxidation

- Alcohols for example can also undergo oxidation.
  Oxidation of a primary alcohol: $K_2Cr_2O_7$ as catalyst – forms and aldehyde.
  Oxidation of a secondary alcohol: $K_2Cr_2O_7$ as catalyst – forms a ketone.

SECTION C: HOMEWORK

QUESTION 1: 15 minutes *(Taken from DoE NSC Physical Sciences P 2 Nov. 2009)*

The environmental effects of CFCs and their substitutes

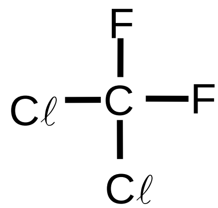
The ozone layer protects the earth and its inhabitants from the dangerous ultraviolet rays of the sun. It was discovered that gases such as chlorofluorocarbons (CFCs) had damaged the ozone layer, creating a huge hole through which dangerous ultraviolet light could reach the earth.

CFCs were widely used as cooling agents in air conditioners and refrigerators and as propellants in aerosol cans because of their special physical properties. CFCs can be produced by the reaction of alkanes with chlorine, followed by the reaction of the resulting product with fluorine.

Since the banning of CFCs in the year 2000, hydrocarbons such as propane and 2-methylpropane are now used as more environmentally friendly alternatives to CFCs.

Both these hydrocarbons and CFCs are greenhouse gases. However, CFCs have greater global warming potential.

1.1 The structural formula for a commonly used CFC is given below.



Write the IUPAC name for this CFC. (2)

1.2 Which physical property of CFCs makes them suitable for use as cooling agents and propellant gases? (1)

1.3 CFCs have a negative impact on the environment.

1.3.1 State this negative impact. (1)

1.3.2 Describe how this negative impact also affects human health. (2)

1.4 Use condensed structural formulae to write a balanced equation for the preparation of chloroethane from ethane. (3)

1.5 State ONE reaction condition needed for the reaction in QUESTION 1.4 to occur.(1)

1.6 Write a structural formula of an isomer of 2-methylpropane. (2)

1.7 Give TWO reasons why propane and 2-methylpropane are considered more environmentally friendly than CFCs. (2)

[14]

QUESTION 2: 15 minutes *(Taken from DoE NSC Physical Sciences P2 Nov 2009)*

Compound P and Compound Q form during dehydration of butan-2-ol. When Compound P reacts with HBr, Compounds X and Y are formed. When Compound Q reacts with HBr, only Compound X is formed. Both Compounds X and Y are haloalkanes.

2.1 Name the type of organic reaction of which dehydration is an example. (1)

2.2 To which homologous series do compounds P and Q belong? (1)

2.3 What type of reaction takes place when compound P is converted to compounds X and Y? (1)

2.4 Use condensed structural formulae to write a balanced equation for the preparation of compound Q as described above. (4)

2.5 Which compound, P or Q, will be the major product?
Give a reason for your answer. (2)

2.6 Write the condensed structural formula and the IUPAC name for compound X. (3)

2.7 A learner indicates that he can convert butan-2-ol directly into compound X.
Name the type of reaction that will take place during a direct conversion (1)
[13]

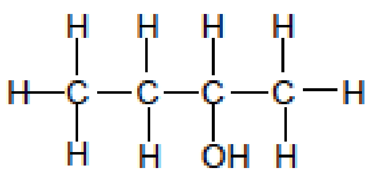
SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 III - elimination/dehydration ✓ (1)

1.2 I – hydration✓
II - hydrohalogenation ✓ (2)

1.3



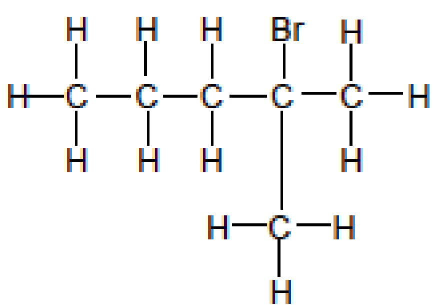
✓✓

2–butanol/butan–2–ol ✓

(3)

1.4 H_2SO_4 ✓ (1)

1.5



✓✓

2-bromo-2-methylpentane ✓
2-bromo-2-metielpentaan/2-broom-2-metielpentaan

(3)

1.6 Alkenes ✓✓ (2)
[12]

QUESTION 2

2.1 Ketones✓

2.2 butane✓

2.3 haloalkanes✓

2.4 aldehydes✓

2.5 haloalkanes✓

2.6 hydrolysis✓

2.7 amines✓

2.8 but-1-ene✓

2.9 ethyne✓

2.10 hydrohalogenation✓

[10]

TOPIC: CONSOLIDATION EXERCISES

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes

A driver of a 3 ton truck takes his eyes off the road for a split second to answer his cell phone. At that moment the truck is travelling at a 100 $km \cdot h^{-1}$. He crashes into a stationary car (with a mass of 500 kg). The car and truck move off together as a unit.

1.1 Determine the speed of the car and truck as they move off together as a unit after the crash. (5)

1.2 Determine the change in momentum of the truck. (3)

1.3 Why should the use of cell phones by drivers be banned? (2)

[10]

QUESTION 2: 20 minutes *(Taken from the IEB Paper 1 Nov 2008)*

Here is a table of the frequencies and wavelengths of various types of electromagnetic radiation:

	Wavelength in m	**Frequency in Hz**
Y-rays	10^{-12} and less	10^{20} and more
X-rays	$10^{-12} – 10^{-9}$	$10^{17} – 10^{20}$
Ultraviolet light	$10^{-9} – 10^{-7}$	$10^{15} – 10^{17}$
Visible light	$10^{-7} – 10^{-6}$	$10^{14} – 10^{15}$
Infra-red light	$10^{-6} – 10^{-3}$	$10^{11} – 10^{14}$
microwaves	$10^{-3} – 1$	$10^{8} – 10^{11}$
Radio waves	$1 – 10^{4}$	$10^{5} – 10^{8}$

2.1 State the relationship between wavelength and frequency of electromagnetic radiation **in words**. (2)

2.2 Calculate the wavelength of blue light with a frequency of $6,67 \times 10^{14}$. (2)

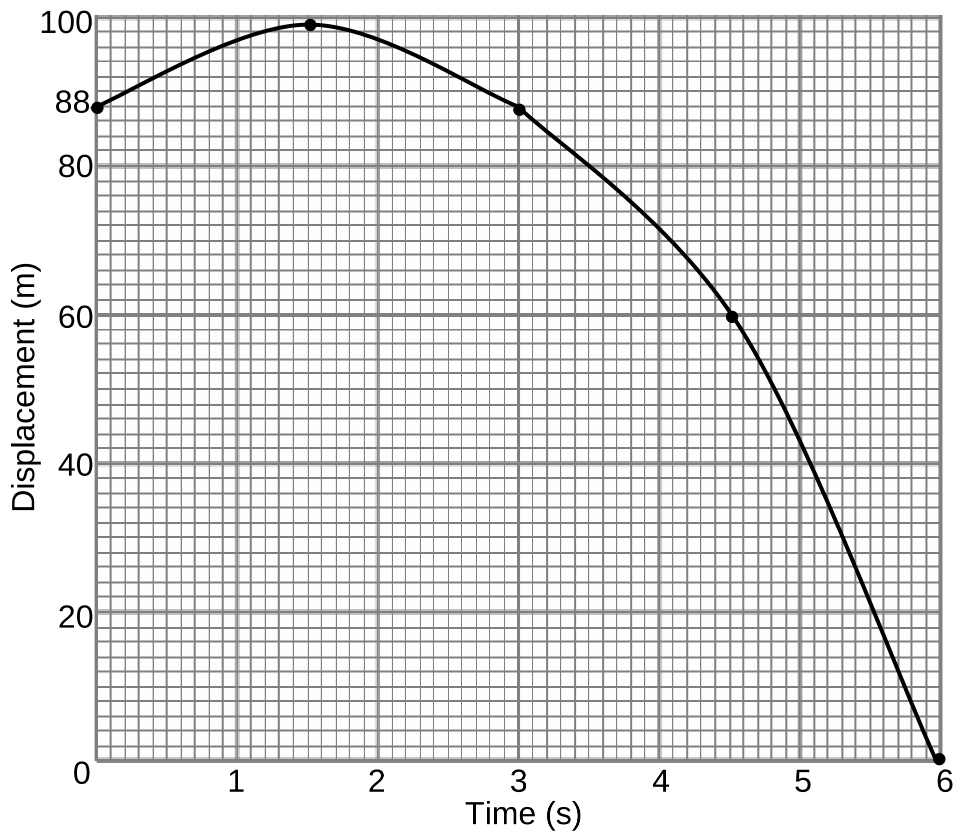
2.3 Where will the following electromagnetic radiations be used in day to day life?
(a) radiation with a frequency of $2,4 \times 10^{18}$ Hz (1)
(b) radiation with a wavelength of 1 378 m (1)
(c) radiation with a wavelength of $4,3 \times 10^{-5}$ m (1)

2.4 (a) Give the equation relating the energy and frequency for all types of electromagnetic radiation. (1)
(b) Use the relationship written down in (a) to explain why radiation with a frequency of $3,12 \times 10^{22}$ Hz can be life threatening. (2)
(c) Give the **name** of this radiation. (1)
(d) Mention **where and when** (no need for a date) this radiation was used to annihilate millions of people, forever changing history. (2)

[13]

QUESTION 3: **10 minutes** *(NSC Exemplar 2008)*

A hot-air balloon is rising vertically at constant velocity. When the balloon is at a height of 88 m above the ground, a stone is released from it. The displacement-time graph below represents the motion of the stone from the moment it is released from the balloon until it strikes the ground. Ignore the effect of air resistance.



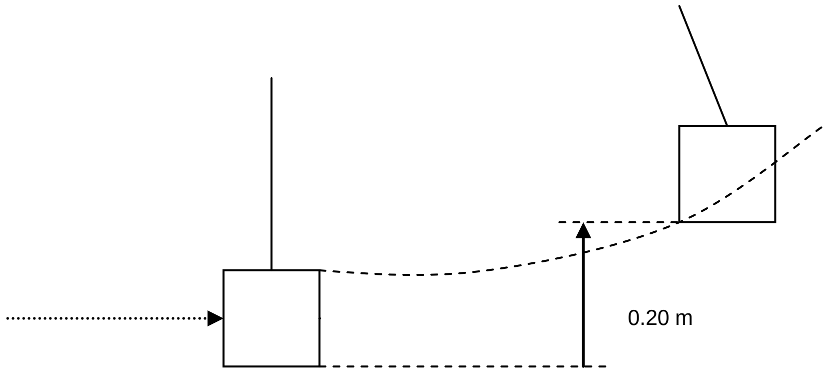
Use information from the graph to answer the following questions:

3.1 Calculate the velocity of the hot-air balloon at the instant the stone is released. (6)

3.2 Draw a sketch graph of velocity versus time for the motion of the stone from the moment it is released from the balloon until it strikes the ground. Indicate the respective values of the intercepts on your velocity-time graph. (3)

[9]

QUESTION 4: 20 minutes



An arrow of mass 0.10kg is shot by a crossbow into a wooden block suspended by a cord from the ceiling in a room. The arrow penetrates the block, becoming stuck in it. The block then swings upward, reaching a vertical height of 0.20m above the level where it was struck.

4.1 If the mass of the wooden block is 3.9kg, calculate the potential energy of the block plus arrow after swinging to a vertical height of 0,20m. (4)

4.2 Calculate the velocity of the block immediately after being struck by the arrow. (6)

4.3 State the law of Conservation of Momentum. (3)

4.4 Use the Law of Conservation of Momentum to calculate the velocity of the arrow just before striking the block. (5)

4.5 In another test, it was found that an identical arrow shot with the same velocity would penetrate 100mm into a block of wood clamped into a vice. Calculate the average force the arrow exerts on the block. (6)

[24]

TOPIC 1 : SOUND AND DOPPLER EFFECT

Learner Note: Always remember to write down the formula with the ± before manipulating and changing it. Please do not insert any zero values into this equation. Leave them out.

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 5 minutes

A car is travelling towards you at 16 m·s^{-1} sounding its hooter with a frequency of 320Hz. The velocity of sound is 330m·s^{-1}. What is the frequency of the sound that you will hear? [5]

QUESTION 2: 10 minutes

Calculate the frequency heard by a stationary listener when an ambulance passes him at a speed of 25 m·s^{-1}:

2.1. when the ambulance is moving towards him and (5)

2.2. when the ambulance is moving away from him. (5)

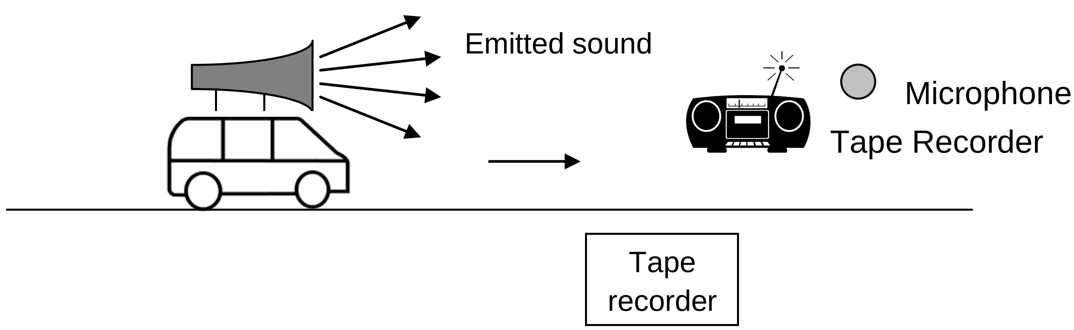
Take the speed of sound to be 340 m·s^{-1} and the frequency of the siren to be 1 500 Hz. [10]

QUESTION 3: 5 minutes

A flying bat emits squeaks at a frequency of 85 kHz. If a stationary observer picks up the frequency of the squeaks as 80 kHz, is the bat moving towards or away from the listener? Determine the speed at which the bat is flying.Take the speed of sound to be 335 m·s^{-1} [5]

QUESTION 4 : 15 minutes *(DoE Physics Paper 1 Exemplar 2008)*

During an experiment to determine the speed of sound, learners are given a siren that sounds a single note of frequency 426 Hz. They attach it to a remote controlled car and move it at constant speed past a stationary tape recorder which is mounted in the middle of a runway. Ignore the effects of friction. The tape recorder records the sound of the siren.



The learners make the following observation:
The pitch of the sound from the siren as it moved towards the tape recorder was higher than the pitch as the siren moved away from the recorder

4.1 In one of the trials the speed of the remote controlled car was noted as 31 $km \cdot h^{-1}$. Two notes from the siren were recorded: one with a frequency of 437 Hz and the other note with a frequency lower than 426 Hz.
Name the effect which explains this observation (2)

4.2 Convert 31 $km \cdot h^{-1}$ to $m \cdot s^{-1}$ (2)

4.3 Determine the speed of sound in air (5)

4.4 Give a reason why the observed frequencies are respectively higher and lower than the frequency of the source (426 Hz). (2)

[11]

QUESTION 5: 15 minutes *(Taken from DoE Nov. Paper 1 2008)*

An ambulance travelling down a road at constant speed emits sound waves from its siren. A lady stands on the side of the road with a detector which registers sound waves at a frequency of 445 Hz as the ambulance approaches her. After passing her, and moving away at the same constant speed, sound waves of frequency 380 Hz are registered. Assume that the speed of sound in air is 343 $m \cdot s^{-1}$.

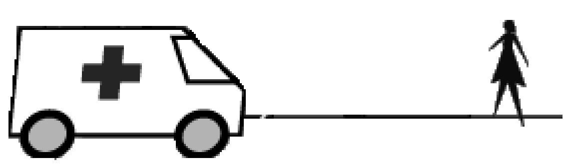
5.1 Name the phenomenon that describes the change in the frequency observed by the lady. (1)

5.2 Calculate:

5.2.1 The speed at which the ambulance is moving. (7)

5.2.2 The frequency at which the siren emits the sound waves. (3)

[11]



HINTS FOR QUESTIONS 1 to 5:
Generally, the direction from the listener (L) towards the source (s) is taken as positive (+).

If the source and the listener move towards each other	If the source and the listener move away from each other
The frequency that is being observed, f_L, will be higher than the emitted frequency, f_S. The equation then becomes $f_L = \frac{v + v_L}{v - v_S} \cdot f_S$ because $v \pm v_L$ must be greater than $v \pm v_S$ thus the + sign is used in the numerator and the in the denominator.	The frequency that is being observed will be lower than the frequency being emitted. The equation then becomes $f_L = \frac{v - v_L}{v + v_S} \cdot f_S$ because $v \pm v_L$ must be smaller than $v \pm v_S$ thus the – sign is used in the numerator and the + sign is used in the denominator.

If the source or the listener is stationary, then leave it out of the equation.

SECTION B: ADDITIONAL CONTENT NOTES

Uses of the Doppler Effect

The blood flow in the heart and foetal heart beats can be detected using Doppler flow meters. This is not the same as ultra sound images.

Ultrasonic waves are emitted by a transmitter and then reflected by the object that is moving. The speed of the moving object, i.e. the foetal heart beat, etc, can be determined by the change in the frequency that is observed.

SECTION C: HOMEWORK

QUESTION 1: 15 minutes

An ambulance is dispatched to see to any injured passengers. The ambulance siren emits sound waves with a frequency of 500Hz.The speed of sound in air at this location is $340 m.s^{-1}$.

1.1 Calculate the wavelength of the sound waves emitted by the ambulance siren. (2)

1.2 How would you know from the sound of the siren if it is moving towards you or away from you? (2)

1.3 Name the effect that changes the sound of the ambulance as it drives towards you. (1)

1.4 Calculate the speed of the ambulance relative to you (a stationary observer) when you hear the siren sound at 495 Hz. (5)

[10]

QUESTION 2: 10 minutes

A spectator at the Formula 1 Grand Prix notices that the sound of the car engines has a higher pitch when the cars are moving towards him and a lower pitch when they move away.

2.1 Explain with the aid of a diagram why this occurs. (2)

2.2 Why is this change in frequency more noticeable at the Formula 1 race than for a car passing a person standing on the pavement in a suburban area? (2)

2.3 If the sound produced by the engine of a formula 1 car is 250 Hz, calculate the frequency of the sound the spectator will hear if the car is approaching him at $200 km\cdot h^{-1}$. (Take the speed of sound to be $340 m\cdot s^{-1}$) (4)

[8]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

$$f_L = \frac{v \pm v_L}{v \pm v_S} \cdot f_S \quad ✓$$

$$= \frac{330\,✓}{330-16\,✓} \times 320\,✓$$

$$= 336\ Hz\,✓$$

[5]

Learner Note: Note the frequency increases as the wave was compressed while the car travelled towards you. You are stationary so v_L is zero and is omitted.

QUESTION 2

2.1

$$f_L = \frac{v \pm v_L}{v \pm v_S} \cdot f_S \quad ✓$$

$$= \frac{340\,✓}{340-25\,✓} \times 1500\,✓$$

$$= 1\,619\ Hz\,✓$$

(5)

2.2.

$$f_L = \frac{v \pm v_L}{v \pm v_S} \cdot f_S \quad ✓$$

$$= \frac{340\,✓}{340+25\,✓} \times 1500\,✓$$

$$= 1\,397\ Hz\,✓$$

(5)
[10]

Learner Note: Always use the value of the speed of sound as given by the examiners or as given on your information sheet.You are stationary so v_L is zero and is omitted.

QUESTION 3

The frequency is lower, thus the bat is moving away from the listener. ✓

$$f_L = \frac{v \pm v_L}{v \pm v_S} \cdot f_S \quad ✓$$

$$80\,000\,✓ = \frac{335}{335 + v_S} \times 85\,000\,✓$$

$$= 20{,}93\ m{\cdot}s^{-1}\,✓$$

[5]

Learner Note: Always use the value of the speed of sound as given by the examiners or as given on your information sheet. You are stationary so v_L is zero and is omitted. Always convert kHZ to Hz by multiplying by 1000.

QUESTION 4

4.1 Doppler Effect✓✓ (2)

4.2 $31\ km \cdot h^{-1} = \frac{31\,000}{3\,600}$ ✓ $= 8,61\ m \cdot s^{-1}$ ✓ (2)

4.3 $f_L = \frac{v}{v - v_S} f_S$ ✓

437 ✓ $= \frac{v}{v - 8,61}(426)$ ✓✓

$v = 342,05\ m \cdot s^{-1}$ ✓ (5)

4.4 Higher frequency: source is moving towards observer. ✓
Lower frequency: source is moving away from observer. ✓ (2)

[11]

QUESTION 5

5.1 Doppler effect✓ (1)

5.2

$$f_L = \frac{v \pm v_L}{v \pm v_S} \cdot f_S \quad ✓$$

When ambulance approaches 445 ✓ $= \frac{343}{343 - v_S} \cdot f_S$ ✓

When ambulance moves away 380 ✓ $= \frac{343}{340 + v_S} f_S$ ✓

$445(343 - v_s) = 380(343 + v_s)$ ✓

$v_L = 27,02\ m \cdot s^{-1}$ ✓ (7)

Learner Note: Many learners find these simultaneous equations very difficult to do. Take time and care when going through the steps to make sure that you understand the mathematics.

5.3 $445(343 - 27,02)$ ✓ $= 343 f_s$ ✓
$f_s = 409,94$ Hz ✓ (3)

[11]

TOPIC 2: LIGHT, ELECTROMAGNETIC WAVES, 2D AND 3D WAVEFRONTS

Learner Note: You need to know your definitions very well. You need to know the difference between refraction, reflection and diffraction. These terms are very often confused

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 2 minutes

A certain electromagnetic wave has a photon energy of 1,89 x 10^{-24} J. What kind of electromagnetic wave is this? [4]

QUESTION 2 : 13 minutes

An electromagnetic wave of frequency 405 MHz is travelling through space.

2.1 What is the wavelength of the wave? (3)

2.2 What type of electromagnetic radiation is this? (2)

2.3 How much energy does each photon have? (4)
[9]

QUESTION 3: 7 minutes

	Mass	Speed
Proton	$1{,}7\times10^{-27}$ kg	$4{,}4\times10^{7}$ m·s^{-1}
Golf ball	50 g	40 m·s^{-1}

Calculate the de Broglie wavelength of both of these objects and suggest why we do not usually take into account the wave nature of everyday macro sized objects. [7]

QUESTION 4: 8 minutes

4.1 The ability of a wave to spread out or bend as it passes through an aperture is called:

A. Diffraction
B. Interference
C. Superposition
D. Refraction

4.2 Lines of constructive interference are called:

A. Nodes
B. Antinodes
C. Peaks
D. Troughs

4.3 Photons are best described as:

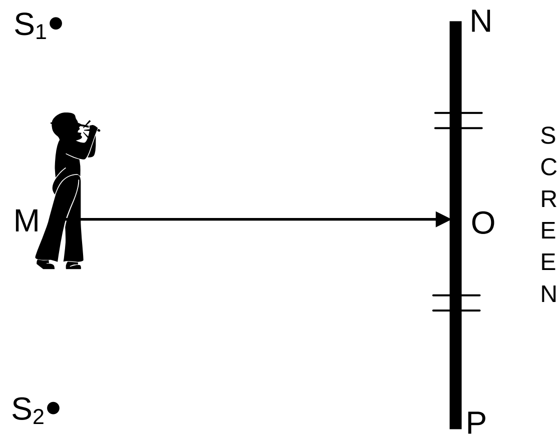
A. Waves
B. Light particles
C. Positive particles
D. Negative particles

4.4 What is the de Broglie wavelength of a proton moving at $4,2 \times 10^{6}$ m·s^{-1}?
The mass of a proton is $1,67 \times 10^{-27}$ kg.

A. $9,4 \times 10^{-14}$ m
B. $7,01 \times 10^{-21}$ m
C. $2,51 \times 10^{33}$ m
D. $3,98 \times 10^{-34}$ m (2 x 4) [8]

QUESTION 5: 10 minutes *(From DoE Physics Paper 1 Exemplar 2008)*

Red light from two stationary narrow slits, S_1 and S_2, reaches a large white screen PON, indicated in the diagram below.



A dark band is observed at point P on the screen. The brightest band is observed at point O on the screen. Bands are arranged such that the band at point N on the screen is dark.

5.1 State Huygens' principle in words. (2)

5.2 Write down the type of interference that occurs at point O. Write down only DESTRUCTIVE or CONSTRUCTIVE. Briefly explain your answer (3)

5.3 Describe the change in brightness, if any, of the light bands formed on the screen as you walk closer to the screen from point M to point O. Briefly explain your answer. (3)

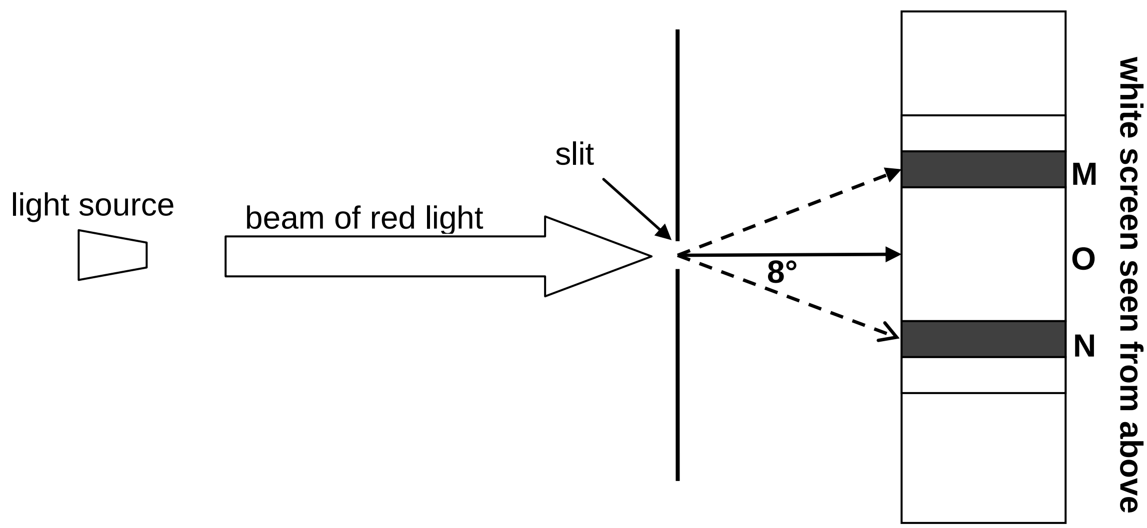
The red light is now replaced with a green light

5.4 How will the new pattern differ from the previous one? (2)
[10]

QUESTION 6: 10 minutes

Monochromatic red light with a wavelength of 650 nm is passed through a single narrow slit and reaches a large white screen as indicated in the diagram below.

(1 nm = 1 x 10^{-9} m)



A wide, red band is observed at point O. On each side of this red band is a narrow dark band followed by alternating narrow red and dark bands. The angle between the central red band O and the first dark band is 8° as shown.

6.1 What is meant by the term “monochromatic”? (2)

6.2 What name is given to this pattern? (1)

6.3 What does the dark band on the screen represent? Explain this phenomenon. (2)

6.4 Calculate the width of the slit through which the red light is passed. (5)

[10]

HINTS FOR QUESTIONS 1 to 6:
Learn the difference between the single slit and the double slit experiment, i.e. the difference between diffraction pattern and the interference pattern.

SECTION B: ADDITIONAL CONTENT NOTES

1. Diffraction

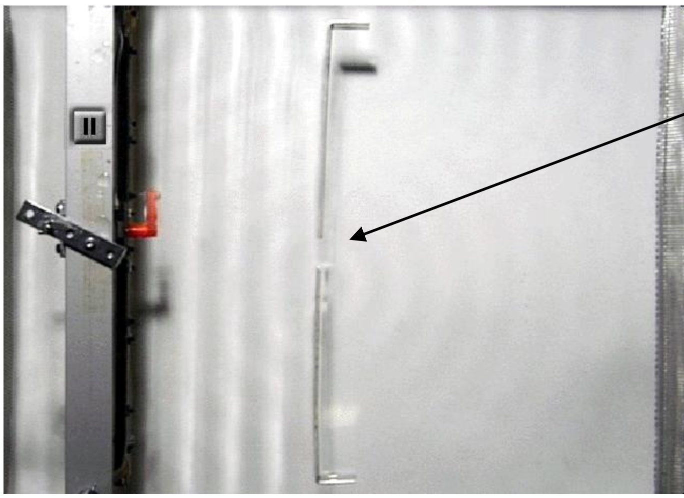
Diffraction is the ability of a wave to spread out in wavefronts as they pass through an aperture (gap) or around a sharp edge.

Water waves seem to 'bend' around corners.

The narrower the opening, the greater the diffraction.

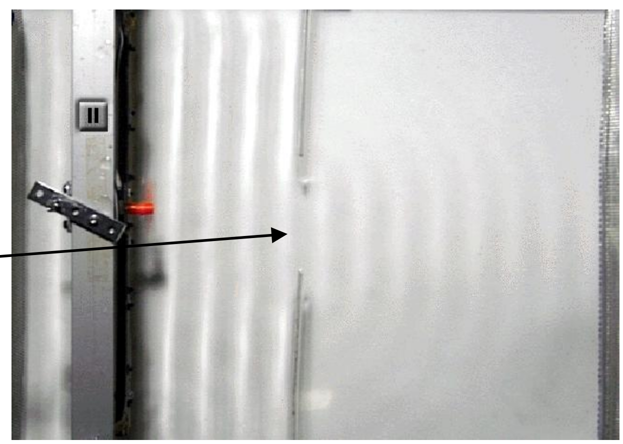
We represent a wave using an imaginary line that joins points that are in phase. This line is called a wavefront.

The shadow region is the area behind the aperture that has no wave fronts.



A narrow opening results in significant bending of the wave. There is little or no shadow region.

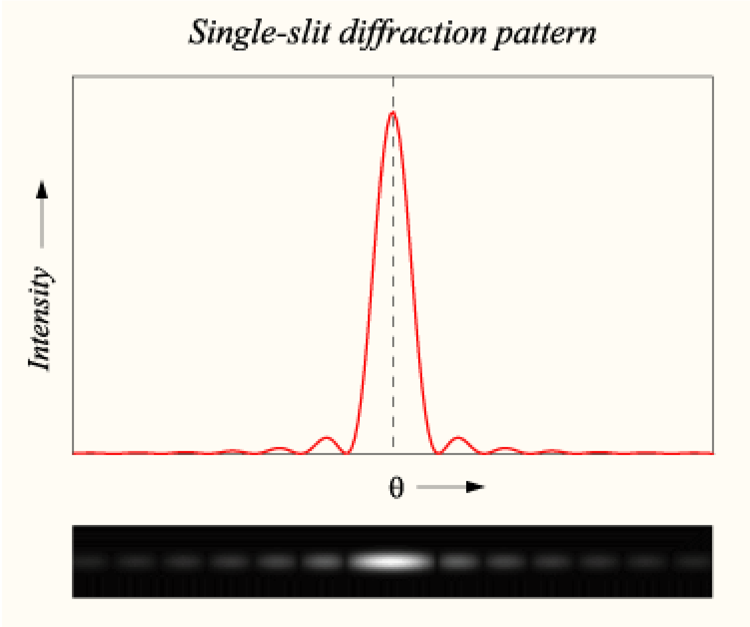
Images captured from Plato Multimedia Science School 11-16 Wave experiment simulations



A wide opening results in slight bending of the wave. There is a significant shadow region.

Diffraction can be explained using Huygens's Principle which suggests that every point on a wave front is the origin of a new circular wavelet.

Huygens's principle states: 'Every point on a wave front may be considered as a new source of circular wave fronts that spreads out in the direction of motion of the wave'.



Source: Diffraction on Wikipedia

Graph and image of single-slit diffraction

From this graph we get the formula: $\sin\theta = \frac{m\lambda}{d}$ for a slit of width d to calculate the position (angle from the horizontal) of the dark bands in a single slit diffraction pattern, where

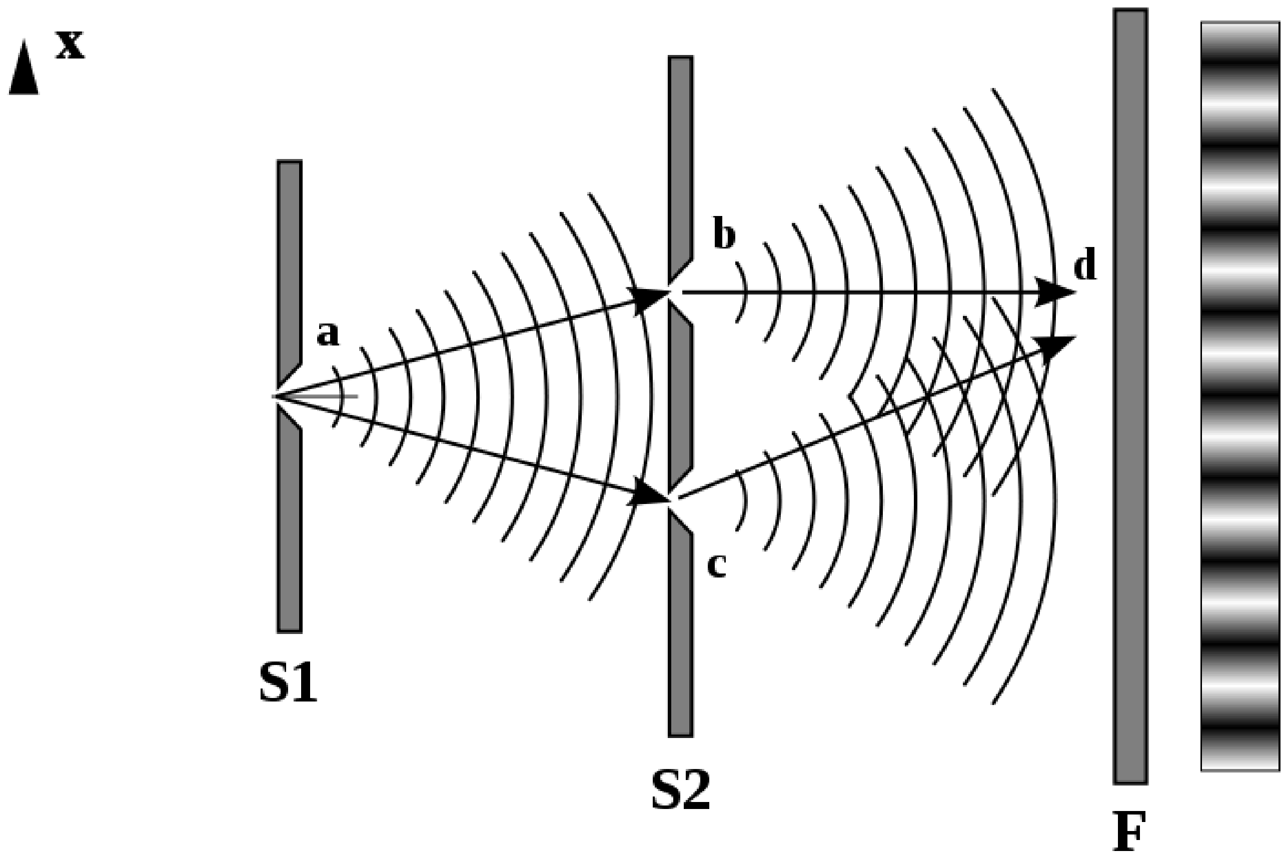
θ = angle of diffraction (between the normal to the slit and the dark fringes).

d = width of slit (m)

λ = wavelength of light (m).

m = the number (+1, +2, +3 etc) of the dark band from the centre of the diffraction pattern.

In Young's double slit experiment, monochromatic light passes through two narrow slits spaced less than 1 mm apart. The light forms circular waves. These waves undergo interference and are then projected onto a distant screen as alternating and evenly spaced bright and darker bands. The formation of the bright bands is as a result of constructive interference, while the darker bands are a result of destructive interference.



SSource: Double- slit experiment from Wikipedia

2. The Principle of superposition

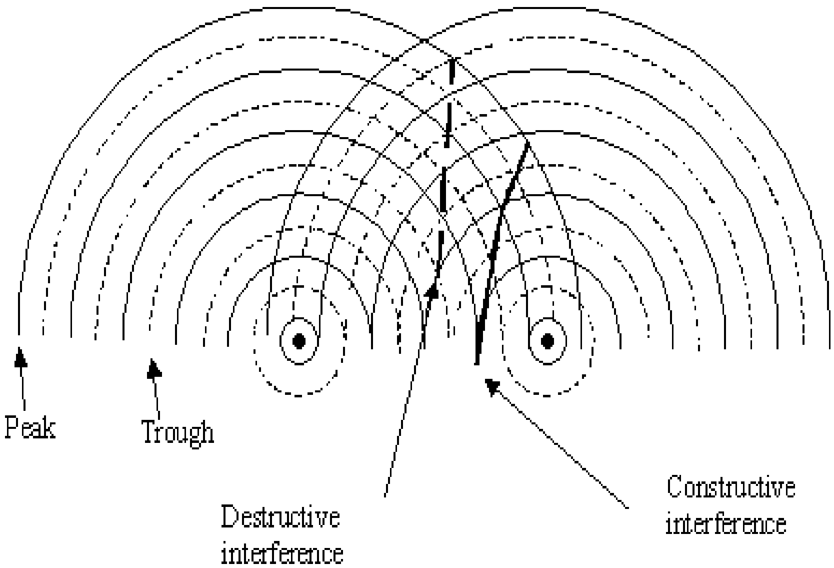
The magnitude of the resultant displacement is the algebraic sum of the displacements of the pulses before interference occurs.

In other words: When two waves meet, they interact with one another.

- When two peaks meet, they make a larger peak equal in amplitude to the size of the sum of the amplitudes of the original two waves. This is constructive interference or an anti-node.
- When two troughs meet, they make a larger trough equal in amplitude to the size of the sum of the amplitudes of the original two waves. This is constructive interference or an anti-node.
- When a peak and a trough meet, they make a smaller peak or trough equal in amplitude to the size of the difference between the amplitudes of the original two waves. This is destructive interference or a node.

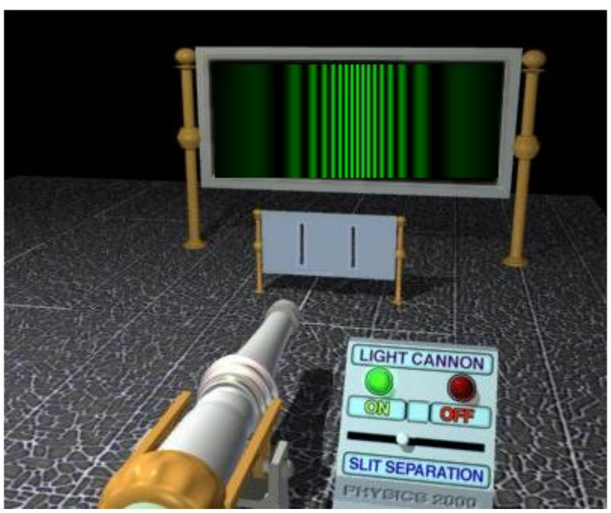
Below is a representation of nodal and anti nodal lines in water waves. This pattern is created by two equivalent vibrating sources close to one another.

Nodal lines are lines of zero disturbance caused by destructive interference (crest & trough)



Anti nodal lines are lines of greater disturbance caused by constructive interference
(2 crests or 2 troughs)

If light is allowed to pass through two, narrow, adjacent slits and the light pattern on the screen is observed, we see light and dark bands. This seems to substantiate the theory that light behaves as a wave since the bands correlate to nodal and anti-nodal lines.



Source: http://www.colorado.edu/physics/2000/schroedinger/two-slit2.html (This website shows a simulation and you can vary conditions)

3. De Broglie's equation

The current theory on light suggests that light is both a wave and a particle simultaneously.
A photon is a "particle" of light made up of waves.
A light wave is a succession of photons.In fact, it is suggested that all particles behave as waves.

de Broglie's wave equation

$$\lambda = \frac{h}{mv}$$

λ – de Broglie's wavelength (m)

h – Plank's constant ($6{,}6\times10^{-34}$ J·s)

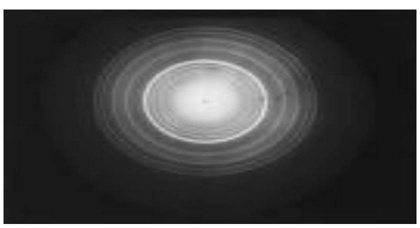
m – mass of particle (kg)

v – velocity of particle ($m\cdot s^{-1}$)

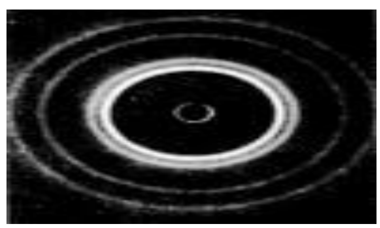
But the larger particles have such short wavelengths that they become insignificant or meaningless.

Small particles, such as electrons (e-), have relatively long wavelengths (0,1nm), which is why electrons seem to reveal a diffraction pattern similar to x-rays. We believe electrons to be particles and x-rays to be waves yet they seem to reveal the same diffraction patterns.

Diffraction patterns of electrons and x-rays



electrons



X-rays

Visible light (λ = 400 nm) has a wavelength 4000 times longer than an electron.
Our current understanding of the atom suggests that electrons produce standing waves at different energy levels.

E.g. What is the de Broglie wavelength of a proton moving at $2{,}8 \times 10^{6}\ m\cdot s^{-1}$?

The mass of a proton is $1{,}67 \times 10^{-27}$ kg.

$$\lambda = \frac{h}{mv}$$

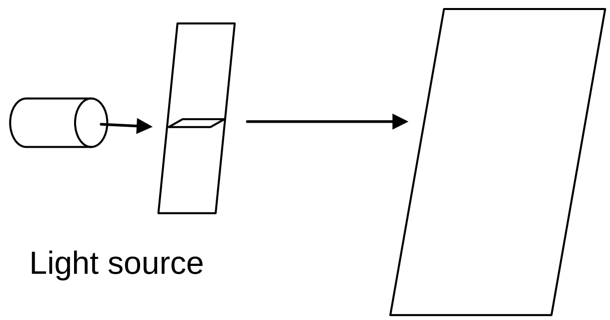
$$= \frac{6{,}6 \times 10^{-34}}{1{,}67 \times 10^{-27} \times 2{,}8 \times 10^{6}}$$

$$= 1{,}41 \times 10^{-13} m$$

SECTION C: HOMEWORK

QUESTION 1: 14 minutes *(From GDE Preliminary Examination 2009)*

Red light with a wavelength of 700 nm is shone through a single slit with a width of 5 μm. A diffraction pattern is observed on a screen 200 cm from the slit.



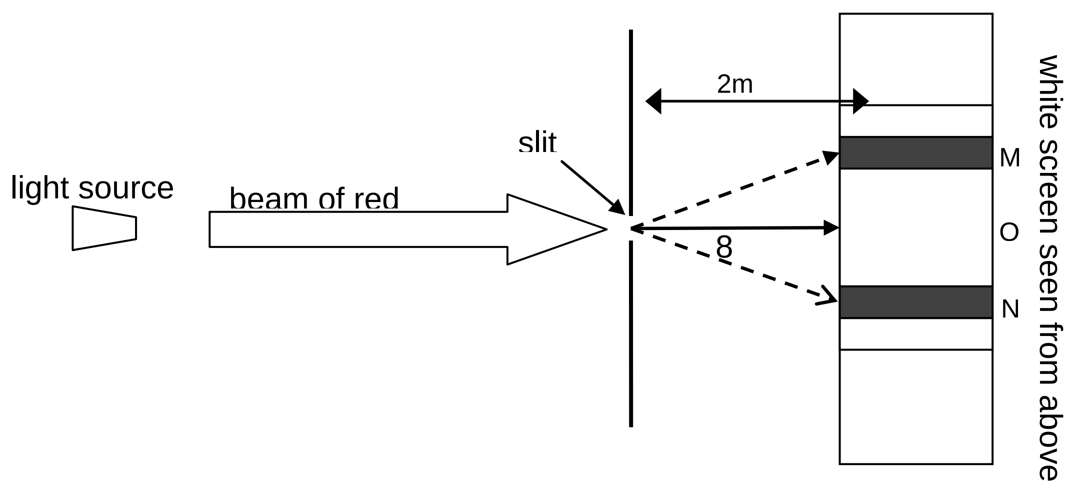
1.1 Describe the diffraction pattern which will be observed on the screen. (2)

1.2 How will the pattern change if the single slit is replaced by a double slit? (2)

1.3 Calculate the width of the central band in the middle of the single slit pattern. (6)
[10]

QUESTION 2: 15 minutes

Monochromatic light is passed through a single narrow slit of width 4,59μm, and reaches a large white screen 2m away from the slit.



A wide, red band is observed at point O. On each side of this red band is a narrow dark band followed by alternating narrow red and dark bands. The angle between the central red band O and the first dark band is 8° as shown.

2.1 Calculate the wavelength of the monochramatic light in nanometres (6)

2.2 Calculate the distance between the 1st two dark bands. (6)

[12]

1. SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

$E = hf$ ✓

$1{,}89 \times 10^{-24} = (6{,}6 \times 10^{-34})f$ ✓

$f = 2{,}9 \times 10^{9}$ Hz✓

This frequency corresponds to the radio wave region of the electromagnetic spectrum.✓

[4]

QUESTION 2

2.1 $v = \lambda f$✓

$3 \times 10^{8} = \lambda\,(405 \times 10^{6})$ ✓

$\lambda = 0{,}74$ m✓ (3)

2.2 radio✓✓ (2)

2.3 $E = hf$✓$= (6{,}6 \times 10^{-34})$ ✓ (405×10^{6}) ✓

$= 2{,}67 \times 10^{-25}$ J✓ (4)

[9]

Learner Note: Remember to convert MHz to Hz and nm to m etc..

QUESTION 3

$\lambda = \frac{h}{mv}$ ✓

$= \frac{6{,}6 \times 10^{-34}}{1{,}7 \times 10^{-27} \times 4.4 \times 10^{7}}$ ✓ ✓

$= 8{,}82 \times 10^{-15}$ m ✓

$\lambda = \frac{h}{mv}$

$= \frac{6{,}6 \times 10^{-34}}{0{,}05 \times 40}$ ✓

$= 3{,}3 \times 10^{-34}$ m ✓

The de Broglie wavelength of a golf ball is about 10^{19} time smaller than a proton. This is truly insignificant to the perceived movement of the golf ball, of to how the golf ball actually behaves.✓ **[7]**

QUESTION 4

4.1. A ✓✓ 4.2. B ✓✓ 4.3. B ✓✓ 4.4. A ✓✓ **[8]**

QUESTION 5

5.1 Every point on a wavefront acts as a source of secondary waves. ✓✓ (2)

5.2 CONSTRUCTIVE ✓ - waves are interfering constructively to increase the amplitude of the wave. ✓✓ (3)

5.3 Brightness of red light remains the same. ✓ The distance from each source to line MO is the same. (The difference in path length is zero) ✓✓ (3)

5.4 Green and dark bands are narrower. ✓✓ (2)

[10]

QUESTION 6

6.1 Light with a single frequency ✓✓and thus one colour. (2)

6.2 Diffraction pattern ✓ (1)

6.3 Destructive interference ✓where waves are out of phase ✓or where a crest and trough meet. (2)

6.4 λ = 650 nm = 650 x 10^{-9} m ✓ , θ = 8°

$$\sin\theta = \frac{m\lambda}{a}✓$$

$$\sin 8°✓ = \frac{650\times10^{-9}}{a}✓$$

$$a = \frac{650\times10^{-9}}{\sin 8} = 4{,}67\times10^{-6}m✓ (= 4{,}67\ \mu m)$$ (5)

[10]

TOPIC 1: ENERGY CHANGES & RATES OF REACTION

Learner Note: Energy changes can be used to determine whether a reaction is exothermic or endothermic. These concepts are important for Rates of Reaction and Chemical Equilibrium.

SECTION A: TYPICAL EXAM OUESTIONS

QUESTION 1: 2 minutes

1.1 Consider the reaction:

$H_2 + I_2 \rightarrow 2HI \quad (\Delta H < 0)$

1.1 Is this reaction exothermic or endothermic? (1)

(HINT: Make sure the different terminology to indicate the heat of the reaction is understood; it is important to be able to identify whether a reaction is exothermic or endothermic.)

1.2 How does the energy of the products compare to that of the reactants? (1)

(HINT: Make sure you know the difference between the reactants and products especially in a reverse reaction.) [2]

Learner Note: A variety of methods are used show the heat of the reaction, i.e.
$A + B \rightarrow C$ + Energy; $A + B \rightarrow C \ \Delta H$ - ; $A + B \rightarrow C \ \Delta H < 0$;
$A + B \rightarrow C \ \Delta H = -20 \text{ kJ·mol}^{-1}$
These are all ways to show that the reaction is exothermic.

QUESTION 2: 8 minutes *(Adapted from DoE Nov 2009)*

Learner Note: The contact process is always asked. Make sure you understand it.

The contact process is used in the industrial preparation of sulphuric acid. The reaction is given below:

$2 SO_2 (g) + O_2 (g) \rightleftarrows 2 SO_3 (g) \qquad \Delta H < 0$

2.1 Draw the potential energy versus reaction coordinate graph for the forward reaction. Indicate the following on the graph:
Activation energy for the forward reaction
Activation energy for the reverse reaction
Activation complex
Heat of the reaction for the forward reaction
Heat of reaction for the reverse reaction (7)
(Refer to criteria for drawing a graph. Know the different labels for this graph. You will often have to read values off it.)

2.2 Is the forward reaction endo or exothermic? (1)

2.3 Is the reverse reaction endo or exothermic? Give a reason for your answer. (2)
[10]

QUESTION 3: 8 minutes *(Adapted from DoE Exemplar 2007)*

During cellular respiration glucose is broken down as shown below

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O \qquad \Delta H = (-)$

The reaction is catalysed by enzymes.

3.1 Is the breakdown of glucose an exothermic or endothermic reaction? Give a reason for your answer. (2)

3.2 Explain what the effect is of the enzymes on the rate of the reaction. (2)
(The effect of a catalyst is always asked, understand and learn it.)

3.3 Write a convincing note to your class mate explaining why regular exercise is necessary. (3)

3.4 In your own words, refer to the reaction and give an explanation of cellular respiration. (3)

[10]

QUESTION 4: 12 minutes *(Taken from: The Answer Series.)*

Study the following reactions

a. $X + Y \rightarrow R + S$ (ΔH = - 200 $kJ{\cdot}mol^{-1}$)
Activation energy for the reaction 350 $kJ{\cdot}mol^{-1}$

b. $C + D \rightarrow E + F$ (ΔH = 150 $kJ{\cdot}mol^{-1}$)
Activation energy for the reaction 600 $kJ{\cdot}mol^{-1}$

(Elements may be represented as letters from the alphabet, don't be put off by this)

4.1 Are the above reactions endothermic of exothermic? Explain. (4)

4.2 What is meant by the term activation energy? (2)

4.3 From the information supplied, what can we deduce about the rate of the reactions? Explain. (5)

4.4 Give an equation whereby ΔH may be calculated. (2)

4.5 What can be done to reduce the amount of activation needed in a reaction? (2)

(15)

Learner Note: NB! Learn how to apply the five factors that influence reaction rate.

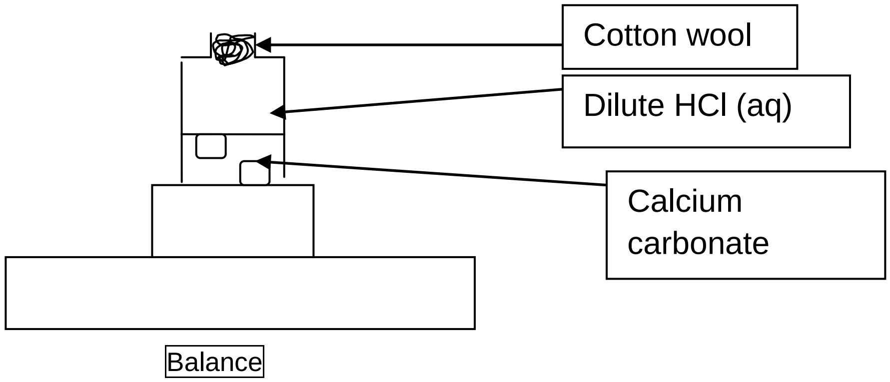
QUESTION 5: 16 minutes *(Source: DoE Physical Sciences Paper 2 Additional Exemplar 2008)*

A learner uses an excess of calcium carbonate chunks and dilute hydrochloric acid during a practical investigation. The following reaction takes place between the two reagents:

$CaCO_3\ (s) + 2HC\ell\ (aq) \rightarrow CaC\ell_2\ (aq) + H_2O\ (\ell)$

The learner provides the following information as part of her laboratory report:

- Set up the apparatus as shown in the diagram below:



- Place 20g of the calcium carbonate into an Erlenmeyer flask and cover it with 50 cm^3 dilute hydrochloric acid.
- Record the mass of the flask and contents at 30 s time intervals.
- Repeat the experiment another two times. Use the same amount of calcium carbonate, but change the size of the calcium carbonate pieces each time by breaking the chunks into smaller particles. Keep the amount and concentration hydrochloric acid constant.

5.1 Write down the investigative question for this investigation. (2)

5.2 Apart from the initial mass of the calcium carbonate and the volume of acid, what initial measurement must the learner make? (1)

5.3 Why does the learner use the same amounts of calcium carbonate and hydrochloric acid during each experiment? (1)

5.4 In recording the time, what important precaution should the learner take? (1)

One set of readings obtained by the learner is shown below:

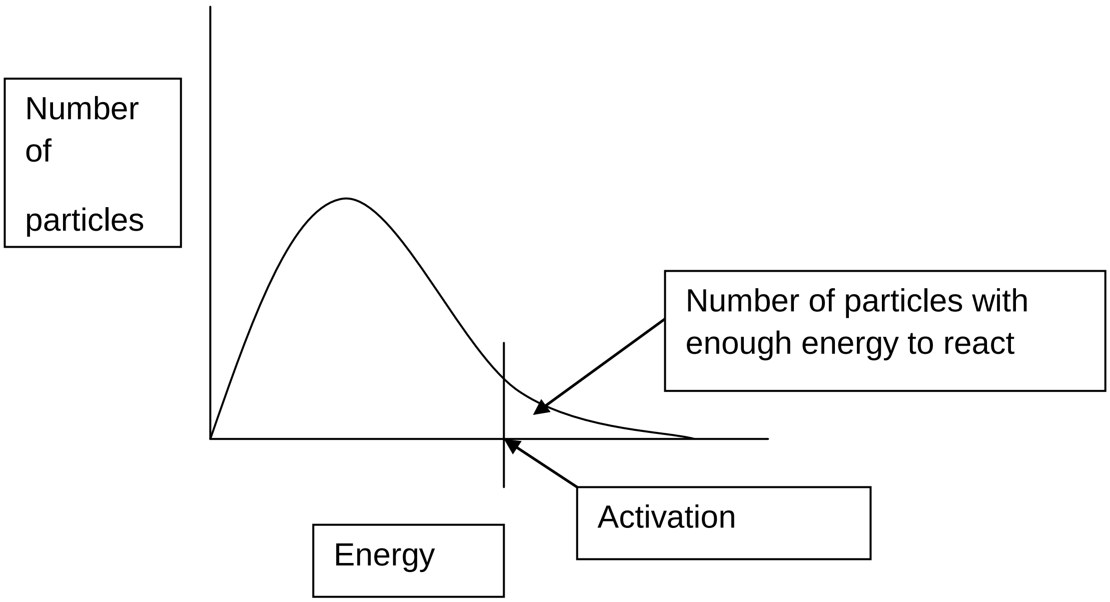
Mass of CO_2 produced(g)	0	0,46	0,70	0,82	0,90	0,95	1,0	1,0
Time (s)	0	60	120	180	240	300	360	420

5.5 Represent the above results on a graph. (6)

5.6 What conclusion can be drawn from the graph? (2)
[13]

QUESTION 6: 9 minutes *(Source: DoE Physical Sciences Paper 2 Additional Exemplar 2008)*

A catalyst speeds up the rate of a reaction. This behaviour of a catalyst can be explained in terms of the activation energy and the collision theory.



6.1 The diagram above shows the Maxwell-Boltzmann distribution curve for a certain reaction.

6.1.1 Explain in terms of the collision theory and activation energy, how a catalyst influences the rate of reaction. (4)

6.1.2 Redraw the above distribution curve into the answer book, and show the new activation energy when a catalyst is added to the reaction mixture on the diagram. (2)

6.2 When milk is left at room temperature, it spoils rapidly. However, in a refrigerator, it stays fresh for a longer time. Use the collision theory to explain this observation. (3)

[9]

SECTION B: ADDITIONAL CONTENT NOTES

ENERGY CHANGES DURING CHEMICAL REACTIONS

- Most reactions do not begin until an amount of energy (activation energy) has been added to the reaction mixture.
- The ***activation energy*** is often called the ***'energy hill'*** which must be 'overcome' by the addition of this amount of energy before a reaction can take place.
- When activation energy is added to the reactants, a so-called ***activated complex*** is formed.
- Activated complex – temporary, unstable, high-energy composition of atoms, which represents a transition state between reactants and the products.
- When the activated complex is formed during a reaction, this complex can lead either to the formation of new bonds, i.e molecules of the products, or to re-formation of the old bonds, thereby returning to being reactants.
- For the reaction

$$AB + C \rightarrow A + BC$$

The formation of an activated complex as a transitional step can be represented as follows:

$$AB + C \rightarrow [ABC] \rightarrow A + BC$$

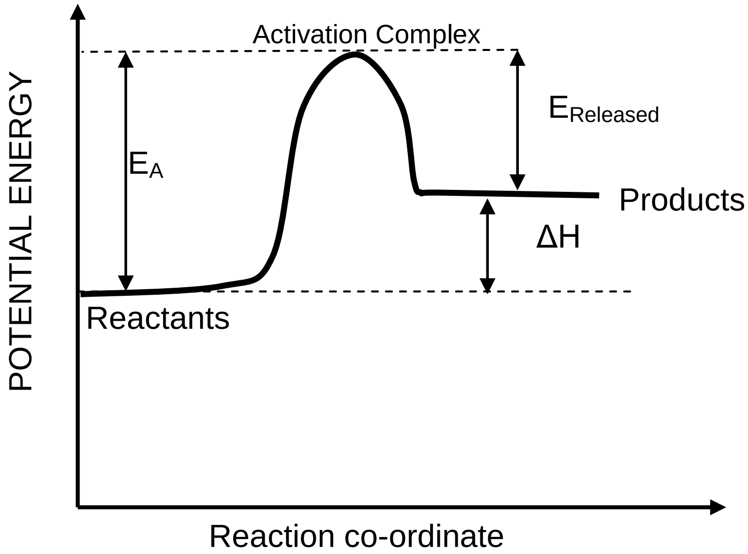
- The peak of the energy hill indicates the energy of the activated complex.
- When an activated complex is formed during a reaction, this complex can lead either to the formation of new bonds, i.e. molecules of the products or to the re-formation of the old bonds, thereby returning to being the reactants. This is ***reversibility for the reaction***.

HEAT OF REACTION (ENTHALPY)

- Heat of the reaction (ΔH) is the difference between the energy of the products and the energy of the reactants.

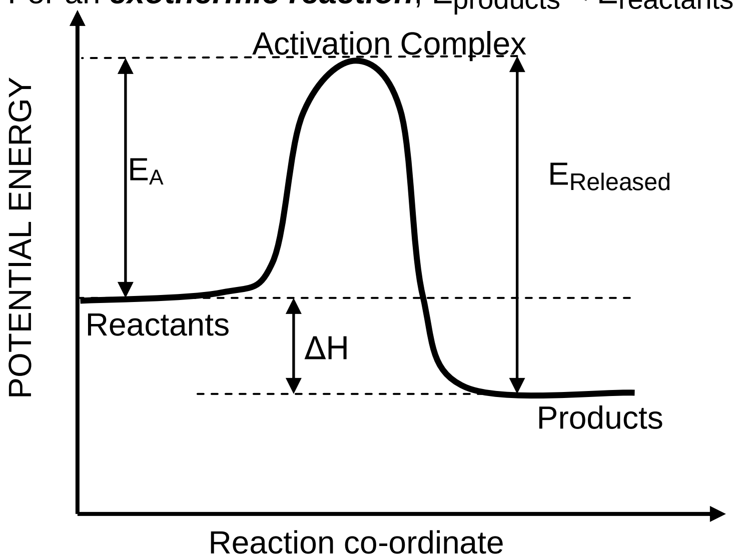
$$\Delta H = E_{products} - E_{reactants}$$

- For an ***endothermic reaction***, $E_{products} > E_{reactants}$, therefore ***$\Delta H$ is positive***.



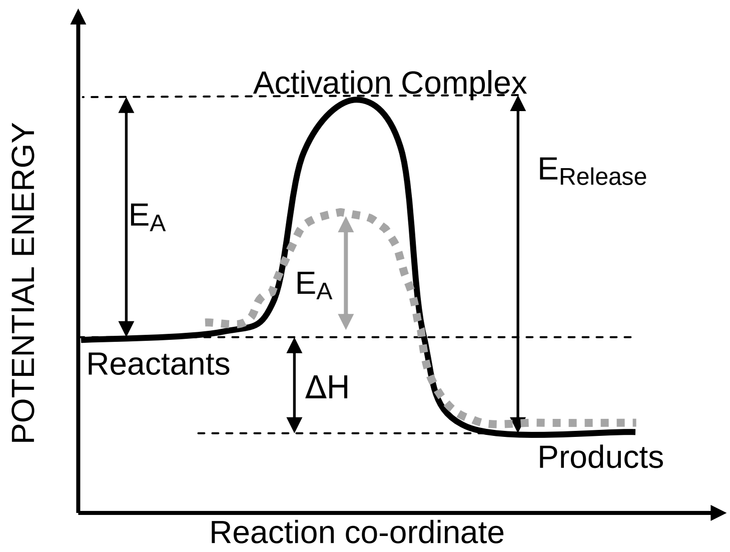
Note: In a reversible reaction, the energy released in forming the products in the forward reaction is the same as the activation energy (E_A) of the reverse reaction.

- For an ***exothermic reaction***, $E_{products} < E_{reactants}$, ***ΔH is negative***.



The Mechanism of a Catalyst

- A catalyst mechanism: the function of a catalyst is to provide an alternate route for the reaction to take place. This route has a lower activation energy, and the rate of the reaction increases. A catalyst forms part of the activated complex and when this decomposes the catalyst is released, unchanged.



- The function of a catalyst is to provide an alternate route for the reaction to take place. This route has a lower activation energy, and the rate of the reaction increases.
- A catalyst forms part of the activated complex and when this decomposes the catalyst is released, unchanged.
- Two kinds of catalysis:
  - Homogenous – catalyst is the same phase as the reactants.
  - Heterogeneous – catalyst in different phase as the reactants.
- Catalysts cannot cause a reaction to occur; they can only affect the rate of the reaction.

RATES – SPEED OF A REACTION

When we study the rate of the reaction, we study the speed at which the reaction occurs.

MACROSCOPIC VS MICROSCOPIC

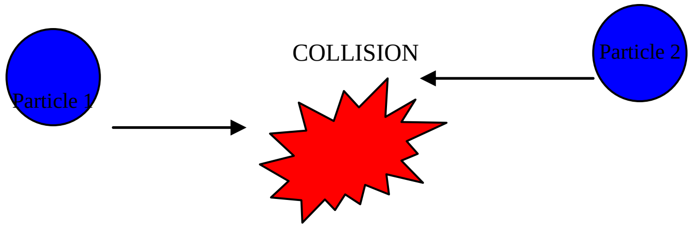
It is important to know that no one has ever seen an atom, and it is very unlikely that anyone will see an atom in the near future.

What we see in chemical reactions are known as MACROSCOPIC observations.

What is actually happening to the atoms, we refer to as MICROSCOPIC changes. Often MICROSCOPIC changes are just THEORY.

COLLISION THEORY

A THEORY is our best explanation of what we observe right now. FACTS have been seen and are what science has proved to be correct.



We need to understand how atoms behave. If we had magic spectacles (glasses) and were able to see atoms moving around, we would notice the following:

- Reactions take place when particles collide.
- Not all collisions lead to reactions.
- Those collisions that do lead to reactions are called effective collisions.
- To increase the rate of a reaction, the number of possible effective collisions should be increased.

In other words, the more often we can make atoms collide, the faster the reaction will take place.

FACTORS THAT INFLUENCE RATE

- *Temperature* – The faster the particles move, the more likely they are to collide, so the more likely they are to react.
- *Pressure* (only in gases) – The more you push the particles together, the more likely they are to collide, so the more likely they are to react.
- *Concentration* (solutions and gases) – the more particles squashed in per dm^3, the more likely they are to collide, so the more likely they are to react.
- *State of division and size of reaction surface* (solids) – the more particles open to be reacted with, the more likely they are to collide, so the more likely they are to react.
- *Catalyst* – the activation energy is lowered for the reaction, making it easier for substances to react, so they react faster.
- *Nature of reacting substances* – different types of substances, by their very nature, react at different speeds. For example, iron oxidises (rusts) relatively slowly while carbon (coal) oxidises (burns) fairly fast

MEASURING REACTION RATE

If we do an experiment to establish the speed (rate) of a reaction under different conditions, we can measure how fast the reaction is proceeding in a number of different ways:

- Measure how reactants disappear or products appear
- colour changes (colour cards or spectrophotometers)
- concentration of ions (conductivity)
- gas volume produced
- mass changes
- volume of solid formed

CATALYSTS

- A catalyst is a substance that speeds up a chemical reaction without being chemically changed itself. It does not form part of the product.
- Catalysts make it possible for reactants to enter a new transition state that has less potential energy. (Lower activation energy)
- Catalysts provide a new MECHANISM for the reaction.
- The reaction mechanism is the sequence of events at a molecular level that control the speed and outcome of a reaction.

TYPES OF CATALYSTS

- Heterogeneous – usually solid with gas or liquid moving over it (motor vehicle catalytic converters)

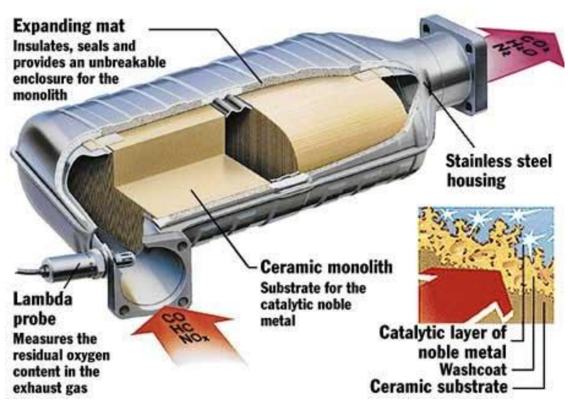


Image from: http://www.ace.mmu.ac.uk/Resources/Fact_Sheets/Key_Stage_4/Air_Pollution/25.html

- Homogeneous – usually all in the liquid phase
- Enzymes – very specific shaped biological molecules (lock and key mechanisms)

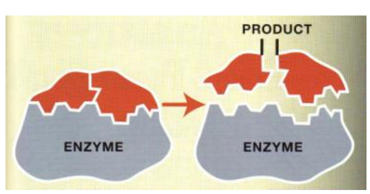


Image from: http://www.mercury-poison.com

SECTION C: HOMEWORK

QUESTION 1: 5 minutes

1. Explain the following terms:

1.1. Heat of reaction (2)

1.2. Endothermic reaction (2)

1.3. Activation energy (2)

[6]

QUESTION 2: 5 minutes

Classify each of the following as either endothermic or exothermic.

2.1 $CO + NO_2 \rightarrow CO_2$ $\Delta H = -226\ kJ \cdot mol^{-1}$

2.2 $2HI \rightarrow H_2 + I_2$ $\Delta H = +40\ kJ \cdot mol^{-1}$

2.3 $H_2 + F_2 \rightarrow 2HF$ $\Delta H = -536\ kJ \cdot mol^{-1}$ [6]

QUESTION 3: 5 minutes

What provides activation energy for the following chemical changes?

3.1 Paint on a roof fades

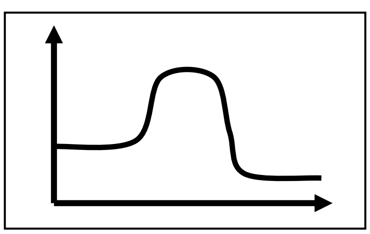
3.2 A Bunsen burner is lit

3.3 A bush fire starts [6]

QUESTION 4: 5 minutes

The graph in the diagram alongside represents the change in energy that occurs during the reaction...

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$



4.1 Provide labels for the x and the y-axes. (2)

4.2 Compare the energy of the products to that of the reactants. (2)

4.3 What is an activated complex? (2)

4.4 Is ΔH for this reaction positive or negative? (1)

4.5 Is this reaction endothermic or exothermic? (1)

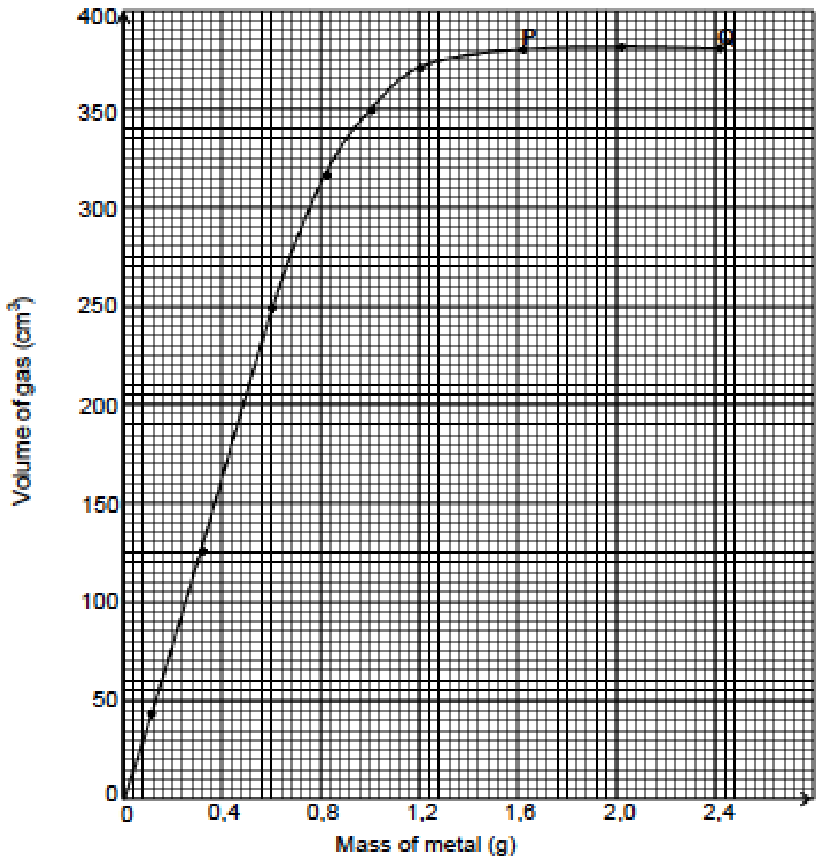
[8]

QUESTION 5: 12 minutes *(Source: DoE Physical Sciences Paper 2 Exemplar 2008)*

A learner investigates the relationship between the mass of a metal and the volume of the gas produced when the metal reacts with dilute hydrochloric acid. During the investigation the learner adds the metal in amounts of 0,4 g to a certain volume of acid in a container. After the complete reaction between the metal and the acid, the learner measures the volume of gas that forms after each addition of the metal.

5.1 State a possible hypothesis for this investigation. (2)

The learner plotted the graph shown below after conducting the investigation.



5.2 Name TWO variables that must be controlled during this investigation. (4)

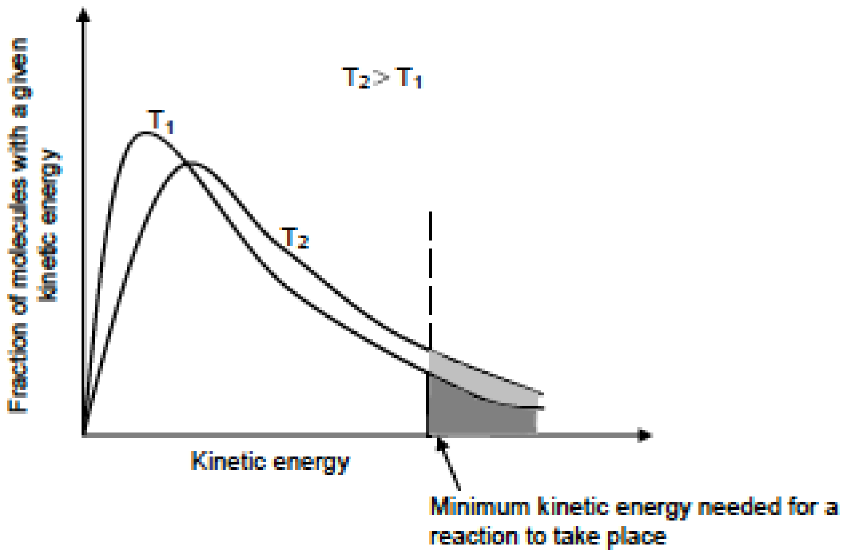
5.3 What conclusion can be drawn from the section PQ on the graph? (2)

5.4 Use the graph to predict the volume of gas that will be produced when 0,4g of the metal reacts with the acid. (2)

[10]

QUESTION 6: **5 minutes** *(Taken from DoE Physical Sciences Paper 2 Exemplar 2008)*

In general a teaspoonful of sugar dissolves much quicker in hot water than in the same amount of cold water. Use the graph that follows, and knowledge of the collision theory to explain this observation.



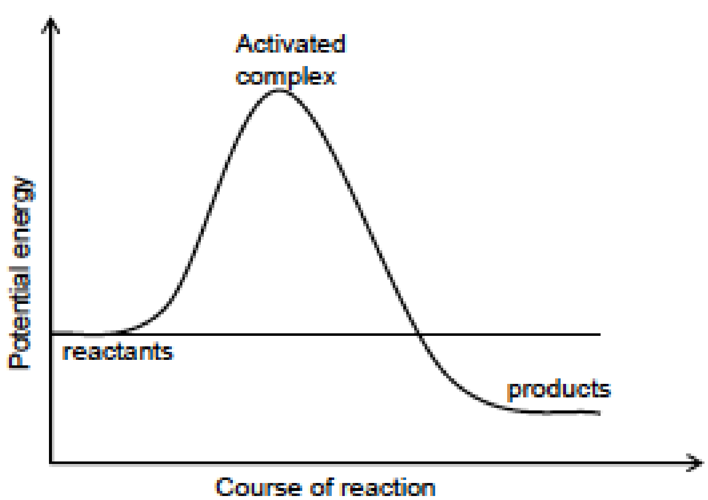
[5]

QUESTION 7 **8 minutes** *(Taken from DoE Physical Sciences Paper 2 Exemplar 2008)*

In a limited supply of oxygen, such as in a car which is not tuned properly, octane burns incompletely to produce, amongst others, carbon monoxide. The following balanced chemical equation represents the reaction during which carbon monoxide forms:

$$2C_8H_{18}\ (l)\ +\ 17O_2\ (g) \rightarrow 16CO\ (g)\ +\ 18H_2O\ (g) \qquad \Delta H < 0$$

The reaction can be represented by the potential energy graph below:



7.1 By comparing the activation energies of the forward and reverse reactions, explain whether it will be easier to form the products from reactants or reactants from products. (2)

7.2 Use the chemical equation above and give a reason why vehicles with incorrectly tuned engines are a health hazard. (2)

7.3.1 Part of the action of catalytic converters is to speed up the complete oxidation of carbon monoxide (CO) and petrol (C_8H_{18}) from incorrectly tuned engines according to the equations below:

$$2C_8H_{18}\ (l)\ +\ 25O_2\ (g)\ \rightarrow\ 16CO_2\ (g)\ +\ 18H_2O\ (g)\ \ldots\ldots\ldots\text{(i)}$$

$$2CO\ (g)\ +\ O_2\ (g)\ \rightarrow\ 2CO_2\ (g)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

Why should people support legislation that makes catalytic converters a necessary component of exhaust systems of automobiles? (2)
[6]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

ENERGY CHANGES & RATES OF REACTION

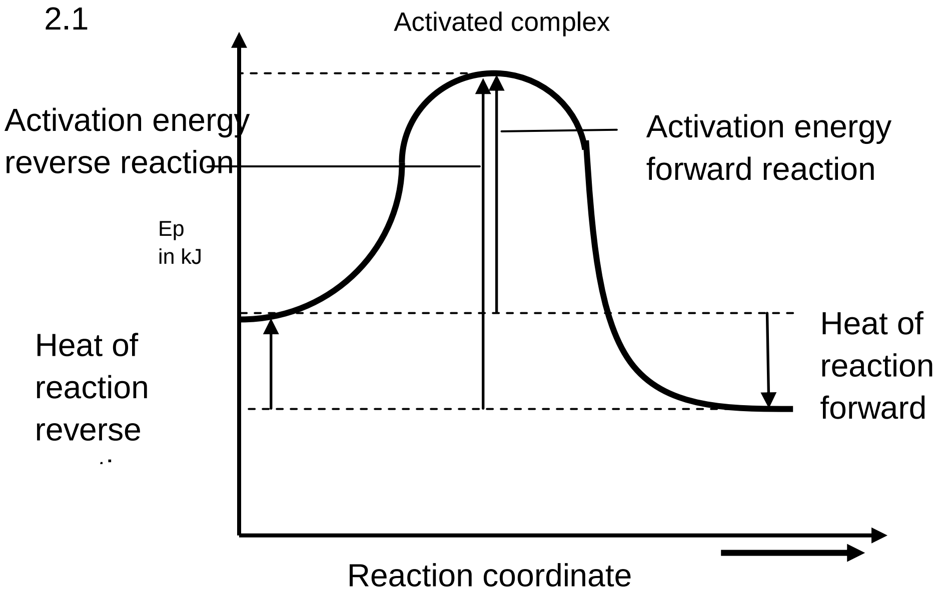
QUESTION 1

1.1 Exothermic ✓ (1)

1.2 E products < E reactants ✓ (1)
(Make sure you look carefully at the bigger than or smaller than sign, it can easily be confused if you do not concentrate) **[2]**

QUESTION 2

2.1



Mark allocation

Activation energy for the forward reaction ✓
Activation energy for the reverse reaction ✓
Activation complex ✓
Heat of the reaction for the forward reaction ✓
Heat of reaction for the reverse reaction ✓
Axes labelled ✓
Shape of graph ✓
(Learn the labels – for the forward and reverse reaction.)

(7)

2.2 Exothermic ✓ (1)

2.3 Endothermic, ✓ energy of the products are greater than the energy of the reactants ✓ (2)

[10]

Learner Note: It is important to be able to draw the energy curves for forward and reverse reactions. Ensure that you are able to answer questions for both reactions if one of the graphs, i.e. forward or reverse is given. Practise this. Remember to label the axes!

QUESTION 3

3.1 Exothermic, ✓ the heat of the reaction is negative; energy is given off ✓ (2)

3.2 Enzymes are catalysts ✓ - catalysts speed the reaction up ✓and increase the rate of the reaction. (2)

3.3 Glucose is broken up by the body during exercise, ✓ it reduces weight gain ✓ as it uses energy ✓ (3)

3.4 Cellular respiration is the reaction of glucose with oxygen (oxidation of glucose) ✓ to produce carbon dioxide, water and energy. ✓ It occurs in the presence of a catalyst ✓ (3)

[10]

Learner Note: Learn the function of a catalyst – it reduces the activation energy for the forward and reverse reaction.

QUESTION 4

4.1 a. Exothermic, ✓ heat of the reaction is negative ✓ (2)

b. Endothermic, ✓ heat of the reaction is positive ✓ (2)

4.2 The minimum amount of energy needed to start a reaction ✓✓ (2)

4.3 a Has the lowest activation energy ✓ therefore it will have a greater reaction rate ✓ – less energy is needed to start the reaction ✓ (3)

b Has a lower rate of reaction✓ – more energy is required to get the reaction to take place ✓ (2)

4.4 $\Delta H = H_{products} - H_{reactants}$ ✓✓ (2)

4.5 By adding a catalyst ✓ the amount of activation energy is reduced ✓ (2)

[15]

QUESTION 5

5.1 Use the checklist*:*

Examples:

What is the relationship between the reaction rate and size of particles?

Does the rate of reaction depend on surface area /particle size of reactants?

How will the rate of reaction change when the surface area of particles change?

Checklist:

Criteria for investigative question:	**Mark**
Question that refers to independent variable.	✓
Question that refers to dependent variable	✓

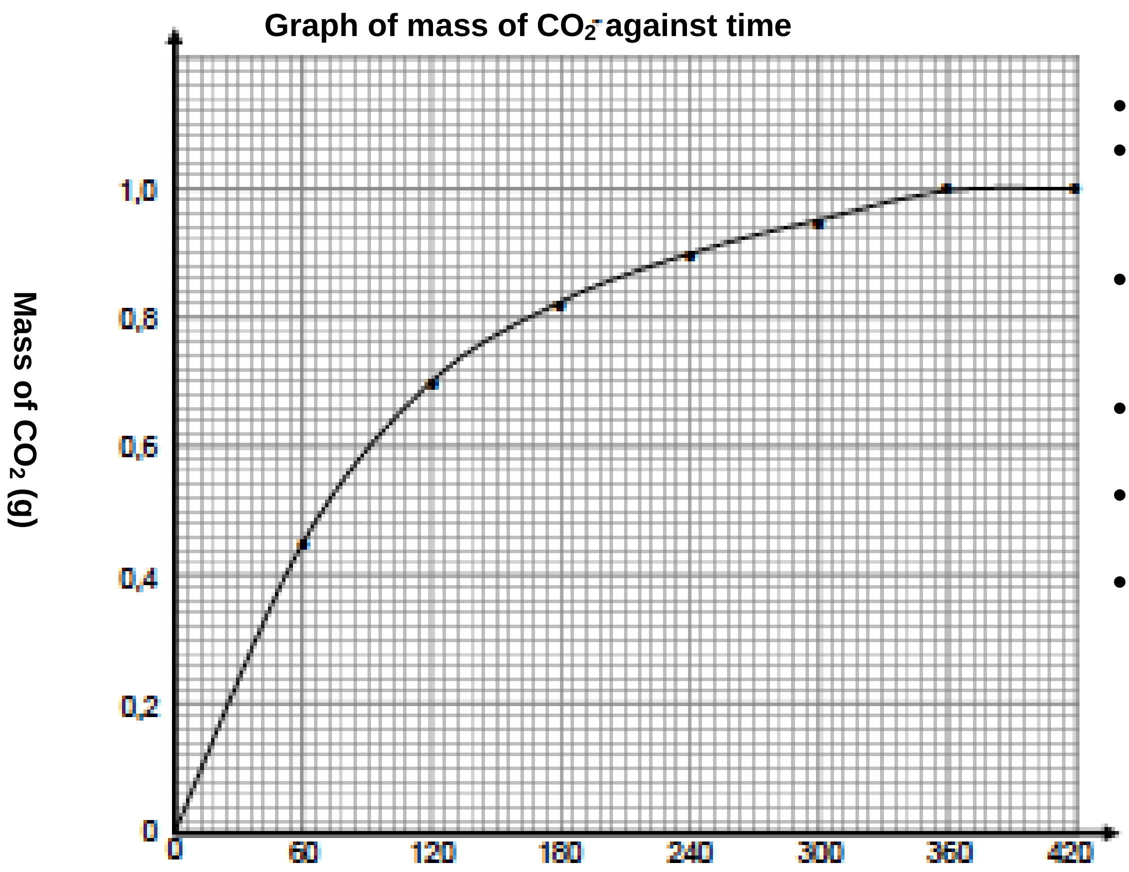
(2)

5.2 The initial mass of the conical flask and its contents ✓ (1)

5.3 To ensure a fair test. ✓ (1)

5.4 The time must be taken from the moment the calcium carbonate is added to the acid. ✓ (1)

5.5



- Appropriate heading
- Independent variable (time) on the horizontal axis
- Dependent variable (mass) on the vertical axis
- Appropriate scale on both axes
- Points correctly plotted
- Best fit curve drawn through points

5.6 The mass of CO_2 produced each time interval decreases ✓✓ as the concentration of reactants decreases until the reaction stops and no CO_2 is produced.

OR

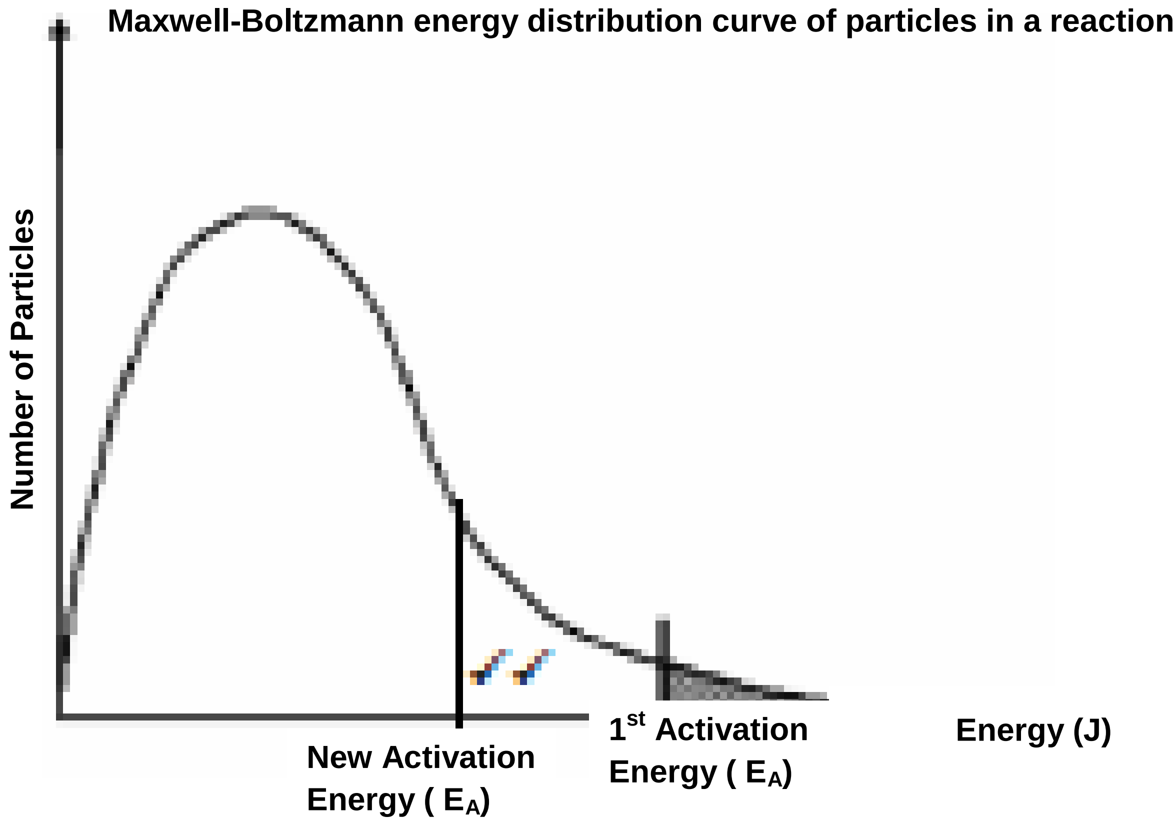
The rate of the reaction / production of CO_2 (g) decreases as the reaction proceeds. (2)

[7]

QUESTION 6

6.1.1 The catalyst provides an alternative pathway/route for the reaction ✓ with a lower activation energy. ✓ More molecules/particles have enough energy ✓ and more effective collisions occur, ✓ increasing the rate of reaction. (4)

6.1.2 (2)



6.2 At higher temperature, average kinetic energy of molecules increases ✓ and the number of effective collisions increases ✓ and the number of effective collisions increases ✓ hence the spoiling process goes faster ✓ than at lower temperatures.

(3)

[9]

TOPIC 2: CHEMICAL EQUILIBRIUM

Learner Note: Please understand and learn the factors affecting the rate of a reaction very well before attempting this section on chemical equilibrium. The only factors affecting chemical equilibrium are temperature, concentration and pressure.

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 5 minutes

Consider the following equilibrium reaction:

$$N_{2\,(g)} + 3\,H_{2(g)} \leftrightarrows 2NH_{3\,(g)} \quad \triangle H< 0$$

9 mol of N_2 and 15 mol of H_2 are pumped into a 500cm^3 container at room temperature.

The temperature of the gas mixture is now raised to 405°C resulting in 8 mol NH_3 being present at equilibrium.

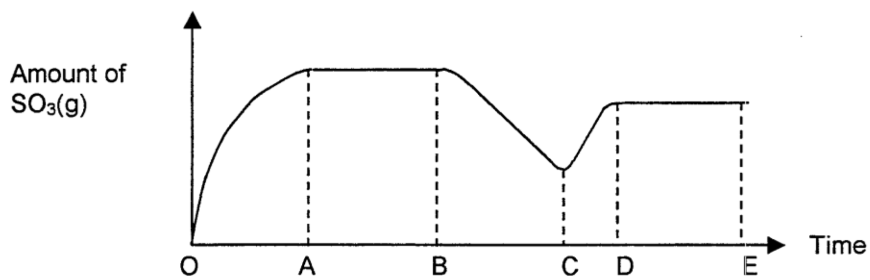
Calculate the value of K_c at 405°C0 [6]

QUESTION 2: 18 minutes

Consider the following reaction:

$$2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2SO_{3\,(g)} \qquad \Delta H < 0$$

A graph of the AMOUNT of $SO_{3\,(g)}$ was plotted against time as shown below:



2.1 How does the rate of the forward reaction compare to the rate of the reverse reaction during the following intervals?:(Write down only GREATER THAN, EQUAL TO or LESS THAN.)

2.1.1 OA (1)
2.1.2 BC (1)
2.1.3 DE (1)

2.2 Initially 8,0 moles of $SO_{2\,(g)}$ and x moles of $O_{2\,(g)}$ are placed in a 2,0 dm^3 empty container and sealed at a specific temperature. At equilibrium 6,0 moles of $SO_{3\,(g)}$ are present in the container. If the K_C value of the above equilibrium at this temperature is 9, calculate x, that is, the initial amount of $O_{2\,(g)}$ that was placed in the container. (6)

2.3 If the changes in the graph from B to D are due to changes in the TEMPERATURE, at which points (B, C or D) will the temperature be the lowest? (1)

2.4 Give an explanation for the answer to 2.3. (2)

2.5 At which point (B, C or D) will the K_C value be the greatest? (1)

2.6 Give an explanation for the answer to 2.5. (2)

2.7 If the changes in the graph from B to D are due to PRESSURE changes, at which point (B, C or D) will the pressure be the lowest? (1)

2.8 Give an explanation for the answer to 2.7. (2)
[18]

QUESTION 3: 7 minutes

3. A mixture of 5 moles of $H_{2\,(g)}$ and 10 moles of $I_{2\,(g)}$ is placed in a $5dm^3$ container and is allowed to reach equilibrium at 448°C. The equation for the equilibrium reaction is:

$$H_2(g) + I_{2\,(g)} \rightleftharpoons 2HI_{(g)}$$

At equilibrium the concentration of the $HI_{(g)}$ is equal to 1,88 $mol.dm^{-3}$.

3.1 Calculate the value of K_c at 448°C. (6)

3.2 While the system is in equilibrium, $H_{2\,(g)}$ is added to it. Explain by using Le Chatelier's principle how the addition of $H_{2\,(g)}$ influences the number of moles of $HI_{(g)}$ when a new equilibrium has been established. Assume that the temperature is kept constant (3)
[9]

QUESTION 4: 20 minutes *(Physical Sciences Paper 2 DoE Feb – March 2010)*

Combustion in air at high temperatures produces oxides of nitrogen of which nitrogen dioxide (NO_2(g)), is the most common. Natural sources of nitrogen dioxide include lightning and the activity of some soil bacteria. These natural sources are small compared to emissions caused by human activity.

NO_2 can irritate the lungs and cause respiratory infection. When NO_2(g) dissolves in rainwater in air it forms nitric acid which contributes to acid rain.

4.1 State TWO human activities that contribute to high nitrogen dioxide levels in the atmosphere. (2)

4.2 Write a balanced equation to show how nitric acid forms from nitrogen dioxide in air. (2)

4.3 High levels of nitrogen dioxide in the atmosphere can result in damage to crops and eventually food shortages. Briefly state how high levels of nitrogen dioxide can damage crops. (1)

4.4 Nitric acid can cause corrosion of copper cables whilst hydrochloric acid does no harm to copper cables. Refer to the relative strengths of the oxidising agents involved to explain this phenomenon (3)

4.5 2 mol of $NO_2(g)$ and an unknown amount of $N_2O_4(g)$ are sealed in a 2 dm^3 container, that is fitted with a plunger, at a certain temperature. The following reaction takes place:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

At equilibrium it is found that the NO_2 concentration is 0,4 $mol \cdot dm^{-3}$. The equilibrium constant at this temperature is 2.

4.5.1 Calculate the initial amount (in mol) of $N_2O_4(g)$ that was sealed in the container. (9)

The plunger is now pushed into the container causing the pressure of the enclosed gas to increase by decreasing the volume.

4.5.2 How will this change influence the amount of nitrogen dioxide at equilibrium? Only write down INCREASES, DECREASES or REMAINS THE SAME. (1)

4.5.3 Use Le Chatelier's principle to explain your answer to QUESTION 4.5.2. (2)

[21]

SECTION B: ADDITIONAL CONTENT NOTES

EQUILIBRIUM

EFFECTIVENESS OF REACTIONS

What is equilibrium?

- ⇆ Reactions that take place in both the forward and reverse directions simultaneously are called reversible reactions.
- ⇆ Observable macroscopic changes stop, while microscopic changes continue as reactants change to products, and products change back into reactants.
- ⇆ When the rate of the forward reaction equals the rate of the reverse reaction, we say a state of dynamic equilibrium has been reached.

Le Chatelier's Principle

If the conditions of an equilibrium system are changed by changing temperature, pressure or concentration, a process takes place which tends to oppose the effect of the change.

⇆ An equilibrium may be disturbed by changing any one (or more) of the factors for the equilibrium.

- Temperature
- Concentration (gases and solutions)
- Pressure (gases only)

Changing Equilibrium Conditions

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftarrows 2NH_{3\,(g)} \quad (\Delta H < 0)$$

Concentration

- An increase in concentration of any reactant will cause an increase in the reaction rate of the forward reaction.
- Increasing the concentration of the N_2 or H_2 would, therefore, increase the rate of the forward reaction, hence favouring the nshift of the equilibrium towards the forward reaction.

Temperature

- An increase in temperature causes an increase in the rate of **both** reactions.
- ΔH refers to the forward reaction. If it is negative, the reaction is exothermic (energy is liberated).
- Increasing the temperature will favour the endothermic (reverse) reaction.

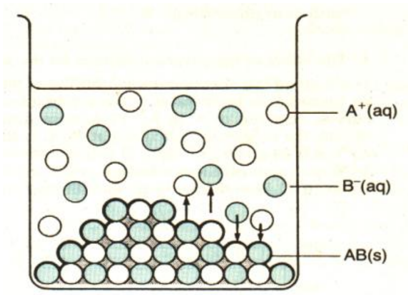
Pressure

- Pressure can be increased by decreasing the volume of the container.
- When the volume of the container decreases, the total concentration of all gases increases.
- According to Le Chatelier, the reaction that will decrease the total number of gas moles in the space will be favoured. (favours side with lowest number of gas moles)

So to ensure maximum yield of ammonia:

- Use catalyst to reach equilibrium quickly.
- Once equilibrium is reached:
  - Drop temperature to 450 °C
  - Increase conc. of N_2 & H_2 & decrease conc. of NH_3
  - Increase pressure in container by reducing volume.

Equilibrium in solutions



$$K_{sp} = [A^+][B^-]$$

The equation for the equilibrium reaction of a saturated salt solution can be represented as follows:

$$AB_{(s)} \leftrightarrows A^+_{(aq)} + B^-_{(aq)}$$

$$NaCl(s) \leftrightarrows Na^+(aq) + Cl^-(aq)$$

- Adding HCl (H^+ and Cl^- ions) to the above solution in equilibrium causes the equilibrium to favour the reverse reaction to compensate for the additional Cl^- ions that were added to the product side.
- NaCl is, therefore, precipitated until the equilibrium is restored. More white solid is formed
- Shifting the equilibrium of a salt in a solution by increasing the concentration of one kind of ion is called the *common ion effect*.

Equilibrium in acids

☺ When the acid is strong, the equilibrium lies far to the product side (lots of ions form).

$$HCl(aq) \leftrightarrows H^+(aq) + Cl^-(aq)$$

☺ When the acid is weak, the equilibrium lies far to the reactant side (few ions form).

$$CH_3COOH(aq) \leftrightarrows CH_3COO^-(aq) + H^+(aq)$$

Equilibrium Constant

If we look at the following GENERAL equation

$$aA + bB \rightleftharpoons cC + dD$$

The expression for the Equilibrium constant – K_c will be as follows:

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

If A, B, C or D are solids or pure liquids, they must be LEFT OUT of the K_c expression.

- When K_c has a high value, there will be proportionally more of the substance on the product side - we say the equilibrium *lies to the product side* (vice versa for a low value).
- **Only temperature** alters the K_c value for a specific reaction
- If pressure or concentration are changed, the system adjusts the product and reactant concentrations in such a way that K_c stays exactly the same (on condition the temperature does NOT change)

Graph examples

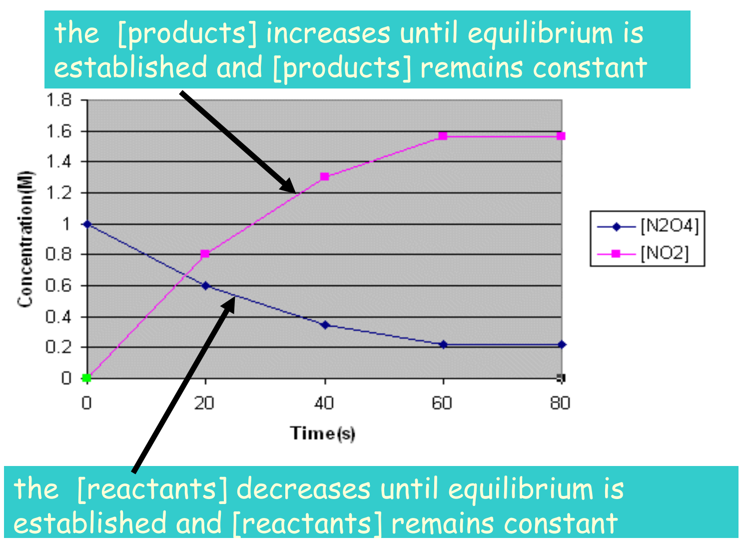
Comparing reaction rates of the forward and reverse reactions

- [A] (square brackets mean concentration of A) and [B] initially decrease.
- [C] and [D] initially increase.
- The rate of the forward reaction becomes constant and becomes equal to the rate of the reverse reaction.
- At this point (equilibrium) the concentrations of reactants and products remain constant.

Comparing concentrations of products and reactants graphically.

$N_2O_{4\,(g)} \leftrightharpoons 2NO_{2\,(g)}$

light brown dark brown



- If I were to increase the temperature, more NO_2 to form.
- This suggests that the forward reaction must be endothermic. ($\Delta H > 0$)
- Also increasing pressure favours side with least gas moles (reactants) therefore reverse reaction (1 mole as opposed to 2 moles of gas) is favoured.

SECTION C: HOMEWORK

QUESTION 1: 17 minutes *(Taken from DoE Physical Sciences Paper 2 Exemplar 2008)*

1.1 Many industries use ammonia as a coolant in their plants. Ammonia is also used in the fertiliser industry. The ammonia is manufactured by the Haber process in the presence of a catalyst at a temperature of 500°C. The equilibrium process may be represented by the equation below:

$$N_2 (g) + 3H_2 (g) \leftrightarrows 2NH_3 (g) \qquad \Delta H < 0$$

The temperature is now decreased to 100°C. Explain whether or not the ammonia can now be produced profitably. (3)

1.2 Ammonia is used in the industrial preparation of nitric acid. One of the reactions in this process, shown below, reached equilibrium in a closed container at a temperature of 1 000 °C.

$$4NH_3 (g) + 5O_2 (g) \leftrightarrows 4NO (g) + 6H_2O (g)$$

The initial concentrations of NH_3 (g) and O_2 (g) were both equal to 1 mol·dm^{-3} .At equilibrium it is found that the concentration of NH_3 (g) has changed by 0,25 mol·dm^{-3}.

1.2.1 Calculate the value of the equilibrium constant at the given temperature. (9)

1.2.2 Is the yield of NO high or low at this temperature? Give a reason for your answer (3)

[15]

QUESTION 2: 8 minutes *(Taken from DoE Physical Science Paper 2 November 2004)*

7 Mol of nitrogen gas and 2 mol of oxygen gas are placed in an empty container of volume 2 dm^3. The container is sealed and the following equilibrium is established:

$$N_2 (g) + O_2 (g) \leftrightarrows 2NO (g)$$

At equilibrium, there is 0,4 mol NO (g) present. Determine the value of K_c at this temperature.

[6]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

	N_2	H_2	NH_3
Initial number of mole (mol)	9	15	0
Number of moles used/formed (mol)	4	12	8
Number of moles at equilibrium (mol)	5	3	8
Equilibrium concentration ($mol \cdot dm^{-3}$) c = n/V	10√	6√	16√

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} \quad \surd$$

$$= \frac{16^2}{(10)(6)^3} \quad \surd$$

$$=0,12 \quad \surd$$

[6]

QUESTION 2

2.1.1. greater than √ (1)
2.1.2. less than√ (1)
2.1.3. equal to√ (1)
2.2.

	SO_2	O_2	SO_3
Initial number of mole (mol)	8	x	0
Number of moles used/formed (mol)	6	3	6
Number of moles at equilibrium (mol)	2	x - 3	6
Equilibrium concentration ($mol \cdot dm^{-3}$) c = n/V	1√	$\frac{x-3}{2}$√	3√

$K_c = \dfrac{[SO_3]^2}{[O_2][SO_2]^2}$ √

$9 = \dfrac{3^2}{\left(\frac{x-3}{2}\right)(1)^2}$ √

$x = 5$ mol √ (6)

2.3. B√ (1)
2.4. Forward is exo. √ Exo is favoured at colder temperatures√ (2)
2.5. B√ (1)
2.6. More product √therefore larger Kc√ (2)
2.7. C√ (1)
2.8. Low pressure favours reverse reaction √since more gas moles are at reactants side√ (2)
[18]

QUESTION 3

3.1

	H_2	I_2	HI
Initial number of mole (mol)	5	10	0
Number of moles used/formed (mol)	4,7	4,7	9,4
Number of moles at equilibrium (mol)	0,3	5,3	9,4√
Equilibrium concentration ($mol \cdot dm^{-3}$) c = n/V	0,06√	1,06√	1,88

$K_c = \dfrac{[HI]^2}{[H_2][I_2]}$ √

$= \dfrac{(1,88)^2}{(0,06)(1,06)}$ √

$= 55,57$ √ (6)

3.2. An increase in H_2 will according to Le Chatelier's Principle cause the equilibrium to shift so as to decrease the H_2 by forming more product. √This favours the forward reaction. √ In addition an increase in H_2 increases the pressure which will also favour the forward reaction to produce lower moles of gas. √ (3)
[9]

QUESTION 4

4.1 Any two

- Burning of fuel when cars are used - exhaust gases contains oxides of nitrogen. ✓
- Burning of coal (generation of electricity)/nitrogen containing compounds/organic waste. ✓
- Factories and other industrial plants that emits nitrogen oxides into the atmosphere as waste. (2)

4.2 $4NO_2(g) + O_2(g) + 2H_2O(\ell)$ ✓ $\rightarrow 4HNO_3(aq)$ ✓ bal ✓

OR

$3NO_2(g) + H_2O(\ell)$ ✓ $\rightarrow 2HNO_3(aq) + NO(g)$ ✓ bal ✓ (3)

4.3 $NO_2(g)$ dissolves in rainwater to form <u>acid rain</u> that burns/destroys crops. ✓ (1)

4.4 $NO_3^-(aq)$ is a strong oxidising agent ✓

and oxidise Cu (to Cu^{2+}). ✓

$H^+(aq)$ is not a strong enough oxidising agent ✓ and cannot oxidise Cu to Cu^{2+}. (3)

4.5.1

	$2NO_2$	N_2O_4
Initial number of mole (mol)	2	x
Number of moles used/formed (mol)	-1,2✓	+0,6 ✓
Number of moles at equilibrium(mol)	0,8✓	x + 0,6 ✓
Equilibrium concentration (mol·dm^{-3})	0,4	$\frac{x+0,6}{2}$ ✓

+

$$K_c = \frac{[N_2O_4]}{[NO_2]^2} ✓ \therefore 2 ✓ = \frac{\left(\frac{x+0,6}{2}\right)}{(0,4)^2} ✓ \therefore x = 0,04 \text{ mol} ✓$$ (9)

4.5.2 Decreases ✓ (1)

4.5.3 Expressions with the same meaning as "<u>forward reaction is favoured</u>

Equilibrium position shifts to the right. / Equilibrium lies to the right

Accept: the equilibrium shift to the right (2)

[21]