SENIOR SECONDARY INTERVENTION PROGRAMME 2013

education
Department: Education
GAUTENG PROVINCE

GRADE 12

PHYSICAL SCIENCES

TEACHER NOTES

The SSIP is supported by

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TOPIC 1: MECHANICS – PROJECTILE MOTION

Teacher Note: Encourage the learners always to draw a diagram of the situation. Encourage them also to place all the numerical values on the diagram and to SELECT A DIRECTION AS POSITIVE OR NEGATIVE.

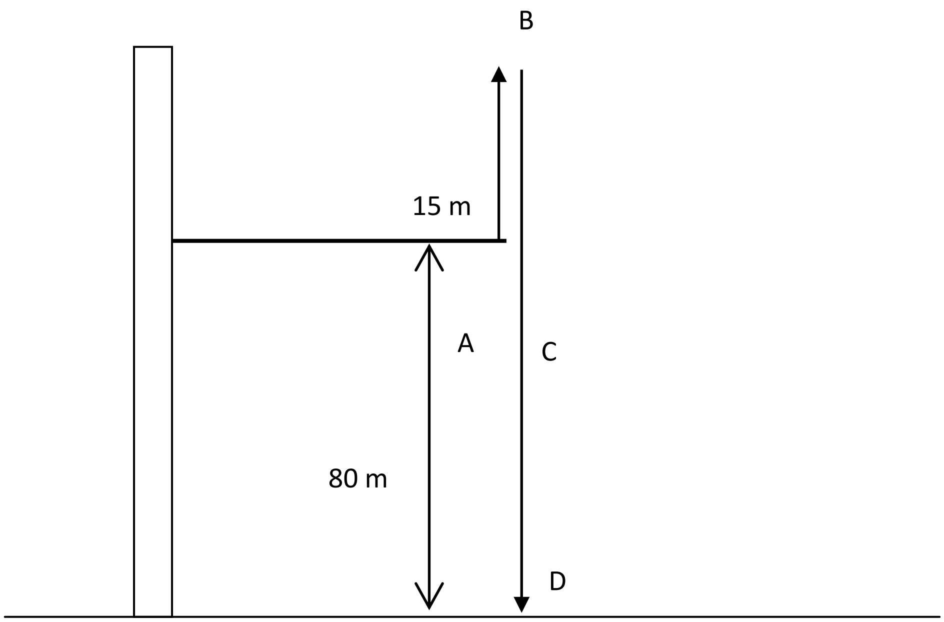
LESSON OVERVIEW

1. Introduce session: 5 minutes
2. Typical exam questions: 30 minutes
3. Review/solutions/memo: 25 minutes

SECTION A: TYPICAL EXAM OUESTIONS

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.



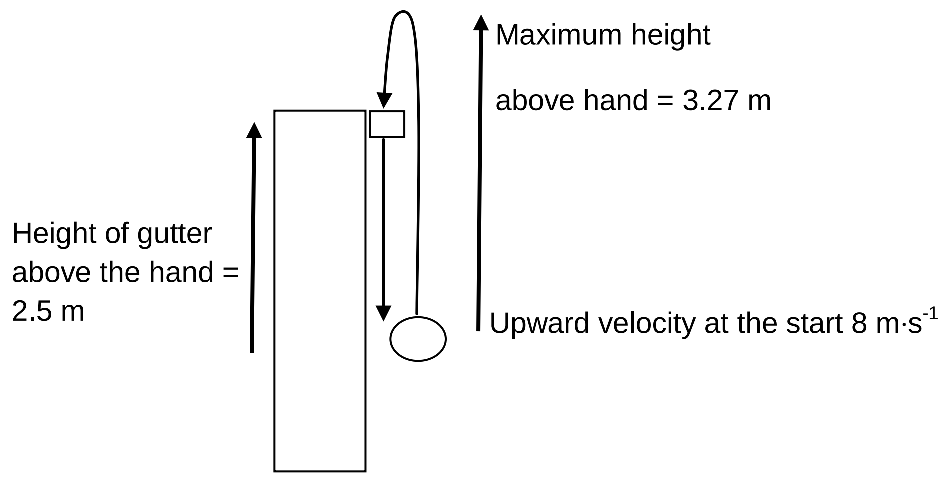
1.1 Calculate the magnitude of the velocity of the arrow at the instant it is shot up into the air from the top of the platform. (4)

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. <u>Ignore friction as well as all horizontal movement and answer the following questions:</u>



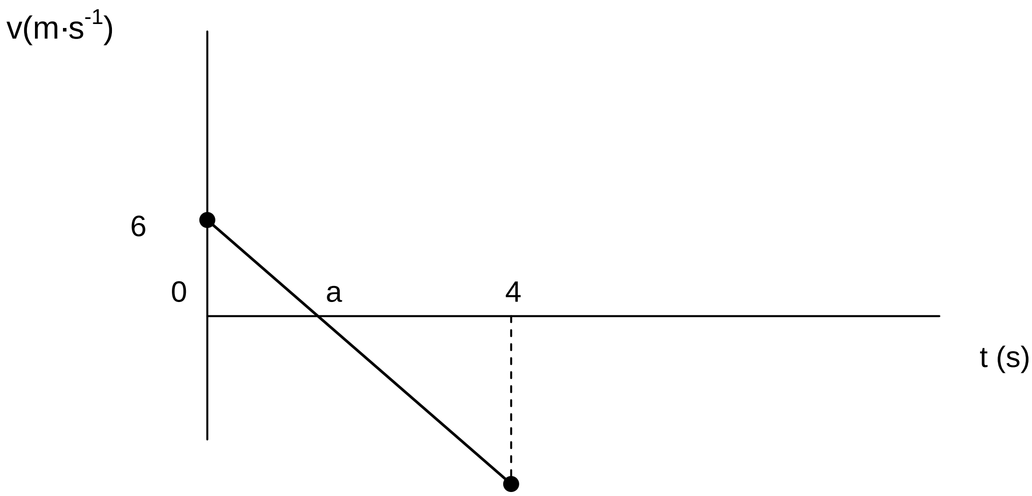
2.1 At what speed would the ball have fallen into Sandile's hand if the ball had not fallen into the gutter? (1)

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: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 Take downwards as the positive direction / upward is negative

$v_f = 0$

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

$\Delta y = -15\ m$

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$0^2 = v_i^2 + 2(9{,}8)(-15)$ ✓ ✓

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

(4)

1.2

$\Delta x = 95\ m$

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

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

$\Delta t = ?$

$\Delta y = v_i\Delta t + \frac{1}{2}g\Delta t^2$ ✓

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

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

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

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

OR (4)

AB

$v_f = -17{,}15 s$

$v_i = 0$

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

$\Delta y = ??$

$\Delta t = ??$

$v_f = v_i + a\Delta t$

$0 = (-17{,}15) + (9{,}8)\Delta t$ ✓

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

BCD

$v_f = 0$

$v_i =$

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

$\Delta y = 95 m$

$\Delta t = ??$

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

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

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

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

[8]

QUESTION 2

2.1 8 $m \cdot s^{-1}$ ✓ (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 $m \cdot s^{-2}$ 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 $m \cdot s^{-1}$ down ✓ (4)

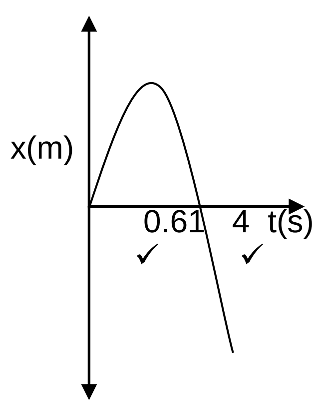
✓ ✓ ✓

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

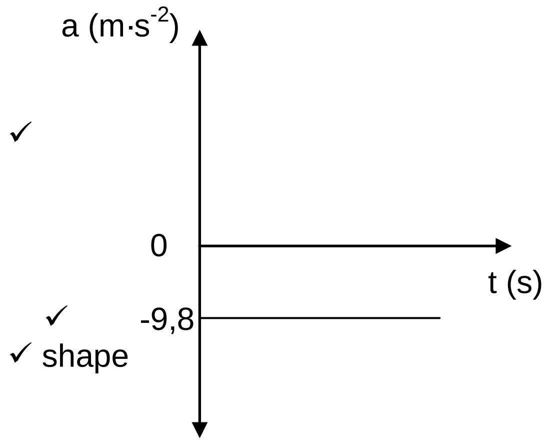
Maximum height reached = 100 + 1,8 = 101,8 m ✓ (5)

3.6

✓



✓ ✓ shape



(8)
[25]

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.

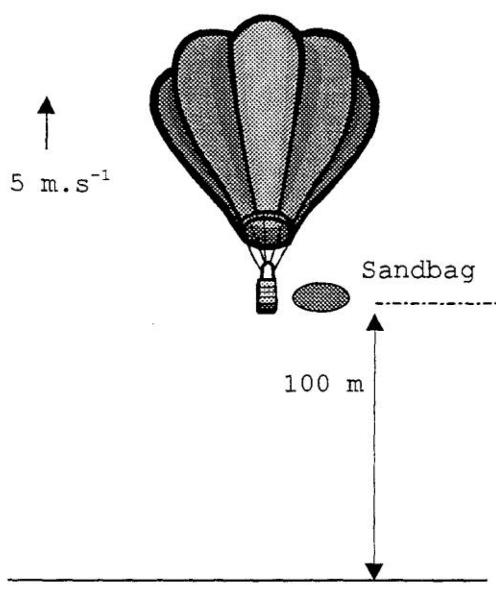


FIGURE 1

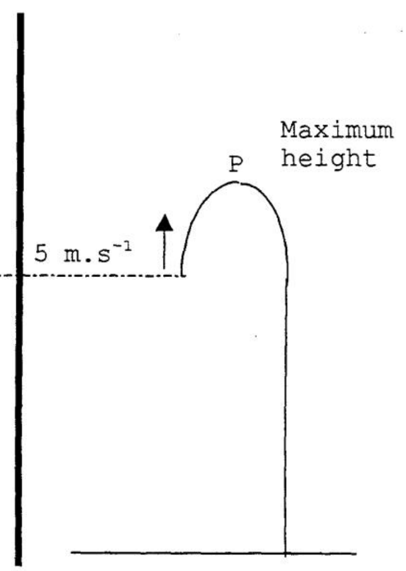


FIGURE 2 Motion of sandbag

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 TO HOMEWORK

QUESTION 1

1.1 $0\ m{\cdot}s^{-2}$ ✓ (1)

1.2 $9{,}8\ m{\cdot}s^{-2}$ ✓downwards ✓ ✓✓ (2)

1.2

$\Delta y = ?$

$v_i = 5\ m{\cdot}s^{-1}$

$V_f = 0\ m{\cdot}s^{-1}$

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

$v_f^2 = v_i^2 + 2g\Delta y$

$0^2 = (5)^2 + 2(-9{,}8)\Delta y$ ✓

$y = 1{,}28\ m$ ✓

$\therefore y = 1{,}28\ m$ upwards

$\therefore$ Maximum height (P) is 101,28 m ✓ (3)

1.3

$t = ?$

$v_i = 5\ m{\cdot}s^{-1}$

$V_f = 0\ m{\cdot}s^{-1}$

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

$v_f = v_i + g\Delta t$ ✓

$0 = 5 + (-9{,}8)\Delta t$ ✓

$\therefore t = 0{,}51\ s$ ✓

(3)

1.4

$\Delta x = 101{,}28$ m
$t = ?$
$v_i = 0$ m·s^{-1}
$g = 9{,}8$ m·s^{-2}

$\Delta x = v_i\Delta t + ½g\Delta t^2$ ✓
$101{,}28 = (0)\Delta t + ½(9{,}8)(\Delta t)^2$ ✓
$101{,}28 = 4{,}9t^2$
$t^2 = 20{,}67$
$t = 4{,}55$ s ✓
$\therefore$ total time $= 0{,}51 + 4{,}55 = 5{,}06$ s ✓ (4)

1.5 Velocity increases ✓✓

$F_R = 0$; so F_A = - weight, but weight decreases, but F_A is constant ; so there is an upwards F_R; and an upwards acceleration etc. ✓✓ (4)

[17]

TOPIC 2: CONSERVATION OF MOMENTUM

Teacher Note: Encourage the learners always to draw a diagram of the situation before and after the collision. Encourage them also to place all the numerical values on the diagram and to SELECT A DIRECTION AS POSITIVE OR NEGATIVE.

LESSON OVERVIEW

1. Introduce session: 5 minutes
2. Typical exam questions: 30 minutes
3. Review/solutions/memo: 25 minutes

SECTION A: TYPICAL EXAM OUESTIONS

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)

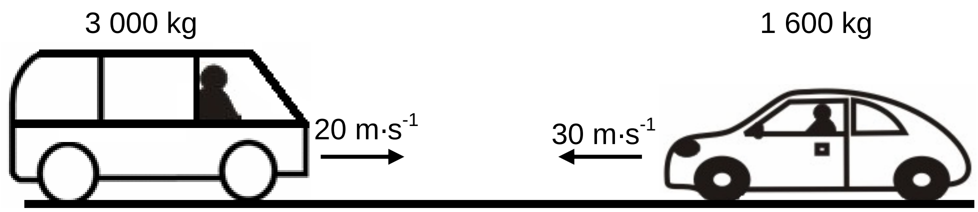
1.2.2 Average force exerted on the car (3)

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)

[12]

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

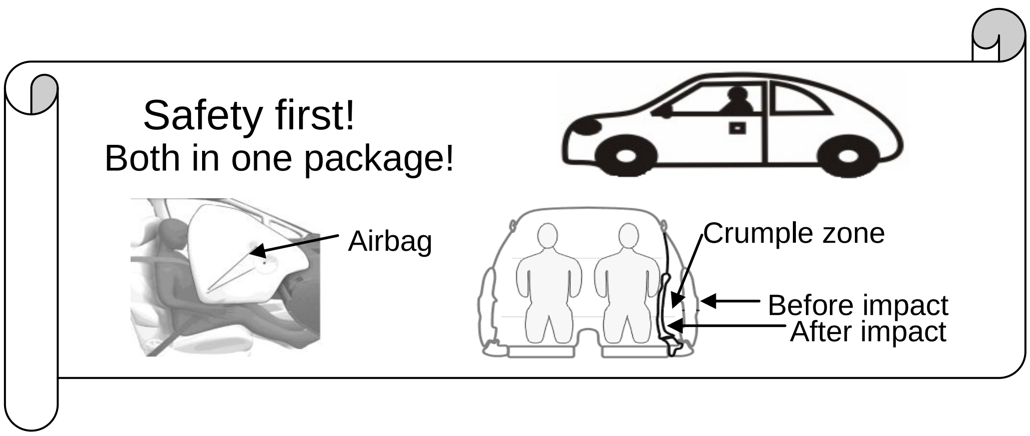
Collisions happen on the roads in our country daily. In one of these collisions, a car of mass 1 600 kg, travelling at a speed of 30 m·s^{-1} to the left, collides head-on with a minibus of mass 3 000 kg, travelling at 20 m·s^{-1} to the right. The two vehicles move together as a unit in a straight line 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: 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 $F_{net} = \Delta p/\Delta t$ ✓. (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.)

Teacher Note: Remind learners to copy the equation off the information sheet as given. Then only do they 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)

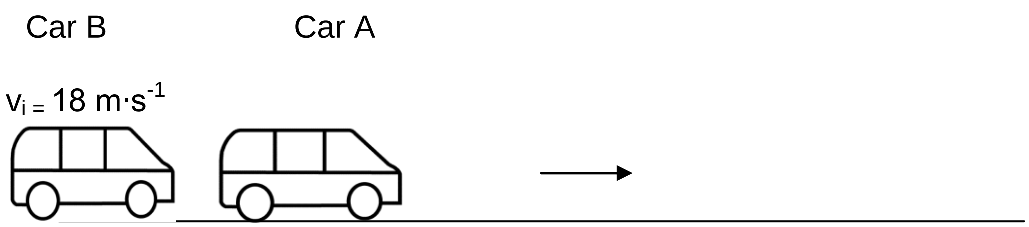
[15]

SECTION C: HOMEWORK

Teacher Note: As learners attempt the homework, they need to ensure that they are able to answer the questions in the allocated time frames. If they get stuck, they should refer either to the additional notes or their class teacher.

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 $m\cdot s^{-1}$. Immediately after the collision Car A moves forward at 12 $m\cdot s^{-1}$.



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)

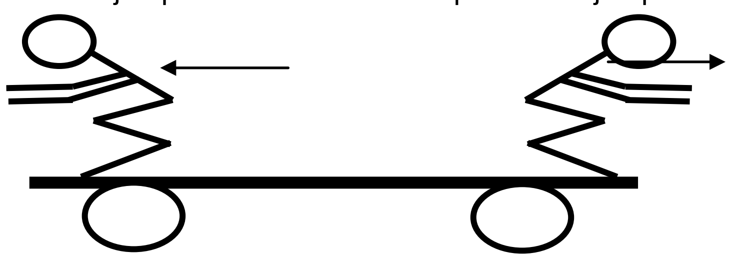
1.3 A traffic officer appears at the scene of the accident and mentions the dangers of a head-on collision. He mentions that for cars involved in a head-on collision, the risk of injury for passengers in a heavier car would be less than for passengers in a lighter car. Use principles of Physics to explain 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 $m \cdot s^{-1}$ relative to the ground.

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



2.1 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 TO HOMEWORK

QUESTION 1

1.1 Consider to the left as positive

$\Sigma m_i v_i = \Sigma m_f v_f$

$p_{before} = p_{after}$ OR $m_A v_{iA} + m_B v_{iB} = m_A v_{fA} + m_B v_{fB}$ ✓

$(1\,000)(0) + (1\,200)(18)$ ✓ $= (1000)(12) + (1\,200)v_{fB}$ ✓

$9\,600 = (1\,200)v_{fB}$

$v_{fB} = 8\ \text{m·s}^{-1}$ ✓ (4)

1.2 Not an isolated system / external forces present / frictional forces present / driver in front car has his foot on the brake. ✓✓ (2)

1.3 During the collision, both cars experience a force of equal magnitude ✓
This net force on the car with larger mass causes it to experience a smaller acceleration, ✓ therefore, the passenger will experience a smaller change in velocity and will be less injured. ✓

For a specific Fnet Δt: Δp(heavy car) = Δp(light car) ✓

$m_H(v_f - v_i)_H = m_L(v_f - v_i)_L$ but $m_H > m_L$ and $(v_f - v_i)_H < (v_f - v_i)_L$ ✓

Therefore a passenger will experience a smaller change in velocity ✓ and gets less injured. (3)

[9]

2.1 **Choose the direction to the right as positive**

Total p before collision = Total p after collision ✓

$mv_{i(Franck)} + mv_{i(Mandla)} + mv_{i(trolley)} = mv_{f(Franck)} + mv_{f(Mandla)} + mv_{f(trolley)}$

$(50)(0) + (80)(0) + (180)(0) = (50)(-3)$ ✓ $+ (80)(3)$ ✓ $+ (180).v_f$ ✓ ✓

$0 = -150 + 240 + 180v_f$

$-90 = 180v_f$

$v_f = -0{,}5\ \text{m.s}^{-1}$

$= 0{,}5\ \text{m.s}^{-1}$ to the left ✓

(in the same as Franck) (6)

OR

Choose the direction to the left as positive

Total p before collision = Total p after collision ✓

$mv_{i(Franck)} + mv_{i(Mandla)} + mv_{i(trolley)} = mv_{f(Franck)} + mv_{f(Mandla)} + mv_{f(trolley)}$

$(50)(0) + (80)(0) + (180)(0) = (50)(3)$ ✓ $+ (80)(-3)$ ✓ $+ (180).v_f$ ✓ ✓

$0 = 150 + -240 + 180v_f$

$90 = 180v_f$

$v_f = 0{,}5\ \text{m.s}^{-1}$ to the left ✓

(in the same as Franck)

2.2 There is friction✓ between the ground and✓ the wheels (2)

2.3 Mandla has a <u>larger change in momentum</u> ✓ than Franck (because Mandla has a bigger mass) and will therefore <u>exert a bigger force</u>✓ on the trolley than Franck in the same time (0,2s). This means that there is <u>a resultant force (net force)</u>✓ on the trolley towards Franck (or away from Mandla) and the ✓<u>acceleration</u> of the trolley is <u>towards Franck (or away from Mandla).</u>✓ (4)

2.4 **Direction to the right as positive**✓

$F_{(Trolley\ on\ Mandla)}.\Delta t = m_{(Mandla)}\ \Delta v_{(Mandla)}$

$F(0,2) = (80)(3 - 0)$ ✓

$F = 1200N$ to the right ✓

The magnitude of the force = 1200N

OR

Direction to the left as positive

$F_{(\ Mandla\ on\ trolley\&\ Franck)}.\ \Delta t = m_{(trolley)}\ \Delta v + m_{(Franck)}\Delta v$ ✓

$F(0,2) = (180)(0,5 - 0) + (50)(3 - 0)$ ✓

$F = 1200N$ to the left ✓

(3)

2.5 The two forces act on different objects✓ and cannot cancel ✓each other out

OR

They are action-reaction forces ✓according to Newton's third Law and thus do not cancel each other out✓ (2)

[17]

WORK, ENERGY AND POWER

Teacher Note: Ensure that the learners 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.

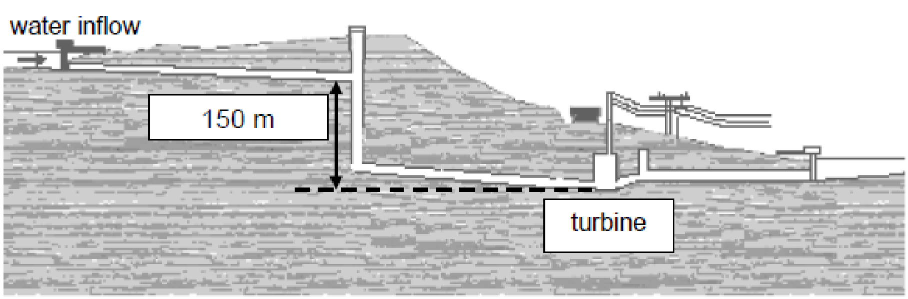
LESSON OVERVIEW

1. Introduce session: 10 minutes
2. Typical exam questions: 30 minutes
3. Review/solutions/memo: 20 minutes

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)

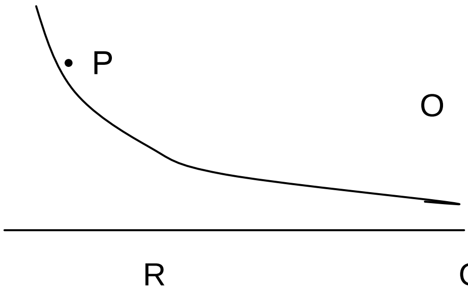
1.5 Explain what happens to the 15% of the kinetic energy that is NOT converted into electrical energy. (1)

[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 fromGDE 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)

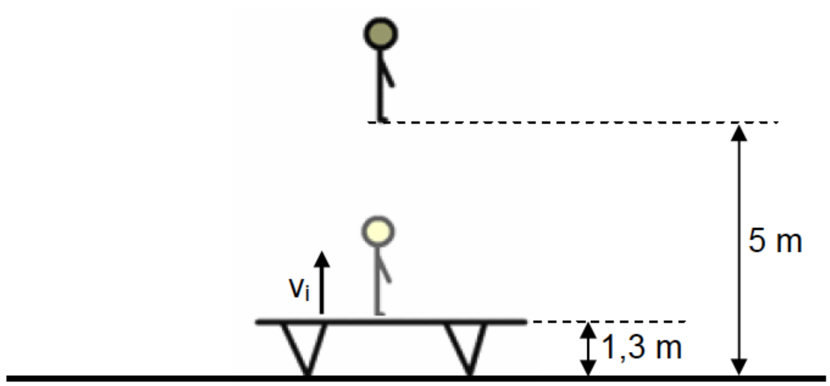
2.2 Determine the work done by friction on the train as it moves from P to O. (8)

2.3 Accept that the average friction force between the train 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.

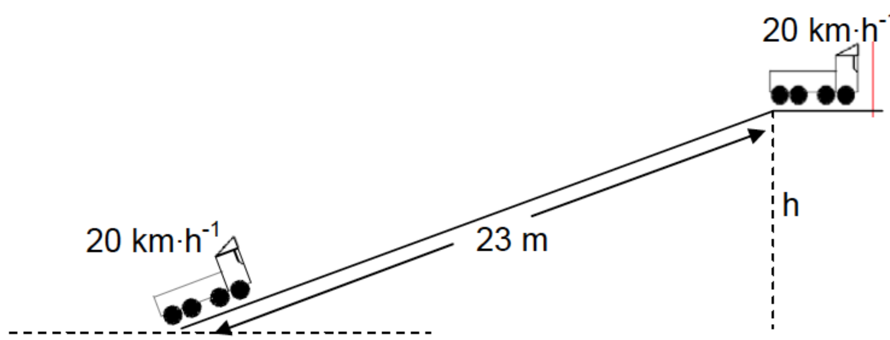
3.1 Write down the work-energy theorem. (2)

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: SOLUTIONS AND HINTS

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 ✓

½mv^{2} + mghi = Ekf + mgh$_{f}$

½(2x10^{5})0^{2} + (2 x 10^{5})(9,8)(150) ✓= Ekf + (2x10^{5})(9,8)(0)✓

∴Ekf = 2,94 x 108 J✓

OR

Wnet = ΔEk

$F\cos\theta \times \Delta y = E_{kf} - E_{ki}$ ✓
$(200\ 000)(9{,}8)(\cos 0^o)(150) =$ ✓ $E_{kf} - 0$ ✓
$\therefore E_{kf} = 2{,}94 \times 10^8$ J ✓ (4)

1.3 $E_{kf} = ½mv^2_f$ ✓
$2{,}94 \times 10^8$ J $= ½(2 \times 105)v_f^2$ ✓
$v_f = 54{,}22$ m·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 $= (E_p + E_k)_P = (mgh + ½\ mv^2)_P$ ✓

$= (2 \times 9{,}8 \times 2 + ½ \times 2 \times 0{,}8^2)$ ✓✓

$= 39{,}84$ J ✓

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

$= (2 \times 9{,}8 \times 0 + ½ \times 2 \times 3^2)$ ✓✓

$= 9$ J ✓

Work done by friction $= 39{,}84 - 9 = 30{,}84$ J ✓ (8)

2.3 $W_{friction} = F_{friction} \times \Delta x \times \cos\theta$ ✓

$F_{friction} = 30{,}84/2{,}5 \times \cos 180°$ ✓ $= -12{,}34$ 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

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

$W_{net} = F\cos\theta\,\Delta y = \frac{1}{2}mv_f^{\,2} - \frac{1}{2}mv_i^2$

$mg\cos180°(h_f - h_i)$ ✓ $= 0 - \frac{1}{2}mv_i^2$ ✓

$m(9,8)\cos180°(5 - 1,3) = -\frac{1}{2}mv_i^2$ ✓

$m(9,8)(-1)(3,7) = -\frac{1}{2}mv_i^2$

$v_i = 8,52\ m\cdot s^{-1}$ ✓ (5)

[7]

QUESTION 4

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

$W_{net} = (mgh_f - mgh_i) + (\frac{1}{2}mv_f^{\,2} - \frac{1}{2}mv_i^2)$

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 ✓= mgḥ ✓

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]**

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·s^{-1}. The water pours from the pipe at the rate of 1 200 kg· 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)

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

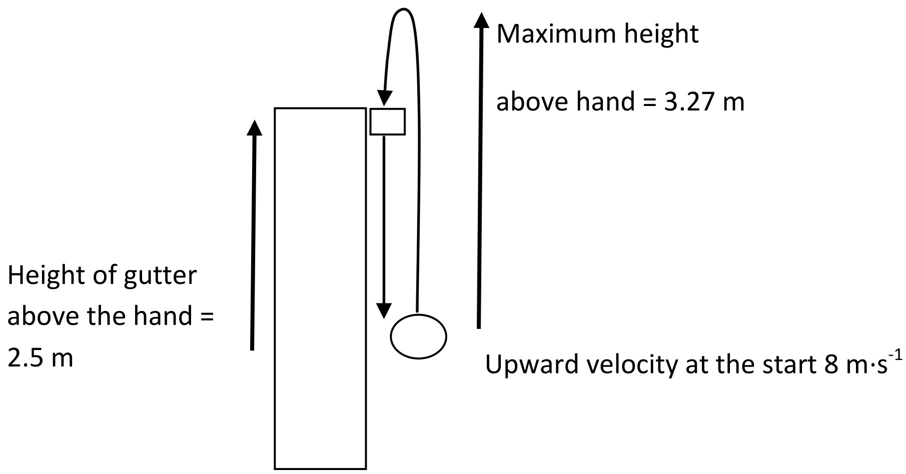
3.3. What is the minimum velocity with which a brick must leave the assistant's hand? (4)

3.4. Calculate the gain in potential energy of each brick as it reaches the builder's hand. (3)

3.5. 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)

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)

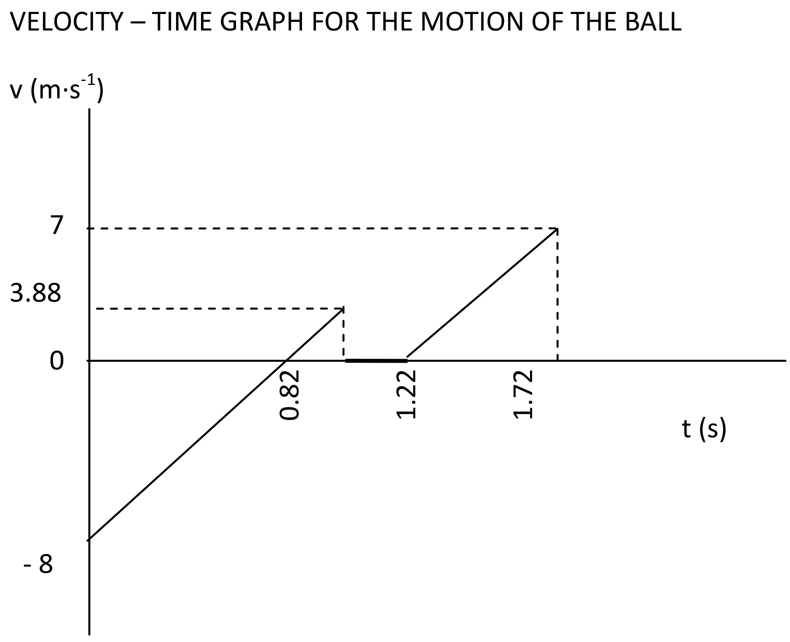
4.3 If the gutter is at a height of 2.5 m above Sandile's hand,

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.

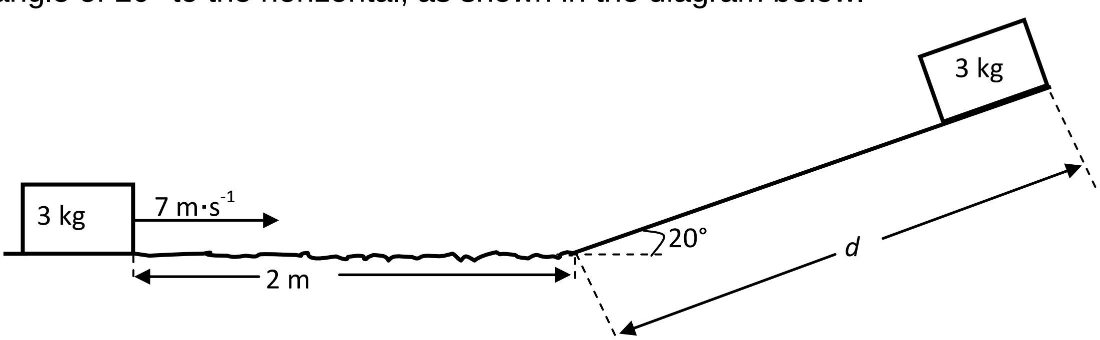


Use the above graph to sketch the displacement – time graph for the ball's motion for the time interval 1.22 s to 2.43 s. In other words from the moment the ball falls into the gutter until Sandile catches it again. The sketch graph must be done in your answer book and it is not necessary to draw it 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 TO HOMEWORK

QUESTION 1

Mechanical Energy = $E_p + E_k$ $= mgh + ½ mv^2$ ✓

$=(1200)(9,8)(10)$ ✓ $+ ½ (1200)(15)^2$ ✓

$= 252\ 600$ J✓

P = W/t✓

P $= 252\ 600/60$✓

$= 4210$ W✓

[7]

QUESTION 2

$W = F\Delta x \cdot \cos\alpha$ ✓ $= (50)(3)\cos 48^o$ ✓ $= 100,37$ J✓ **[3]**

QUESTION 3

3.1. $E_p = mgh$ ✓ $= (88)(9,8)(7)$ ✓ $= 6036,8$ J✓ (3)

3.2. $W = F\Delta x \cdot \cos\alpha$ ✓ $= (108)(7)$ ✓ $= 756$ J✓ (3)

3.3. $v_f^2 = v_i^2 + 2g\Delta x$✓

0 ✓ $= v_i^2 + 2(-9,8)(7)$ ✓

$v_i = 11,71\ m \cdot s^{-1}$✓ (4)

3.4. $E_p = mgh$✓ $= (2)(9,8)(7)$ ✓ $= 137,2$ J✓ (3)

3.5. 12 bricks in a minute – each brick takes 5 s✓

$P = W/t$ ✓ $= 137,2/5$ ✓ $= 27,44$ W✓ (4)

QUESTION 4

4.1 $8 m.s^{-1}$ ✓✓
(2)

4.2 Direction up is positive
$v_f^2 = v_i^2 + 2a\Delta y$ ✓
✓ $(0)^2 = (8)^2 + 2(-9,8)\ \Delta y$ ✓
$0 = 64 – 19,6\ \Delta y$
$\Delta y = 3,27m$ ✓ (4)

4.3.1 When the ball lands in the gutter, the gutter exerts an upward force on the ball. The system is <u>not isolated</u> ✓ any more. Work is done by the upward force and some of the mechanical energy of the ball is <u>converted</u> ✓ into heat and sound. (2)

4.3.2 Energy is converted into other forms (like heat and sound) ✓ (1)

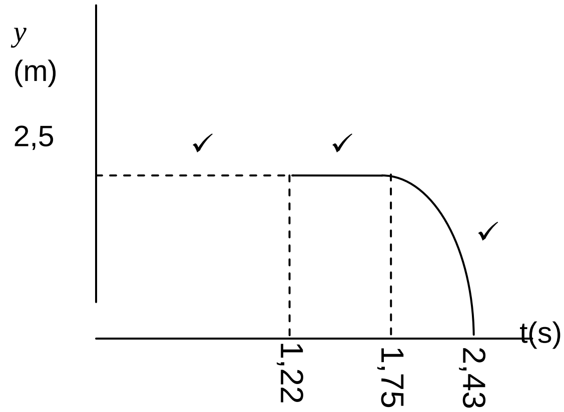
4.4 $E_{mech\ at\ start} = mgh + ½mv^2$
$= (0,01)(9,8)(0) + ½(0,01)(8)^2$ ✓
$= 0,32J$
$E_{mech\ at\ start} = mgh + ½mv^2$
$= (0,01)(9,8)(0) + ½(0,01)(7)^2$ ✓
$= 0,245J$
$W_{gutter} = \Delta E_{mech} = E_{end} - E_{start}$ ✓
$= 0,245 -0,32$
$= -0,075J$ ✓

OR

$E_{mech\ at\ max\ height} = mgh + ½mv^2$ ✓
$= (0,01)(9,8)(3,27) + ½(0,01)(0)^2$✓
$= 0,32J$
$E_{mech\ in\ gutter} = mgh + ½mv^2$ ✓
$= (0,01)(9,8)(2,5) + ½(0,01)(0)^2$
$= 0,245J$ ✓
$W_{gutter} = \Delta E_{mech} = E_{gutter} – E_{max\ height}$ ✓
$= 0,245 -0,32 = -0,075J$

(5)

4.5



- Both Axes correctly labelled
- Intercepts on axes correct ✓
- No graph up to 1,22s
- Constant line between 1,22s and 1,75s
- Curve with negative gradient from 1,75s to 2,43s

(4)

[18]

QUESTION 5

5.1 $W_{net} = \Delta K$ ✓

$W_f + W_N + W_{Fg} = \Delta K$

$f\Delta x\cos\theta + 0 + 0 = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ ✓

$(30)(2)(\cos 180°)$ ✓ $= \frac{1}{2}(3)v_f^2 - \frac{1}{2}(3)(7)^2$ ✓

$-60 = \frac{1}{2}(3)v_f^2 - 73{,}5$

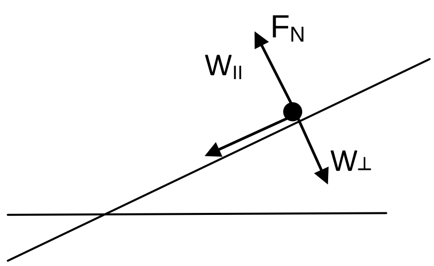
$v_f = 3\ m\cdot s^{-1}$ ✓ (5)

5.2

F_{N} = normal force

W_{II} =parallel component of weight

$W_{\perp}$= perpendicular component of weight



✓ for all 3 forces correctly drawn

✓ for all 3 forces correctly labelled (2)

5.3 $W_{net} = \Delta K$

$W_{WII} + W_N + W_{\perp} = \Delta K$

$W_{II}\,\Delta x\cos\theta + 0 + 0 = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ ✓

$mg\sin 20°\ \Delta x\cos 180°$ ✓ $= 0 - \frac{1}{2}(3)(3)^2$ ✓

$(3)(9{,}8)\sin 20°\ d\ (-1)$ ✓ $= 0 - \frac{1}{2}(3)(3)^2$

$d = 1{,}34\ m$ ✓ (5)

[12]

QUESTION 6:

6.1 E_p=mgh ü= (88)(9,8)(7) ü= 6036,8 Jü (3)

6.2. W = FΔx·cosα ü= (108)(7) ü= 756 Jü (3)

6.3. $v_f^2 = v_i^2 + 2g\Delta x$ü
0 ü= $v_i^2 + 2(-9,8)(7)$ ü
v_i = 11,71 m·s^{-1}ü (4)

6.4. E_p = mghü = (2)(9,8)(7) ü= 137,2 Jü (3)

6.5. 12 bricks in a minute – each brick takes 5 sü
P = W/t ü= 137,2/5 ü= 27,44 Wü (4)

TOPIC 1: PHOTOELECTRIC EFFECT

Teacher Note: Please spend time explaining the concepts photoelectric effect, work function, frequency and intensity of light.

LESSON OVERVIEW

1.	Introduction:	15 minutes
2.	Typical exam questions:	20 minutes
3.	Review/solutions/memo:	25 minutes

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 15 minutes *(Taken from the DoE Additional Exemplar Paper 1 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]

SECTION B: SOLUTIONS AND HINTS

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 $E_k = \dfrac{hc}{\lambda} - W$ ✓

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

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

$= 7{,}5 \times 10^{-20}$ 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

$f_0 = W_o/h$ ✓

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

SECTION C: HOMEWORK

Teacher Note: Stress that as learners attempt the homework, they need to ensure that they are able to answer the questions in the allocated time frames. If they get stuck, they should refer either to the additional notes or their class teacher.

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 TO HOMEWORK

QUESTION 1

1.2 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)

[10]

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: 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 $\Delta E = -4.026 - (-5.990)$
$= 1.964$ eV ✓

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

$= 3.142\times10^{-19}$ J ✓

$\Delta E = hf$

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

f $= 4.74\times10^{14}$ 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]

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 TO HOMEWORK

QUESTION 1

Emission lines are evidence of light (energy) being given off ✓as electrons fall through energy levels✓. Absorption spectra lines are evidence of certain frequencies of energy being taken in ✓by the atom as the electrons go to higher energy levels. ✓ Since the energy levels of a particular element have the same energy level spacings✓, the energy emitted (shown as a colour) will correspond exactly with the energy absorbed (shown by a black line) ✓ **[6]**

QUESTION 2

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. ✓

[5]

QUESTION 3

3.1 v = λf✓

3×10^{8} ✓= λ (405×10^{6}) ✓

λ = 0,74m✓ (4)

3.2 radio✓ (1)

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

= $2,67 \times 10^{-25}$ J✓ (4)

[9]

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]

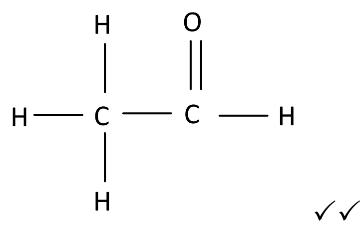
SECTION B: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 ethanal – aldehydes ✓

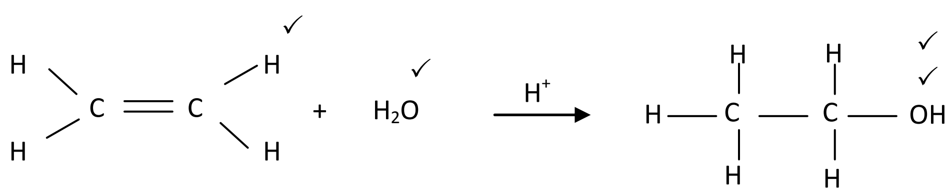
ethanoic acid – carboxylic acids ✓ (2)

1.2



(2)

1.3



(4)

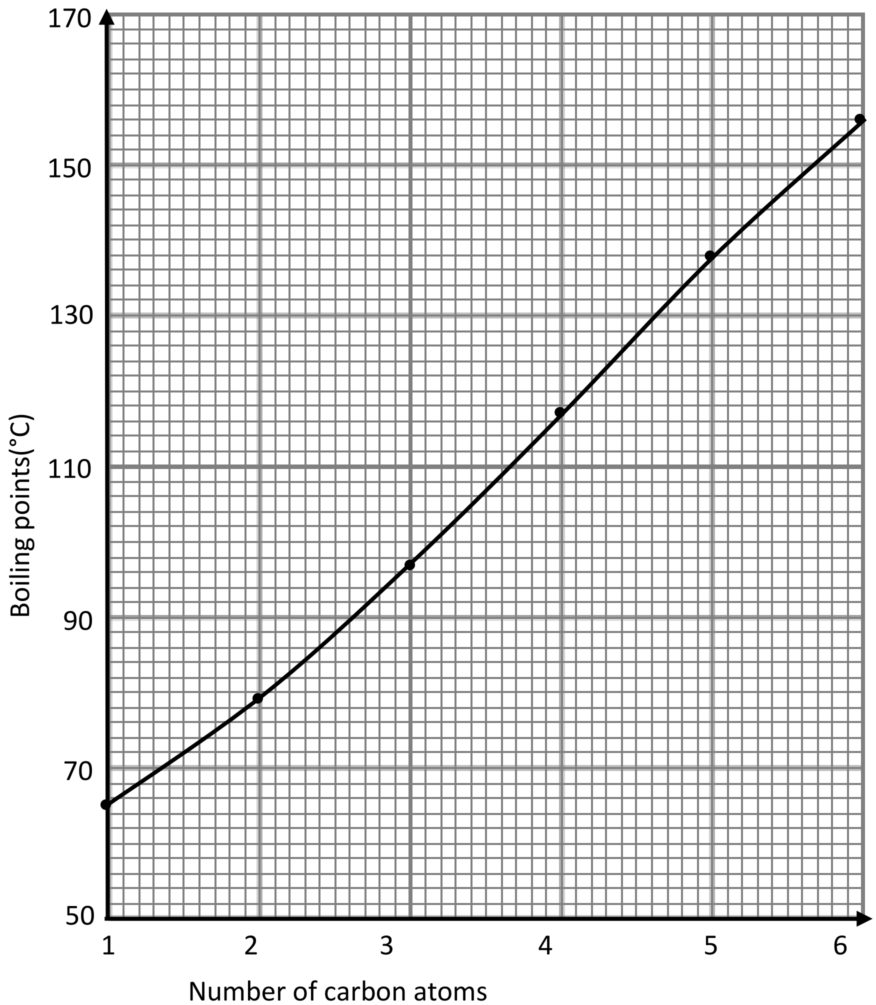
1.4 Any additional intake of alcohol will increase the blood alcohol level ✓✓which may then lead to either loss of coordination / severe poisoning / damage to organs e.g. the liver.✓✓ (4)

[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]

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)

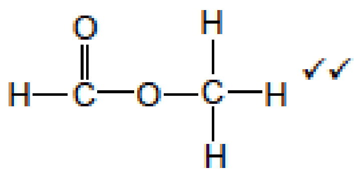
[17]

SECTION D: SOLUTIONS TO HOMEWORK

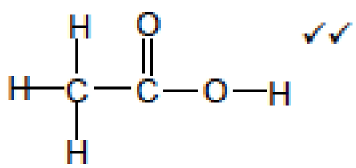
QUESTION 1

1.1 Compounds that have the same molecular formula but different structural formulae. ✓✓ (2)

1.2



methylmethanoate ✓
metielmetanoaat



ethanoic acid ✓
etanoësuur

(6)

1.3.1 Ethanoic acid. ✓ The hydrogen bonds/intermolecular forces between ethanoic acid molecules are stronger than the Van der Waals forces/intermolecular forces between the ester molecules ✓
More energy needed to break bonds between ethanoic acidmolecules. (3)

1.3.2 Methylmethanoate ✓ The Van der Waals forces/intermolecular forces between the ester molecules are weaker than the hydrogen bonds/intermolecular forces between ethanoic acid molecules. ✓
Less energy needed to break bonds between the ester molecules. (3)

1.4 Decrease ✓ Van der Waals forces increase with molecular size ✓ (3)

[17]

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 $CH_3CH_2CH_2-\underset{\underset{CH_3}{|}}{C}=CH_2 + HBr \longrightarrow$

Reaction III $CH_3\underset{\underset{OH}{|}}{CH}CH_2CH_3 \xrightarrow[heat]{H_2SO_4}$

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]

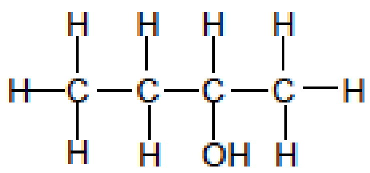
SECTION B: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 III - elimination/dehydration ✓ (1)

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

1.3



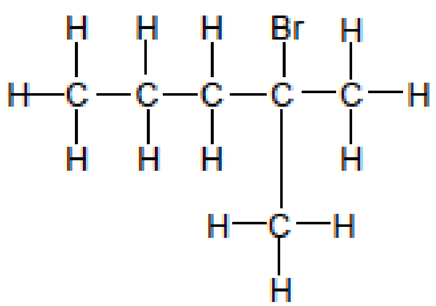
✓✓

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)

[17]

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]

SECTION C: HOMEWORK

QUESTION 1: 15 minutes

(Taken from DoE NSC Physical Sciences Paper2 Nov 2009)

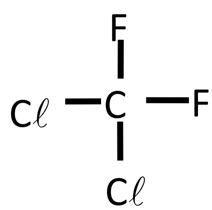
The environmental effects of CFCs and their substitutes

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 Paper 2 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 TO HOMEWORK

QUESTION 1

1.1 Dichlorodifluoromethane ✓✓ (2)

1.2 Low boiling point ✓ (1)

OR

High volatility/high vapour pressure ✓

1.3.1 Damages the ozone layer ✓ (1)

1.3.2 Increase in (dangerous) UV rays that reaches earth ✓
Higher occurrence of skin cancer/cataracts ✓ (2)

1.4

$CH_3CH_3 + C\ell_2$ ✓ → $CH_3CH_2C\ell + HC\ell$ ✓ bal ✓ (3)

1.5 Heat ✓
OR
Ultraviolet light
OR
Sunlight (1)

1.6 $CH_3CH_3CH_3CH_4$✓✓ (2)

1.7 No harm to the ozone layer ✓
Less potent greenhouse gas – contributes less to global warming ✓ (2)
[14]

QUESTION 2

2.1 Elimination✓ (1)

2.2 Alkenes ✓ (1)

2.3 Addition/hydrohalogenation/hydrobromination ✓ (1)

2.4 $CH_3CH_2CH(OH)CH_3$ ✓→ $CH_3CHCHCH_3$ ✓✓+ H_2O ✓ (4)

2.5 Q ✓
The major product is the one in which the H-atom is removed from the least substituted C-atom (the C-atom with the least number of hydrogen atoms✓ (2)

2.6 $CH_3CH_2CHBrCH_3$ ✓✓
2-bromobutane ✓ (3)

No hyphen in the name: -1 mark

2.7 Substitution✓ (1)
[13]

TOPIC: CONSOLIDATION EXERCISES

Note to teachers: Learners should attempt these questions under exam condition in the time indicated. Ask learners to stop writing after Question 1 and discus their answers. Next give instructions to begin question 2, and so on. Learners do not have solutions in their notes but they are in the Learner Homework Solutions booklet.

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)

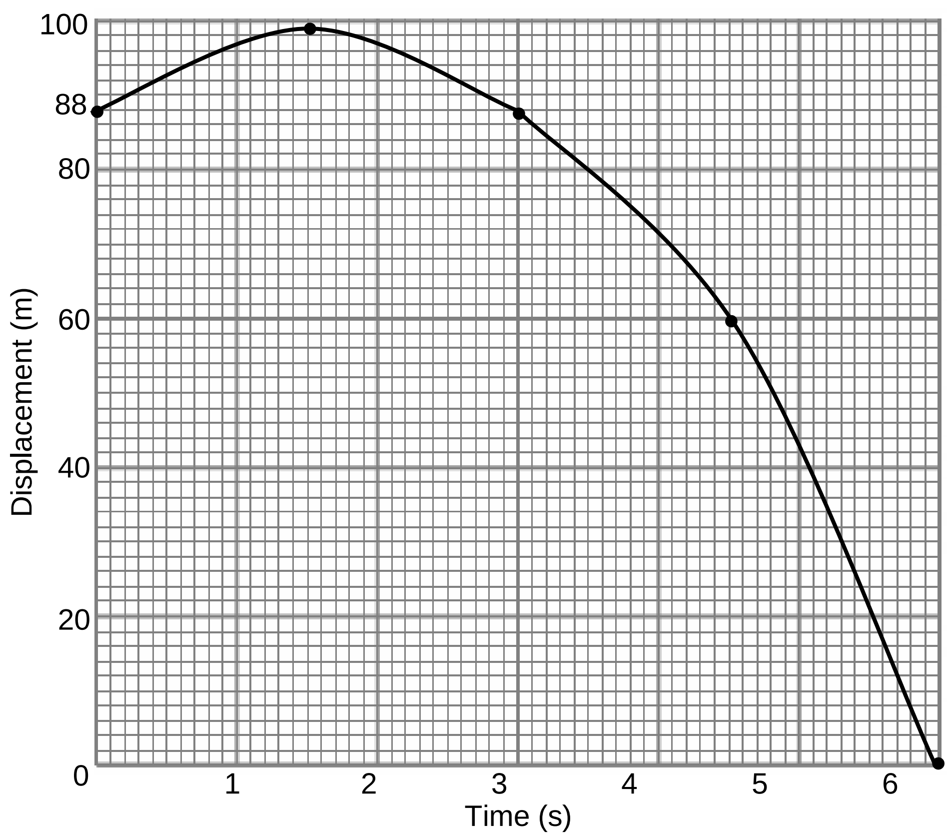
2.2 Calculate the wavelength of blue light with a frequency of $6{,}67 \times 10^{14}$. (2)

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.



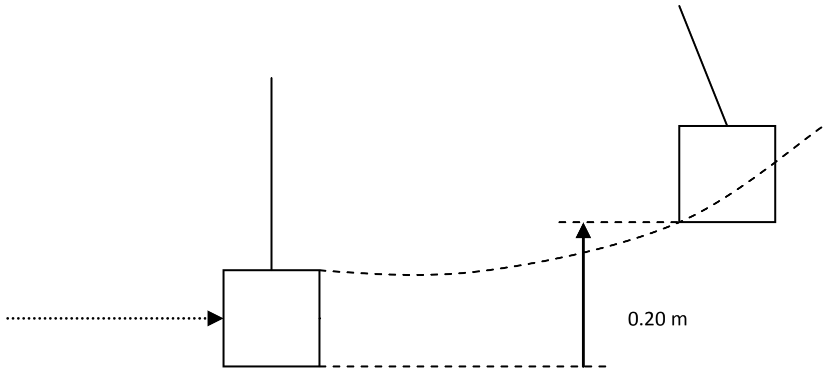
Use information from the graph to answer the following questions:

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]

SECTION B: SOLUTIONS TO SECTION A

QUESTION 1

1.1 $p_{before} = p_{after}$

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

$(3000 \times 27{,}28)$ ✓ $+ 500 \times 0$ ✓ $= (3000 + 500)\ v_f$

$v_f = 23{,}81\ m{\cdot}s^{-1}$ ✓ (5)

1.2 $\Delta p = m(v_f - v_i)$ ✓

$= 3000\ (23{,}81 - 27{,}78)$ ✓

$= -\ 11\ 910\ kg{\cdot}m{\cdot}s^{-1}$

$= 11\ 910\ kg{\cdot}m{\cdot}s^{-1}$ in the opposite direction of the motion✓ (3)

1.3 Drivers are distracted when using a cell phone while driving. This can lead to accidents which can result in injury and death. ✓✓ (2)

[10]

QUESTION 2

2.1 The **frequency is** ✓**inversely proportional** ✓to the **wavelength**. (2)

2.2 $c = f\lambda$ ✓

$3\times10^8 = (6{,}67\times10^{14})\ \lambda$

$\lambda = 4{,}5 \times 10^{-7}$ m ✓UNITS (2)

2.3 (a) At hospital for X-rays/ cancer treatment ✓

(b) A radio/ TV/ radar ✓

(c) Infra red at the physiotherapist/ night vision/ stealth/ heater/ stove ✓ (3)

2.4 (a) $E = hf$✓ (1)

(b) The energy associated with this frequency is very high ✓and is dangerous to all living matter. ✓**damage** (2)

(c) Gamma ✓ (1)

(d) Hiroshima / Nagasaki ✓/ Japan in the 2nd World War. ✓ (2)

[13]

QUESTION 3

3.1

For complete motion of stone

Upward motion negative

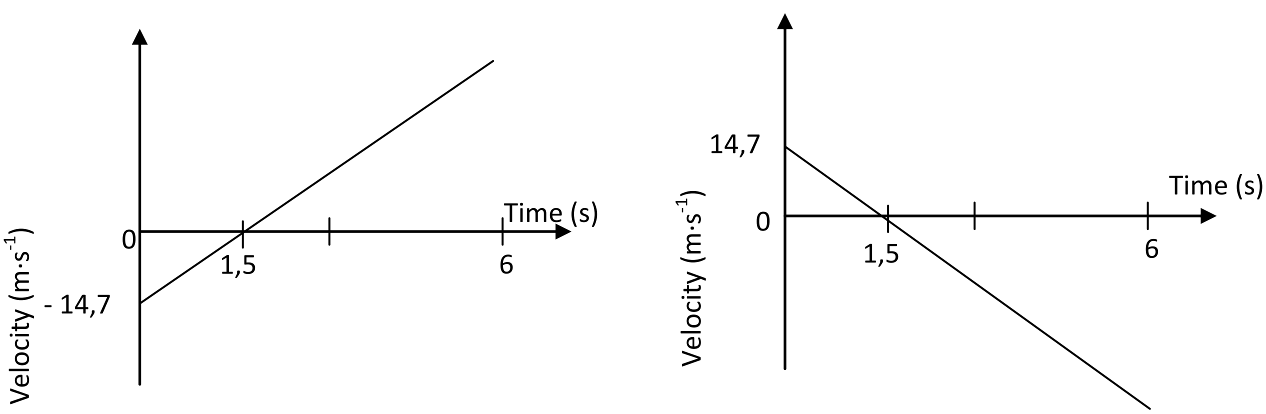
$\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2$ ✓ $\therefore$ 88 ✓ $= v_i(6)$ ✓ $+ \frac{1}{2}(9,8)(6)^2$ ✓

$v_i = -14,7\ m\cdot s^{-1}$ $\therefore$ $14,7\ m\cdot s^{-1}$ upwards ✓

$v_{balloon} = v_{stone}$ ✓ $= 14,7\ m\cdot s^{-1}$ (6)

3.2

Upward motion as negative: Downward motion as negative:



Criteria for graph	Marks
Graph is a straight line that intercepts x-axis at 1,5 s	✓
Maximum velocity after 6 s	✓
Initial velocity indicated as $14,7\ m\cdot s^{-1}$	✓

(3)

[9]

QUESTION 4

4.1 Ep = mgh✓

=4x9,8✓x0,2✓

=7,84J✓ (4)

4.2 By conservation of Mechanical E

Mechanical E top = Mechanical E bottom

$[mgh + \frac{1}{2}mv^2]_{top} = [mgh + \frac{1}{2}mv^2]_{bottom}$ ✓

4 x 9,8 x 0,2 ✓+ ½ x 4 x 0^2✓ =½ x 4 x v^2 ✓+ 4 x 9,8 x 0✓

7,84 = $2v^2$

v= 1,97 ms^{-1} to the right ✓ (6)

4.3 The total linear momentum of an isolated system ✓remains constant ✓in both magnitude and direction. ✓ (3)

4.4

$p_{before} = p_{after}$ ✓

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

(0,1)(v_{i1}) ✓+ (3,9)(0) ✓ = (0,1 + 3,9) (1,97)✓

0,1 v_{i1} = 7,88

v_f = 78,8 $m·s^{-1}$ to the right✓ (5)

4.5 $E_k = F·x\cos\theta$✓

½mv^2 ✓ = F x 0,1✓ cos 0°✓

½(0,1)$(78,8)^2$ ✓ = F x (0,1)

F= 3104,72N in direction of arrow ✓ (6)

[24]

Teacher Note: This session has additional material as Topic 2. Learner will not be able to complete all questions in 1½ hrs. The additional questions and notes are provided for self study

TOPIC 1 : SOUND AND DOPPLER EFFECT

Teacher Note: Review the important properties of waves such as frequency, wavelength, amplitude and the wave equation.

LESSON OVERVIEW

1. Introduce session: 5 minutes
2. Typical exam questions: 55 minutes.
3. Review/solutions/memo: 30 minutes

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 5 minutes

A car is travelling towards you at 16 $m \cdot s^{-1}$ sounding its hooter with a frequency of 320Hz. The velocity of sound is 330$m \cdot s^{-1}$. 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 $m \cdot s^{-1}$:

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

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

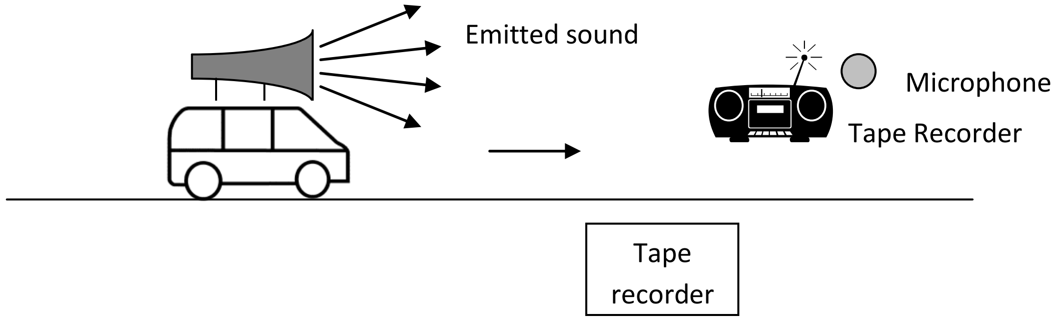
Take the speed of sound to be 340 $m \cdot s^{-1}$ and the frequency of the siren to be 1 500 Hz. [10]

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 $m \cdot s^{-1}$ [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 $m \cdot s^{-1}$.

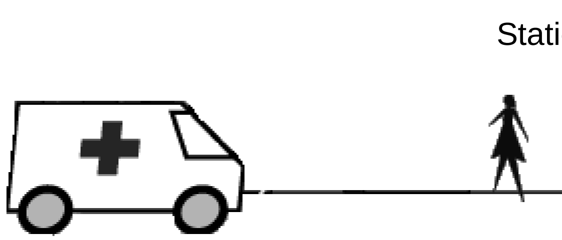
5.1 Name the phenomenon that describes the change in the frequency observed by the lady. (1)

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: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

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

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

$$= 336 \text{ Hz}✓$$

[5]

Teacher 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

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

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

$$= 1\,619 \text{ Hz} \ ✓$$

(5)

2.2.

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

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

$$= 1\,397 \text{ Hz} \ ✓$$

(5)

[10]

Teacher Note: Remind learners always to use the value of the speed of sound as given by the examiners or as given on the information sheet.They 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**.** ✓

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

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

$$= 20{,}93 \text{ m·s}^{-1} \ ✓$$

[5]

Teacher Note: Remind learners always to use the value of the speed of sound as given by the examiners or as given on the information sheet.They are stationary so v_L is zero and is omitted. They must always convert kHZ to Hz by multiplying by 1000.

QUESTION 4

4.1 Doppler Effect✓✓ (2)

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

! **Teacher Note**: Many learners find these simultaneous equations very difficult to do. Take time and care when going through the steps with them to make sure that they understand the mathematics.

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

[11]

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 340m.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·h^{-1}. (Take the speed of sound to be 340 m·s^{-1}) (4)

[8]

SECTION D: SOLUTIONS TO HOMEWORK

QUESTION 1

1.1 v = fλ
340 = 500 x λ ✓
λ = 0,68 m ✓ (2)

1.2 If the pitch is higher, then it is moving towards you. ✓ If the pitch is lower, it is moving away from you. ✓ (2)

1.3 Doppler effect ✓ (1)

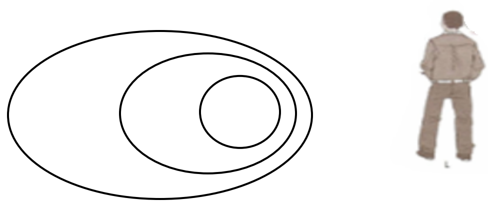
1.4 $f_L = \left(\dfrac{v \pm v_L}{v \pm v_s}\right) f_s = \left(\dfrac{340}{340 + v_s}\right) 500 = 495$ ✓

✓ ✓ ✓

v_s = 343 m·s^{-1} away from observer ✓ (5)

[10]

QUESTION 2



2.1 Diagram shows waves compressed in front and stretched out at back ✓✓ (2)

2.2 Formula One car goes much **faster**✓ and results in **greater compressions**✓**OR**
The engine **revs are higher**✓ making the vibrations take place with greater frequency (2)

2.3 $f_L = \left(\dfrac{v \pm v_L}{v \pm v_s}\right) f_s = \left(\dfrac{340}{340 - 55.56}\right) 250 = 298{,}83\, Hz$

✓ formula

✓substitutions

✓ convert km·h^{-1} to m·s^{-1}

✓ answer (4)

[8]

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

Teacher Note: Learners need to know their definitions very well. They need to know the difference between refraction, reflection and diffraction. These terms are very often confused

SELF STUDY

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	1,7x10^{-27} kg	4,4x10^{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:

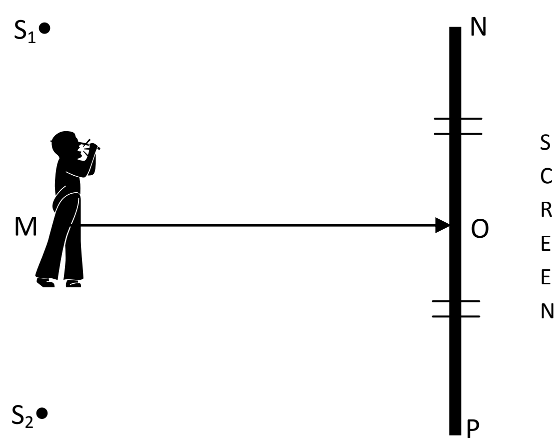
A. Waves
B. Light particles
C. Positive particles
D. Negative particles

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

A. 9,4 x 10^{-14} m
B. 7,01 x 10^{-21} m
C. 2,51 x 10^{33} m
D. 3,98 x 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

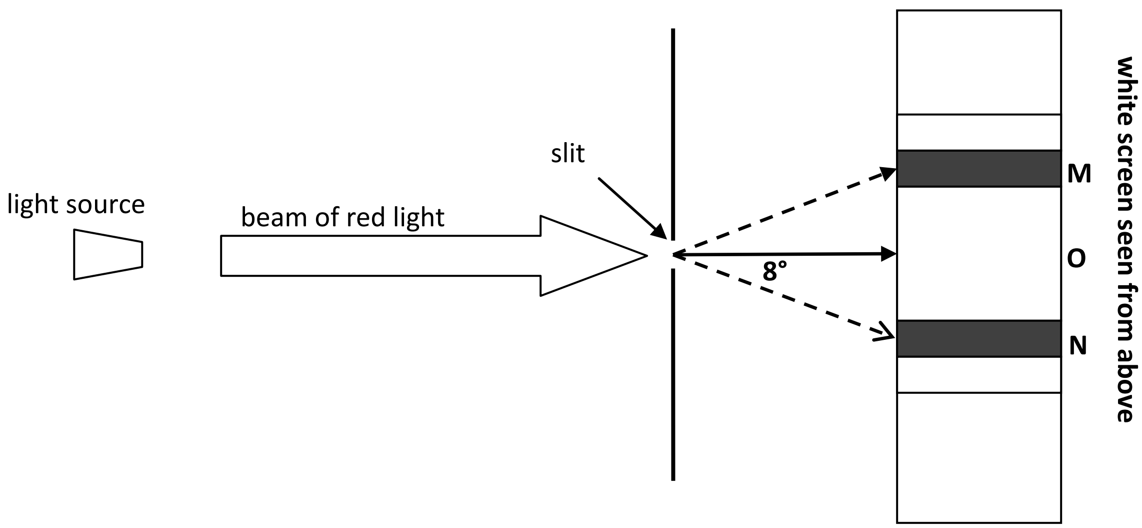
5.4 How will the new pattern differ from the previous one? (2)

[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:
Know the difference between the single slit and the double slit experiment i.e. the difference between diffraction pattern and the interference pattern.

SECTION B: 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]

Teacher 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°

$$\sin\theta = \frac{m\lambda}{a} ✓$$

$$\sin 8° ✓ = \frac{650 \times 10^{-9}}{a} ✓$$

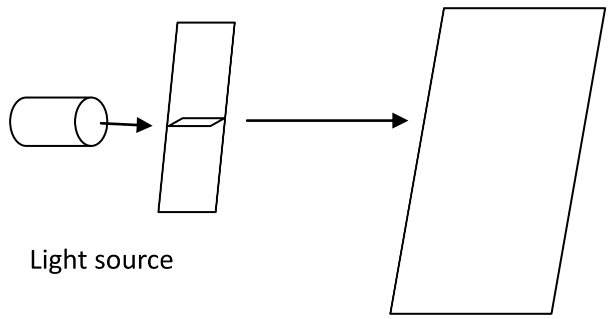
$$a = \frac{650 \times 10^{-9}}{\sin 8} = 4{,}67 \times 10^{-6}\,m ✓ \; (= 4{,}67\ \mu m)$$ (5)

[10]

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.



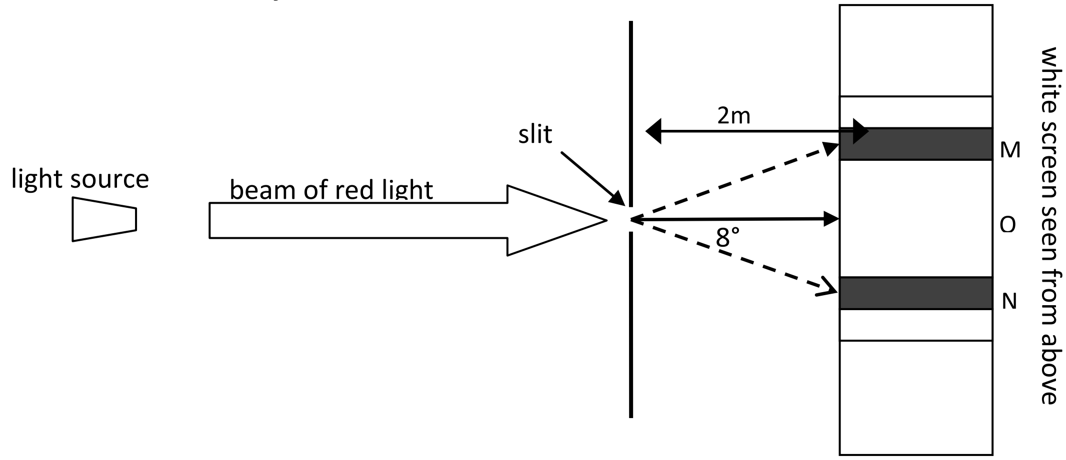
1.1 Describe the diffraction pattern which will be observed on the screen. (2)

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 monochromatic light in nanometres (6)

2.2 Calculate the distance between the 1^{st} two dark bands. (6)
[12]

SECTION D: SOLUTIONS TO HOMEWORK

QUESTION 1

1.1 A broad central band of bright red light flanked by alternating narrower black and not so bright red bands ✓✓ (2)

1.2 All the bands will have equal width✓ and
All the bands will be equally bright ✓ (2)

1.3

$$\sin\theta \overset{\checkmark}{=} \frac{m\lambda}{d} = \frac{1\left(700\times10^{-9}\right)\checkmark}{5\times10^{-6}\checkmark} = 0.14$$

$$\theta = 8.05°$$

$$\checkmark\ \tan 8.05° = \frac{\frac{1}{2}\text{width}}{\text{distance}} = \frac{\frac{1}{2}\text{width}}{2}\checkmark$$

$$\text{width} = 0.028\times2 = 0.056\,\text{m}$$

✓ (6)

QUESTION 2

2.1

$$\sin\theta = \frac{m\lambda}{d} \quad \checkmark$$

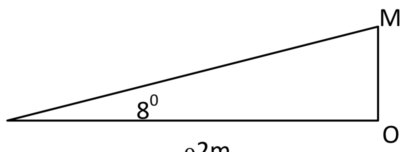
$$\sin 8^0 \overset{\checkmark}{=} \frac{1.\lambda}{4{,}59\times10^{-6}} \checkmark \quad \checkmark$$

$$\lambda = \sin 8^0 .4{,}59\times10^{-6}$$

$$= 6{,}38804\times10^{-7}\ \text{m} \quad \checkmark$$

= 638,80nm ✓ (6)

2.2



$$\tan\theta = \frac{MN}{d}\ \checkmark$$

$$\tan 8^0 = \frac{MN}{2}\ \checkmark$$

$MN = 2.\tan 8^{0}$ 2m

$= 0{,}281$ **m** ✓

Distance MN = 2 x MO✓✓✓ = 0,28 x 2 = 0,56m (6)

[12]

Teacher Note: This session has additional material. Learner will not be able to complete all questions in 1½ hrs. It is sauggested that you select questions from each topic for learners to do in your session. The additional questions are provided for self study

TOPIC 1: ENERGY CHANGES & RATES OF REACTION

Teacher 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.

LESSON OVERVIEW

1.	Introduce session - Topic 1 Energy & Rates	5 minutes
2.	Introduce session - Topic 2: Chemical Equilibrium	5 minutes
3.	Typical exam questions	60 minutes
4.	Review/solutions/memo	20 minutes

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 the learners know the difference between the reactants and products especially in a reverse reaction.) **[2]**

Teacher Note: A variety of methods are used show the heat of the reaction, i.e.

$A + B \rightarrow C + \text{Energy}$; $A + B \rightarrow C \;\; \Delta H$ - ; $A + B \rightarrow C \;\; \Delta H < 0$;

$A + B \rightarrow C \;\; \Delta H = -20 \text{ kJ·mol}^{-1}$

These are all ways to show that the reaction is exothermic.

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

Teacher Note: The contact process is always asked. Make sure it is thoroughly understood.

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

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

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)

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)

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·mol^{-1})
Activation energy for the reaction 350 kJ·mol^{-1}

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

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]

Teacher Note: Learners who struggle with this section, may have a poor understanding of the electronic structure of atoms and ions, and interpreting chemical equations.

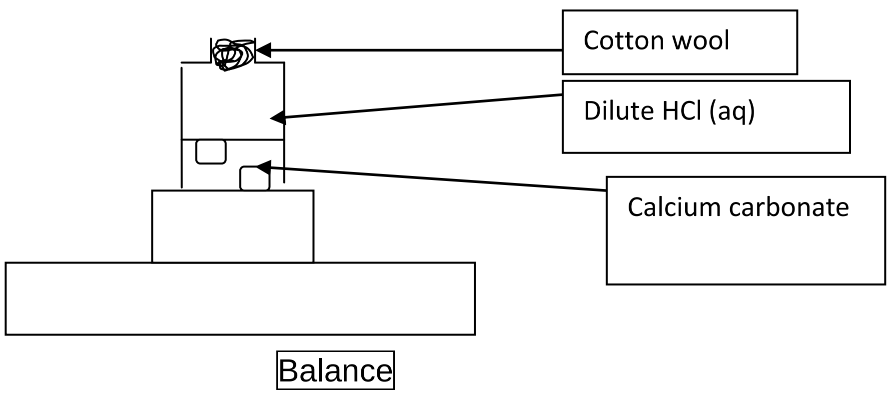
QUESTION 5: 16 minutes *(Source: DoE Physical Sciences Paper 2 Additional Exemplar 2008)*

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) + 2HCℓ (aq) → $CaCℓ_2$ (aq) + H_2O (ℓ)

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:

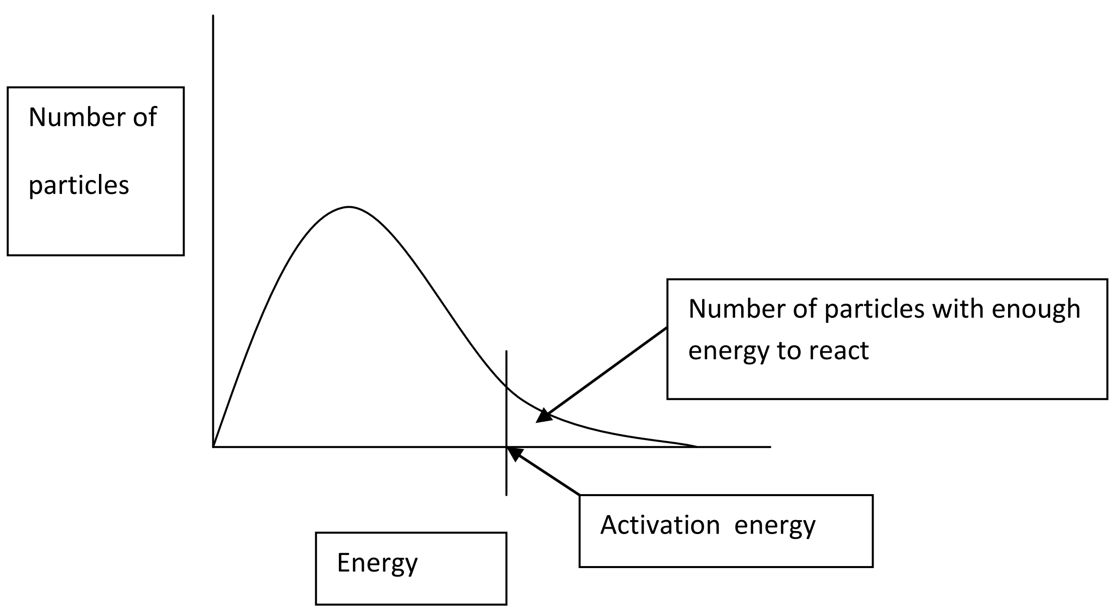
Mass of CO_2 produced(g)	0	0,46	0,70	0,82	0,90	0,95	1,0	1,0
Time (s)	0	60	120	180	240	300	360	420

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: SOLUTIONS AND HINTS TO SECTION A

ENERGY CHANGES & RATES OF REACTION

QUESTION 1

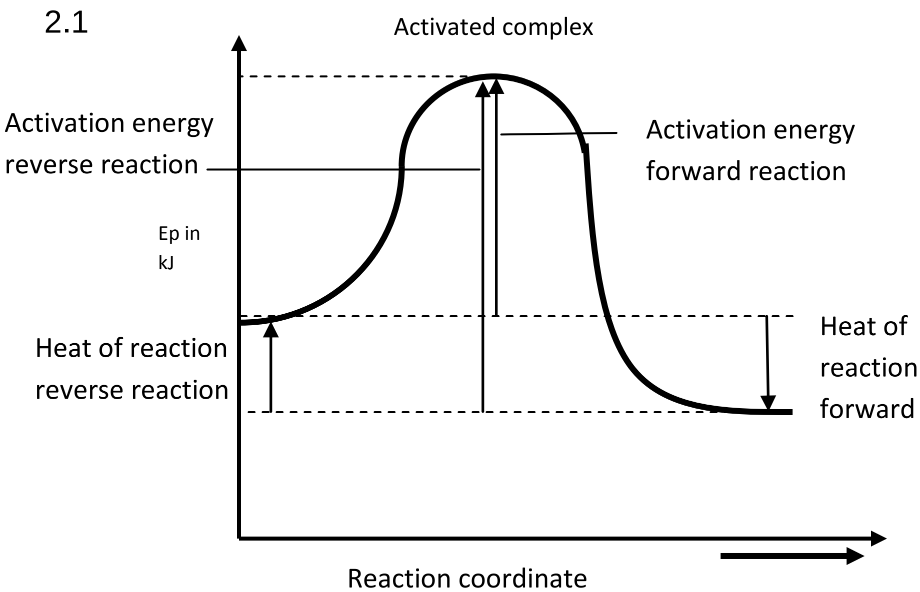
1.1 Exothermic ✓ (1)

1.2 E products < E reactants ✓ (1)

[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 ✓

(7)

2.2.1 Exothermic ✓ (1)

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

[10]

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]

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	✓

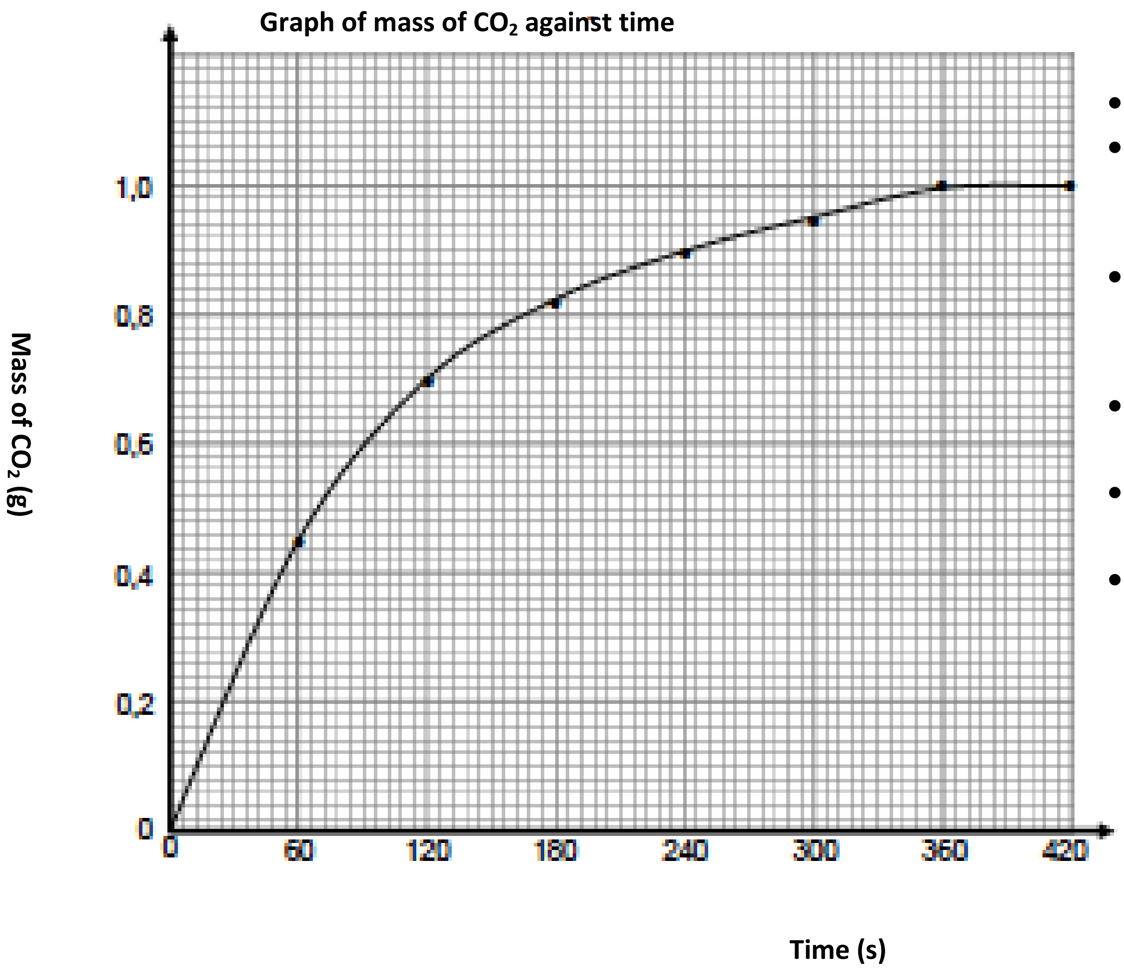
(2)

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

(6)

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

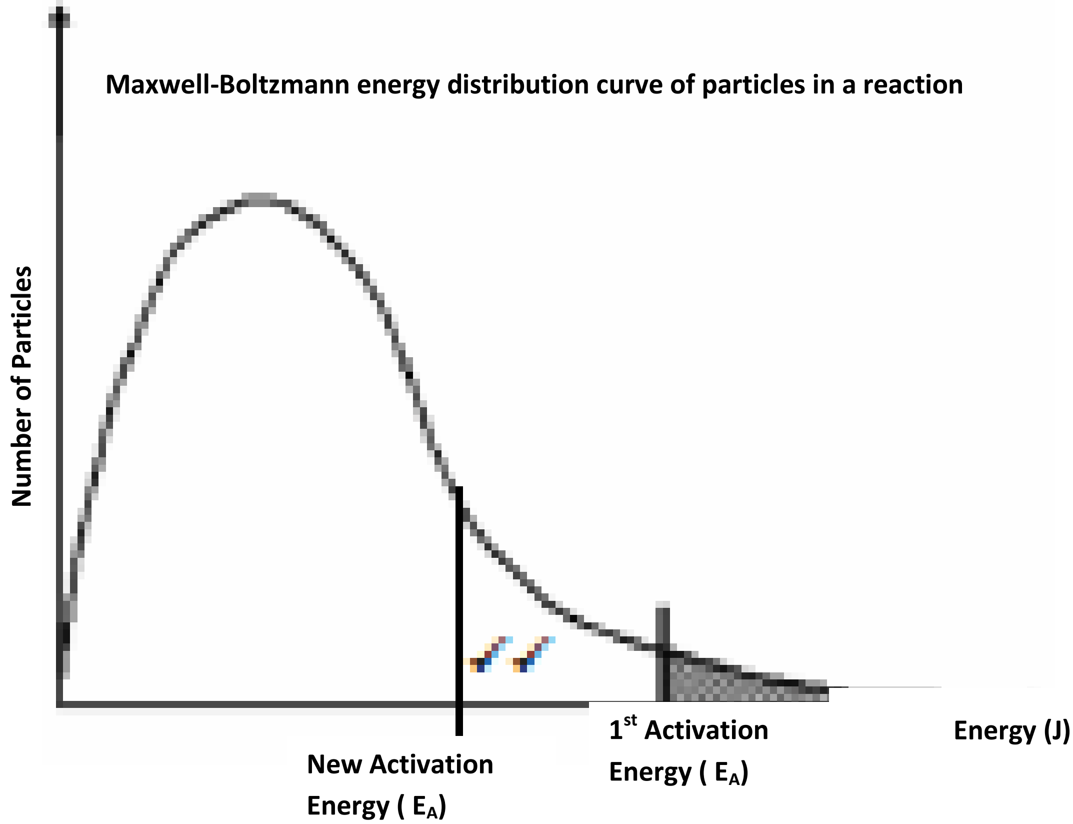
The rate of the reaction / production of CO_2 (g) decreases as the reaction proceeds. (2)

[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]

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

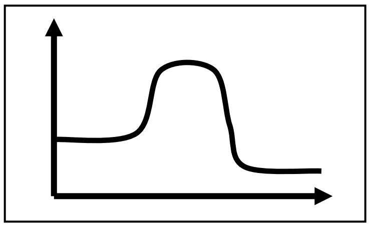
What provides activation energy for the following chemical changes?

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...

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



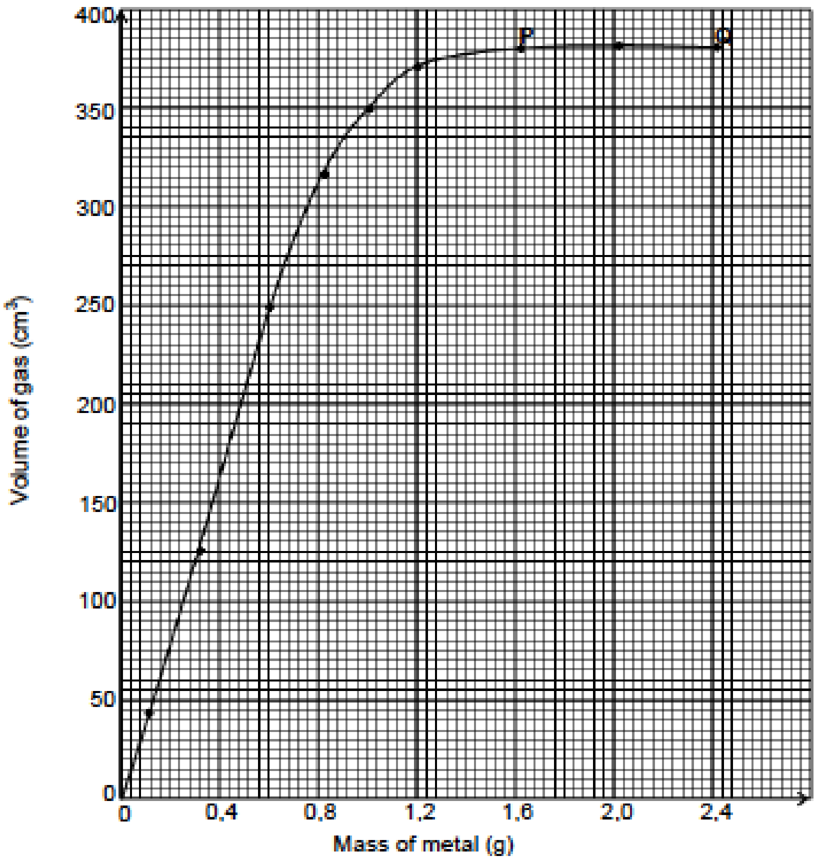
4.1 Provide labels for the x and the y-axes. (2)
4.2 Compare the energy of the products to that of the reactants. (2)
4.4 What is an activated complex? (2)
4.5 Is ΔH for this reaction positive or negative? (1)
4.6 Is this reaction endothermic or exothermic? (1)
[8]

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)

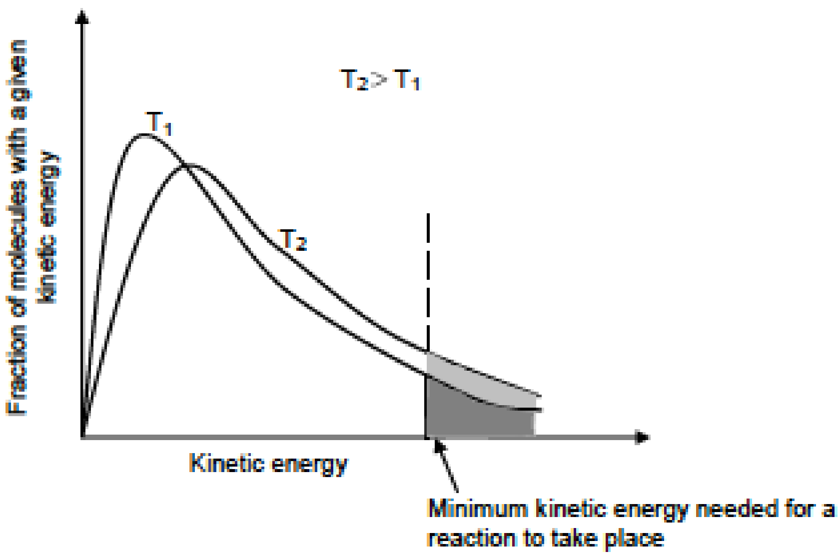
5.3 What conclusion can be drawn from the section PQ on the graph? (2)

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.



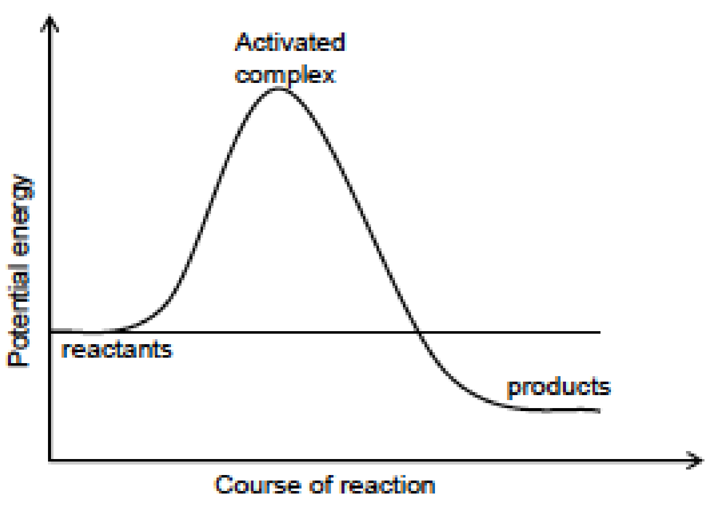
[5]

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:

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

$$2CO\,(g) + O_2\,(g) \rightarrow 2CO_2\,(g)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(ii)$$

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

[6]

SECTION D: SOLUTIONS TO HOMEWORK

QUESTION 1

1.1. Heat of reaction - is the difference between the energy of the products and the energy of the reactants. ✓✓ (2)

1.2. Endothermic reaction – a reaction that takes in energy, products have more energy than the reactants ✓✓ (2)

1.3. Activation energy - the 'energy hill' which must be 'overcome' by the addition of this amount of energy before a reaction can take place. ✓✓ (2)

[6]

QUESTION 2

2.1. Exothermic ✓✓ (2)

2.2. Endothermic ✓✓ (2)

2.3. Exothermic ✓✓ (2)

[6]

QUESTION 3

3.1. The sun ✓✓ (2)

3.2. Flame ✓✓ (2)

3.3. Flame ✓✓ (2)

[6]

QUESTION 4

4.1. X-axis – course of reaction ✓
Y-axis – potential energy ✓ (2)

4.2. Eproducts < Ereactants ✓✓ (2)

4.3. Activated complex - temporary, unstable, high-energy composition of atoms, which represents a transition state between reactants and the products. ✓✓ (2)

4.4. Negative ✓ (1)

4.5. Exothermic ✓ (1)

[8]

QUESTION 5

5.1 A larger mass of metal will produce more gas etc ✓✓ (2)

The relationship between the dependent and independent variables must be given.

5.2 Temperature ✓✓ and concentration✓✓ (4)

5.3 Any mass bigger than 1,6 g will not influence the volume of the gas produced. ✓✓(2)

5.4 160 cm^3 ✓✓ (2)
[10]

QUESTION 6

As the temperature increases✓, the number of molecules with the minimum kinetic energy required for a reaction to occur, increases✓. The molecules will be moving faster✓, the number of effective collisions will increase ✓and thus the rate of the reaction will increase✓. Thus, the sugar dissolves faster in hot water. **[5]**

QUESTION 7

7.1 It will be easier to form products from the reactants ✓ because the activation energy is less ✓ than the activation energy required to form the reactants from the products. (2)

7.2 Carbon monoxide is toxic and can lead to atmospheric pollution and global warming. ✓✓ (2)

7.3.1 It will lower the amount of CO produced and this will lead to less CO poisoning. ✓✓
(2)
[6]

TOPIC 2: CHEMICAL EQUILIBRIUM

Teacher Note: Please ensure that the learners understand and know 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, pressure and concentration.

LESSON OVERVIEW

1. Introduction: 5 minutes
2. Typical exam questions 50 minutes
3. Review/solutions/memo 35 minutes

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.

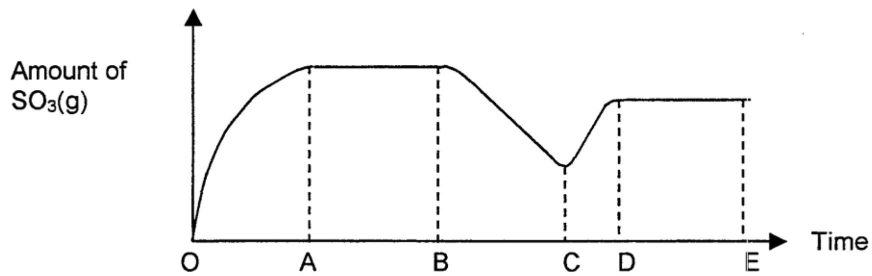
Calculate the value of K_c at 405°C0 [6]

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: SOLUTIONS AND ANSWERS 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
Equilbrium concentration ($mol \cdot dm^{-3}$) c = n/V	10√	6√	16√

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} \checkmark$$

$$= \frac{16^2}{(10)(6)^3} \checkmark$$

$$= 0,12 \checkmark \qquad (6)$$

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√

$$K_c = \frac{[SO_3]^2}{[O_2][SO_2]^2} \checkmark$$

$$9 = \frac{3^2}{\left(\frac{x-3}{2}\right)(1)^2} \checkmark$$

$$x = 5 \text{ mol} \checkmark \qquad (6)$$

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

$K_c = \frac{[HI]^2}{[H_2][I_2]}$ √

$= \frac{(1,88)^2}{(0,06)(1,06)}$ √

= 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 ($mol{\cdot}dm^{-3}$)	0,4	$\frac{x+0,6}{2}$ ✓

+

$K_c = \frac{[N_2O_4]}{[NO_2]^2}$ ✓ ∴ 2 ✓= $\frac{\left(\frac{x+0,6}{2}\right)}{(0,4)^2}$ ✓ ∴ x = 0,04 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]

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:

$$N_2 (g) + 3H_2 (g) \leftrightharpoons 2NH_3 (g) \quad \Delta H < 0$$

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 HOMEWORK

QUESTION 1

1.1 The forward reaction is exothermic. ✓Thus, lowering the temperature favours the forward, exothermic reaction and the ammonia will now have a higher yield. ✓ However, the rate of reaction will be lowered and this will lead to the ammonia production being unprofitable. ✓ (3)

1.2.1

	NH_3	O_2	NO	H_2O
Initial concentration (mol·dm^{-3})	1	1	0	0
Change in concentration (mol·dm^{-3})	0,25	0,3125	0,25	0,375
Equilibrium concentration (mol·dm^{-3})	0,75✓	0,6875✓	0,25✓	0,375✓

$K_c = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$ ✓

$= \frac{(0,25)^4(0,375)^6}{(0,75)^4(0,6875)^5}$ ✓ ✓

$= 2,2 \times 10^{-4}$ ✓✓ (9)

1.2.2 Low. ✓ The small equilibrium constant value indicates that the equilibrium lies towards the reactants side ✓ and that there are more reactant molecules in the reaction mixture at equilibrium, thus NO will have a low yield. ✓ (3)

[15]

QUESTION 2

	N_2	O_2	NO
Initial number of mole (mol)	7	2	0
Number of moles used/formed (mol)	0,2	0,2	0,4
Number of moles at equilibrium (mol)	6,8	1,8	0,4
Equlibrium concentration ($mol{\cdot}dm^{-3}$) c = n/V	3,4✓	0,9✓	0,2✓

$K_c = \frac{[NO]^2}{[N_2][O_2]}$ ✓

$= \frac{(0,2)^2}{(3,4)(0,9)}$ ✓

$= 0,013$ ✓ **[6]**