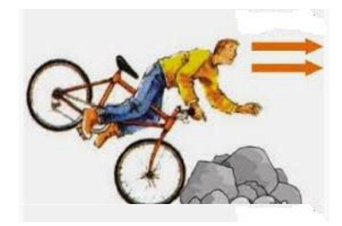
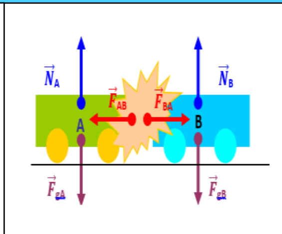
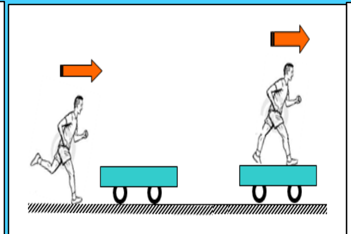
NORTHERN CAPE DEPARTMENT OF EDUCATION

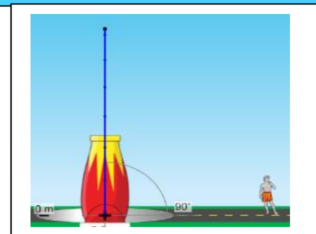
PHISICAL SCIENCES

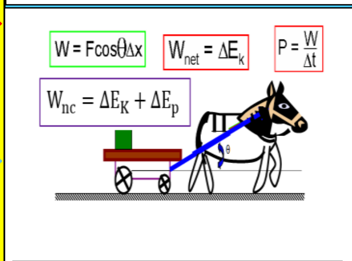
GRADE 12

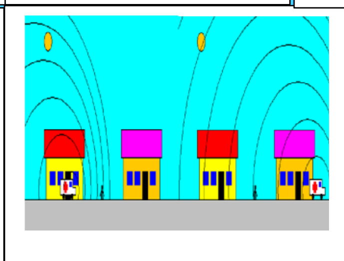


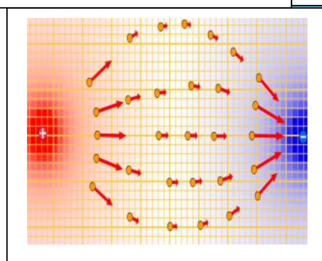


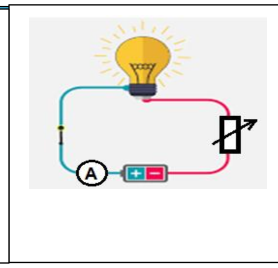


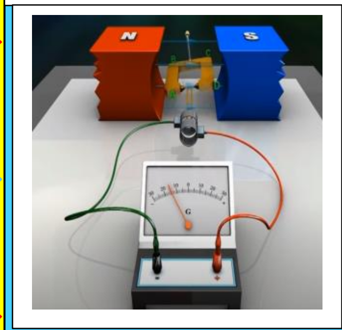


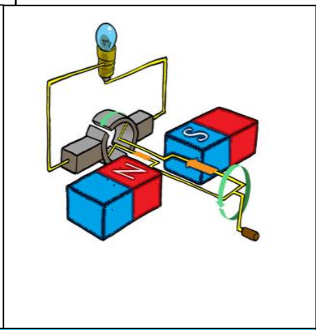


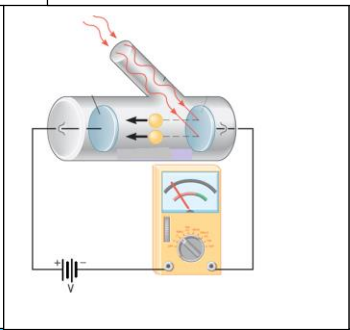


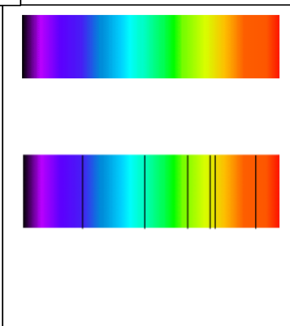












PHYSICS

WORKBOOK

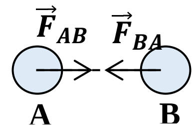
COMPILED BY:
G. IZQUIERDO RODRIGUEZ

2020

Table of Contents

TOPIC 1: MECHANICS

1.1. NEWTON'S LAWS AND APPLICATION OF NEWTON'S LAWS

Newton's First Law of Motion	**Newton's Second Law of Motion**	**Newton's Third Law of Motion**	**Newton's Law of Universal Gravitation**
A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it. $\vec{F}_{net} = \vec{0}$	When a resultant/net force acts on an object, the object will accelerate in the direction of the net force at an acceleration directly proportional to the net force and inversely proportional to the mass of the object. $\vec{F}_{net} = m\vec{a}$ **OR** $\vec{a} = \frac{\vec{F}_{net}}{m}$	When one body exerts a force on a second body, the second body exerts a force of equal magnitude in the opposite direction on the first body.  $\vec{F}_{AB} = -\vec{F}_{BA}$	Each body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. $Fg = \frac{Gm_1m_2}{r^2}$

DIFFERENT TYPES OF FORCES

Normal Force	**Gravitation force (weight)**	**Frictional force**
Force or the component of a force which a surface exerts on an object with which it is in contact, and that is perpendicular to the surface. $\vec{N}$	Weight ($\vec{w}$**)** is the gravitational force that the Earth exerts on the object of mass *m.* $\vec{w} = m\vec{g}$ $\vec{g}$ - acceleration due to gravity. $\vec{g} \approx 9,8\ m/s^2$ close to the surface of the Earth. Use this equation to calculate the acceleration of any other planet: $g = \frac{GM}{r^2}$	**Frictional force** is the parallel component of the force exerted by the surface on the object when the object moves or attempts to move and opposes the relative motion or tendency of motion **Static frictional force (** f_s) is the force (parallel component of the force) exerted by the surface on the object that opposes the tendency of motion of a stationary object relative to a surface and it is parallel to the surface. $f_s^{max} = \mu_s N$ ***Kinetic frictional force*** **(**f_k) is the force (parallel component of the force) exerted by the surface on the object that opposes the motion of a moving object relative to a surface and it is parallel to the surface. . $f_k = \mu_k N$ *<u>You need to know that a frictional force:</u>* • is proportional to the normal force • is independent of the area of contact • is independent of the velocity of motion **<u>NOTE:</u>** If a force ($\vec{F}$) applied to a body parallel to the surface does not cause the object to move, F is equal in magnitude to the static frictional force. The static frictional force is a maximum (f_s^{max}) just before the object starts to move across the surface. If the applied force exceeds (f_s^{max}), a resultant force accelerates the movement of the object.

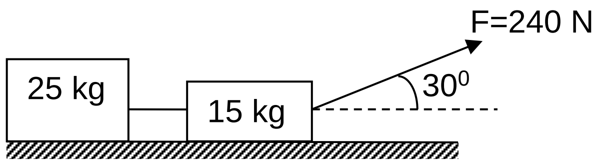
Steps to solve problems of Newton's laws:

Step 1: Read the problem as many times as you need.
Step 2: Sketch the problem if it is necessary.
Step 3: Draw a force diagram for the situation.
Step 4: Draw a free-body diagram; you must resolve the forces into component on the Cartesian plane.
Step 5: List all the given information and converted to SI units if it is necessary.
Step 6: Determine which physical principle can solve the problem.
Step 7: Use the principle to solve the question, often by substituting numerical values into an appropriate equation.
Step 8: Check that the question has been answered and that the answer makes sense.

EXAMPLE

QUESTION 1

Two blocks of 25 kg and 15 kg are connected by a light inextensible string on a horizontal surface. A force of magnitude 240 N is applied to the block of 15 kg forming an angle of 30° with the horizontal as shown in the sketch below. The coefficient of kinetic friction is 0,20.



1.1 State *Newton's Second Law of Motion* in words. (2)

1.2 Draw a free body diagram for the block of 25 kg. (4)

1.3 Calculate the magnitude of the acceleration of the blocks. (8)

1.4 Calculate the magnitude of the tension force in the connecting cord. (4)

1.5 Modern cars are fitted with inertia reel seatbelts to protect passengers in case of an accident. In South Africa every year a big number of children die for not using seatbelts during accidents.

1.5.1. Which ONE of Newton's laws of motion explains the use of seat belts?

1.5.2. Explain why seatbelts are necessary to reduce the risk of being injured during accidents. (3)

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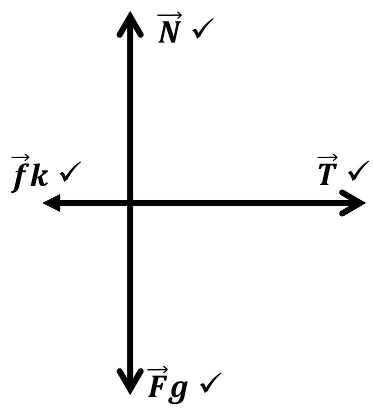
SOLUTION

1.1 If a resultant force acts on a body, it will cause the body to accelerate in the direction of the resultant force. The acceleration of the body will be directly proportional to the resultant force✓ and inversely proportional to the mass of the body. ✓

(2)

1.2



(4)

1.3 **Option 1**

$\vec{F}_R = m_1\vec{a}$ ✓

For block 1:

$\vec{T} + \vec{F}_{f1} = m_1 a_x$

$T - F_{f1} = m_1 a_x$

$T - \mu m_1 g = m_1 a_x$ (1)

✓Any one

For block 2:

$\vec{F}_{R2x} = m_2\vec{a}$

$\vec{F}_x + \vec{T} + \vec{F}_{f2} = m_2 a_x$

$F_x - T - F_{f2} = m_2 a_x$

$F\cos 30^o - T - \mu N_2 = m_1 a_x$

$F\cos 30^o - T - \mu(m_2 g - F\sin 30^o) = m_2 a_x$ (2)

✓Any one ✓

Adding equation (1) and (2).

$T - \mu m_1 g + F\cos 30^o - T - \mu(m_2 g - F\sin 30^o) = m_1 a_x + m_2 a_x$

$-\mu m_1 g + F\cos 30^o - \mu(m_2 g - F\sin 30^o) = (m_1 + m_2)a_x$

$[-(0{,}20)(25)(9{,}8)]$ ✓ $+ 240\cos 30^o - 0{,}2[(15)(9{,}8))$ ✓ $- (240\sin 30^o)]$ ✓ $=$ $(25 + 15)a_x$ ✓

$-49 + 207{,}85 - 0{,}2(147 - 120) = 40a_x$

$-49 + 207{,}85 - 5{,}4 = 40a_x$

$a = 3{,}84 m\cdot s^{-2}$ ✓

(8)

phys

1.4 **Option 1** (using block 1

$\vec{F}_{RxA} = m_A\vec{a}_x$

$T - f_f = m_A\vec{a}_x$ ✓Any one

$T - \mu m_A g = m_A\vec{a}_x$

$T - (0,2)(25)(9,8)$ ✓ $= (25)(3,84)$ ✓

$T = 145N$ ✓

Option 2: (using block 2

$\vec{F}_{RxB} = m_B\vec{a}_x$

$F_{AX} - T - f_f = m_B\vec{a}_x$ ✓Any one

$F\cos 30 - T - \mu(m_B g - F\sin 30) = m_B\vec{a}_x$

$240\cos 30 - T - 0,2[(15)(9,8) - 240\sin 60)]$ ✓ $= (15)(3,84)$ ✓

$207,85 - T - 0,2(27) = 57,6$

$207,85 - T - 5,4 = 57,6$

$T = 144,85\ N$ ✓ $= 145\ N$ (4)

1.5 1.5.1. Newton's First Law of motion.✓

1.5.2. When the car slows down the passenger continues to move forward due to inertia✓, the seatbelt exerts a force on the passenger and causes the passenger to slow down with the car✓. (3)

[**21**]

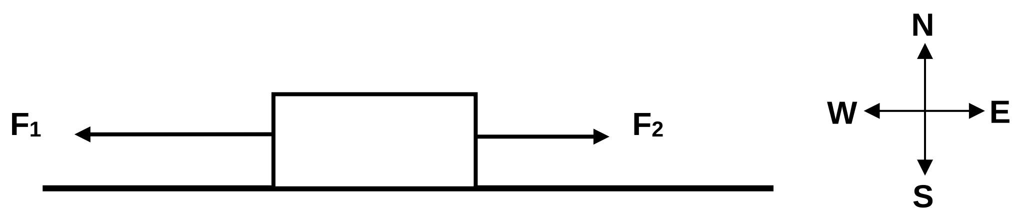
EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 Two forces, $\mathbf{F_1}$ and $\mathbf{F_2}$, are applied on a crate lying on a frictionless, horizontal surface, as shown in the diagram below.

The magnitude of force $\mathbf{F_1}$ is greater than that of force $\mathbf{F_2}$.



The crate will …

A accelerate towards the east.

B accelerate towards the west.

C move at a constant speed towards the east.

D move at a constant speed towards the west. (2)

1.2 A person stands on a bathroom scale that is calibrated in newton, in a stationary elevator. The reading on the bathroom scale is w.

The elevator now moves with a constant upward acceleration of $\frac{1}{4}$g, where g is the gravitational acceleration.

What will the reading on the bathroom scale be now?

A $\frac{1}{4}$w

B $\frac{3}{4}$w

C w

D $\frac{5}{4}$w (2)

1.3 A net force **F** which acts on a body of mass *m* causes an acceleration *a*. If the same net force **F** is applied to a body of mass 2*m*, the acceleration of the body will be …

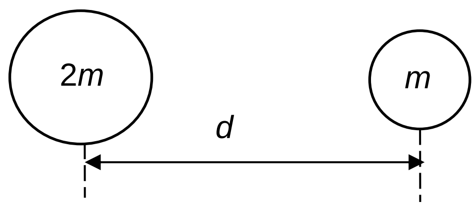
A ¼a

B ½a

C 2a

D 4a (2)

1.4 Two objects of masses 2*m* and *m* are arranged as shown in the diagram below.



Which ONE of the changes below will produce the GREATEST increase in the gravitational force exerted by the one mass on the other?

A Halve the distance between the masses.

B Halve the smaller mass.

C Double the distance between the masses.

D Double the larger mass.

(2)

1.5 The tendency of an object to remain at rest or to continue in its uniform motion in a straight line is known as …

A inertia.

B acceleration.

C Newton's Third Law.

D Newton's Second Law. (2)

1.6 The mass of an astronaut on Earth is M. At a height equal to twice the radius of the Earth, the **mass** of the astronaut will be …

A $\frac{1}{4}$M

B $\frac{1}{9}$M

C M

D 2M (2)

1.7 The physical quantity which is a quantitative measure of the resistance of an object to any change in its state of rest or motion is called …

A weight.

B mass.

C acceleration.

D friction. (2)

1.8 The magnitude of the gravitational acceleration on Earth is g. What will the value of the gravitational acceleration be on planet X, which has the same mass as Earth, but half the radius?

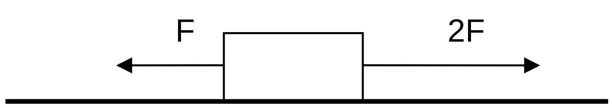
A $\frac{1}{4}g$

B $\frac{1}{2}g$

C $2g$

D $4g$ (2)

1.9 A block is placed on a surface with negligible friction. Forces **F** and 2**F** are applied on the block as shown below.



Which ONE of the following correctly describes the motion of the block?

A The block moves at constant velocity to the right.

B The block moves with increasing acceleration to the right.

C The block moves with constant acceleration to the right.

D The block moves with constant acceleration to the left. (2)

1.10 Equal forces act on each of two objects, **A** and **B** as shown below. The mass of **B** is three times the mass of **A**. Ignore the effect of friction.

If the rate of change in velocity of object **B** is X, then the rate of change in velocity of object **A** is…

A $\frac{X}{9}$

B $\frac{X}{3}$

C X

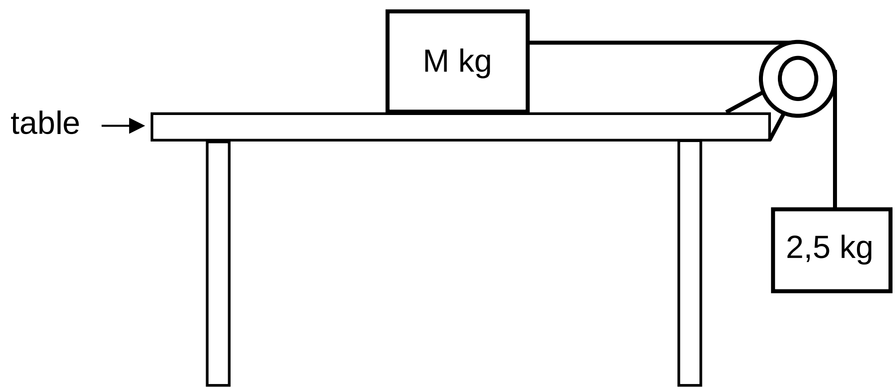
D $3X$ (2)

[20]

QUESTION 2 ((DBE/Nov 2015).)

2.1 Two blocks of mass M kg and 2,5 kg respectively are connected by a light, inextensible string. The string runs over a light, frictionless pulley, as shown in the diagram below.

The blocks are **stationary**.



2.1.1 State Newton's THIRD law in words. (2)

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2.1.2 Calculate the tension in the string. (3)

The coefficient of static friction (μ_s) between the unknown mass M and the surface of the table is 0,2.

2.1.3 Calculate the minimum value of M that will prevent the blocks from moving. (5)

The block of unknown mass M is now replaced with a block of mass 5 kg. The 2,5 kg block now accelerates downwards. The coefficient of kinetic friction (μ_k) between the 5 kg block and the surface of the table is 0,15.

2.1.4 Calculate the magnitude of the acceleration of the 5 kg block. (5)

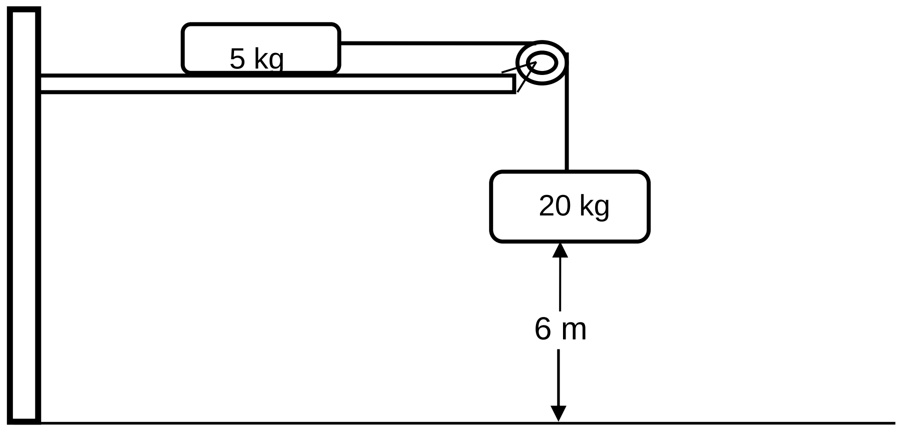
2.2 A small hypothetical planet X has a mass of 6,5 x 10^{20} kg and a radius of 550 km.

Calculate the gravitational force (weight) that planet X exerts on a 90 kg rock on this planet's surface. (4)

[19]

QUESTION 3 (DBE/ Feb.–Mar. 2016)

3.1 A 5 kg mass and a 20 kg mass are connected by a light inextensible string which passes over a light frictionless pulley. Initially, the 5 kg mass is held stationary on a horizontal surface, while the 20 kg mass hangs vertically downwards, 6 m above the ground, as shown in the diagram below.
The diagram is not drawn to scale.



When the *stationary* 5 kg mass is released, the two masses begin to move. The coefficient of kinetic friction, μ_k, between the 5 kg mass and the horizontal surface is 0,4. Ignore the effects of air friction.

3.1.1 Calculate the acceleration of the 20 kg mass. (5)

3.1.2 Calculate the speed of the 20 kg mass as it strikes the ground. (4)

3.1.3 At what minimum distance from the pulley should the 5 kg mass be placed initially, so that the 20 kg mass just strikes the ground? (1)

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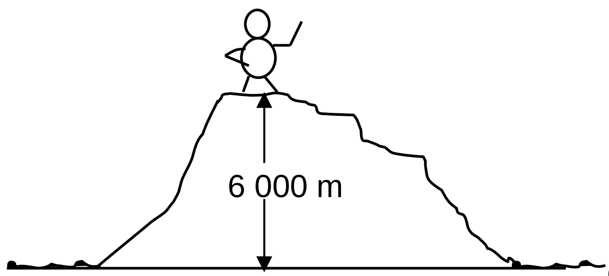
3.2 A person of mass 60 kg climbs to the top of a mountain which is 6 000 m above ground level.



3.2.1 State Newton's Law of Universal Gravitation in words. (2)

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____
____
____

3.2.2 Calculate the *difference* in the weight of the climber at the top of the mountain and at ground level. (6)

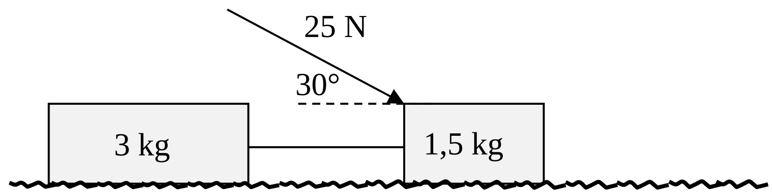
[18]

phys

QUESTION 4 (DBE/November 2016)

A learner constructs a push toy using two blocks with masses 1,5 kg and 3 kg respectively. The blocks are connected by a massless, inextensible cord.

The learner then applies a force of 25 N at an angle of 30° to the 1,5 kg block by means of a light rigid rod, causing the toy to move across a flat, rough, horizontal surface, as shown in the diagram below.



The coefficient of kinetic friction (μ_k) between the surface and each block is 0,15.

4.1 State Newton's Second Law of Motion in words. (2)

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4.2 Calculate the magnitude of the kinetic frictional force acting on the 3 kg block. (3)

4.3 Draw a labelled free-body diagram showing ALL the forces acting on the 1,5 kg block.

(5)

4.4 Calculate the magnitude of the:

4.4.1 Kinetic frictional force acting on the 1,5 kg block. (3)

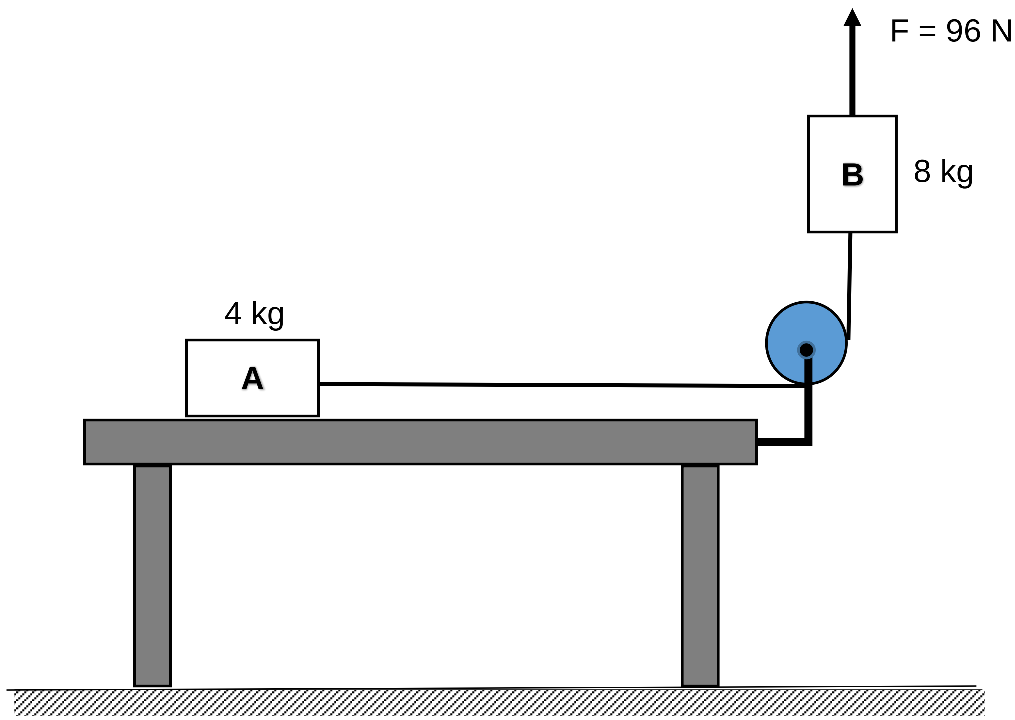
4.4.2 Tension in the cord connecting the two blocks. (5)

[18]

phys

QUESTION 5 (NC preparatory examination 2019)

A block **A** of mass 4 kg, resting on a rough horizontal table, is connected to another block **B** of mass 8 kg by a light inextensible string which passes over a light frictionless pulley. A force of magnitude 96 N is applied vertically upwards on block **B** as shown in the diagram below.



The kinetic frictional force acting on block **A** is 11,76 N. Ignore the effects of air friction.

5.1 State *Newton's second law of motion* in words. (2)

5.2 Draw a labelled free-body diagram for block **B**. (3)

5.3 Calculate the magnitude of the:

5.3.1 Normal force acting on block **A** (3)

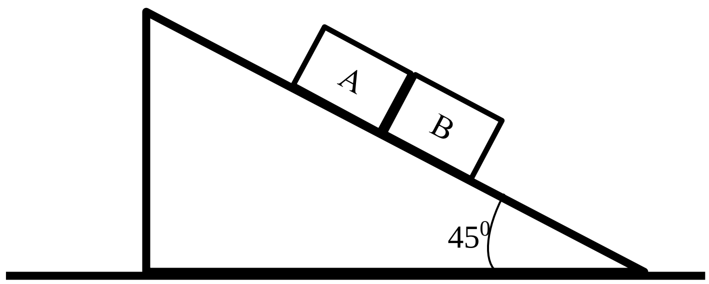
5.3.2 Tension force acting on block **A** (6)

[14]

phys

QUESTION 6 (NC preparatory examination 2017)

Two blocks A and B of equal mass 0,2 kg slide down on an inclined planed as shown in the sketch below. The coefficient of kinetic friction between block A and the inclined plane is μ_A = 0,01 and the coefficient of kinetic friction between block B and the inclined plane is μ_B = 1,00.



6.1 State Newton`s second law of motion in words. (2)

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____

6.2 Draw a labelled free-body diagram showing ALL the forces acting on block **A** as it slides down the incline. (4)

6.3 Calculate the acceleration of the two blocks. (8)

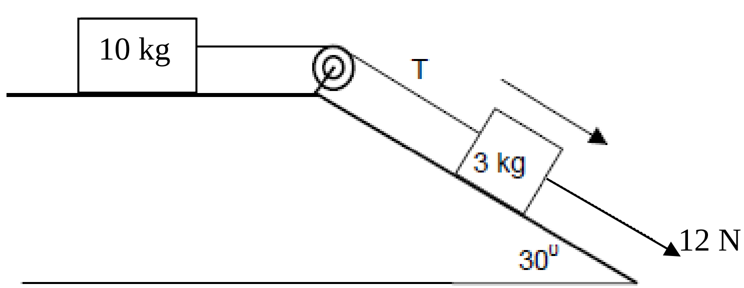
6.4 Calculate the magnitude of the force exerted by block B on Block A. (3)

6.5 If the system is placed on the Moon where the magnitude of the acceleration due to gravity is 1,62 $m \cdot s^{-2}$. How will it affect the acceleration of the blocks calculated in question 6.3? Write down INCREASES, DECREASES OR REMAINS THE SAME. Explain the answer. (3)

[20]

QUESTION 7 NC/June 2017)

Two blocks of masses 10 kg and 3 kg respectively are connected by a light inextensible string that runs over a light frictionless pulley as shown in the diagram below. The 10 kg block experiences a frictional force of 8 N, the coefficient of kinetic friction between the 3 kg block and the surface of the inclined plane is 0,30. A pulling force of 12 N is applied to the 3 kg block and an angle of 60° to the surface of the incline.



7.1 State *Newton's second law of motion* in words. (2)

phys

7.2. Draw a labelled free-body diagram showing all the forces acting on the 3 kg block. (5)

7.3 Define *kinetic frictional force* in words.

____

____

____ (2)

7.4 Calculate:

7.4.1 The magnitude of the frictional force acting on the 3 kg block.

(4)

7.4.2 The tension T in the string.

(6)

phys

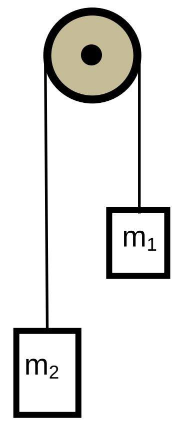
7.5 How would the magnitude of the frictional force acting on the 3 kg block compare to your answer in QUESTION 7.4.1 if the 12 N force is now applied forming an angle of 60° to the surface of the inclined plane? Write down only GREATER THAN, EQUAL TO or LESS THAN. (1)

____

[20]

QUESTION 8 (NC/September 2014)

Two mass pieces of 4 kg and 2 kg connected by a light inextensible string passes over a frictionless pulley as shown below. The masses of the pulley and the string may be ignored.



The system of mass pieces is then released from rest.

8.1 Draw a free body diagram of ALL the forces acting on the 4 kg mass piece. (2)

8.2 Write down *Newton's second law of motion* in words.

____
____
____
(2)

8.3 Calculate the magnitude of the:

8.3.1 acceleration of the system. (5)

8.3.2 tension in the connecting string. (3)

8.4 How does the magnitude of the net force on the 2 kg mass piece compare with the net force acting on the 4 kg mass piece?
Only write down GREATER THAN, SMALLER THAN or EQUAL TO. (1)

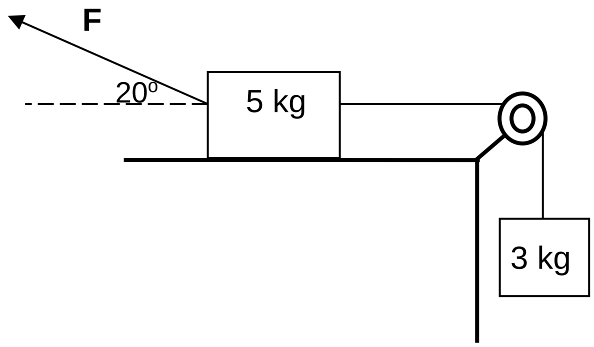
____

[13]

QUESTION 9 (FS-NC preparatory examination 2016 .)

A 5 kg block, resting on a rough horizontal surface, is connected by a light inextensible string passing over a light frictionless pulley to a second block of mass 3 kg hanging vertically.

An applied force **F** is acting on the 5 kg block as shown in the diagram below and the coefficient of kinetic friction between the 5 kg block and the surface is 0,2.
The 5 kg block accelerates to the left.



9.1 Define the term *frictional force.* (2)

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9.2 Calculate the magnitude of the:

9.2.1 Vertical component of **F** if the magnitude of the horizontal component of **F** equals 38 N (2)

9.2.2 Normal force acting on the 5 kg block (3)

phys

9.3 State *Newton's Second Law of motion.* (2)

____

____

____

9.4 Draw a labelled free-body diagram to indicate all the forces acting on the 3 kg block. (2)

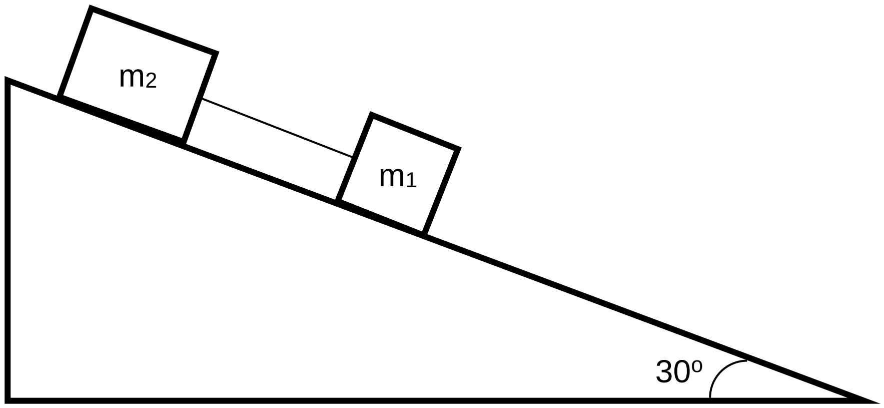
9.5 Calculate the magnitude of the tension force in the string connecting the two blocks. (6)

[17]

phys

QUESTION 10

Two blocks of masses m_1 = 8 Kg and m_2 = 16 Kg are connected by a light string. The system slide down on a rough incline plane that makes an angle of 30^o with the horizontal. The magnitude of the frictional force acting on block 1 is 16 N and the magnitude of the frictional force acting on block 2 is 62 N.



10.1 State Newton's Second Law of motion in words.

____

____

____ (2)

10.2 Draw a free-body diagram of all the forces acting on block 2.

(4)

10.3 Calculate the:

10.3.1 Acceleration of the blocks (6)

10.3.2 Magnitude of the tension force acting on the blocks. (3)

[15]

phys

TOPIC 1: MECHANICS

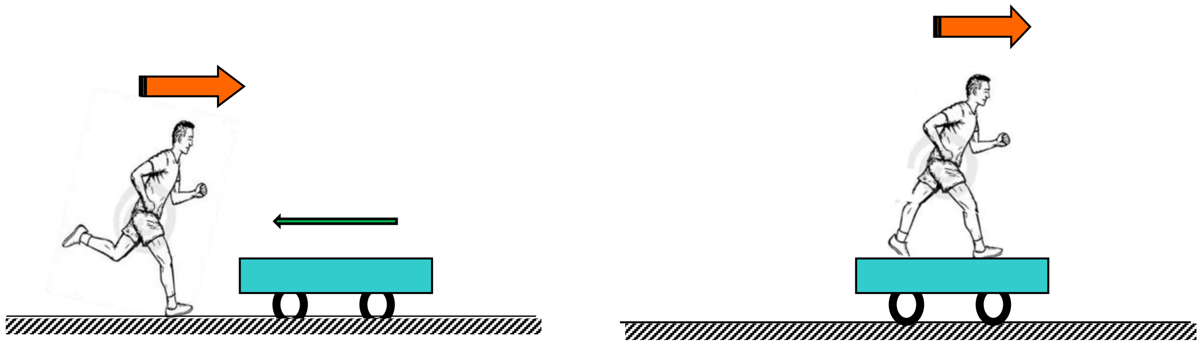
1.2. MOMENTUM AND IMPULSE

Physical quantities		Newton's second law in terms of momentum	Impulse-momentum theorem	Law of conservation of lineal momentum.
Momentum and change in momentum	**Impulse**			
Momentum is the product of an object mass and its velocity. Momentum is a vector quantity $\vec{\boldsymbol{p}} = \boldsymbol{m}\vec{\boldsymbol{v}}$ SI units $[kg \cdot m \cdot s^{-1}]$ $\Delta\vec{p} = \vec{p}_f - \vec{p}_f$ $\Delta\vec{p} = m\vec{v}_f - m\vec{v}_f$ $\Delta\vec{p} = m(\vec{v}_f - \vec{v}_f)$ $\Delta\vec{\boldsymbol{p}} = \boldsymbol{m}\Delta\vec{\boldsymbol{v}}$	***Impulse of a force is the product of the force acting on an objet and the time the force acts on the object.*** Impulse is a vector quantity. $\vec{\boldsymbol{J}} = \vec{\boldsymbol{F}}\Delta\boldsymbol{t}$ SI units $[N \cdot s]$	***The resultant/ net force acting on an object is equal to the rate of change of momentum of the object in the direction of the resultant/net force.*** $\vec{\boldsymbol{F}}_{\boldsymbol{net}} = \frac{\Delta\vec{\boldsymbol{p}}}{\Delta\boldsymbol{t}}$	$\vec{\boldsymbol{J}} = \Delta\vec{\boldsymbol{p}}$ $\vec{F}_{net}\Delta t = m\Delta\vec{v}$ $\vec{F}_{net}\Delta t = mv_f - mv_i$	*An **isolated system** in physics is a system on which the resultant/net external force is zero*. $\vec{F}_{net} = \vec{0}$ The law of conservation of momentum state that ***the total momentum of an isolated system is constant.*** $\sum\vec{\boldsymbol{F}}_{\boldsymbol{ext}} = \vec{\boldsymbol{0}}$ Then $\Delta\vec{p}_{net} = \vec{0}$ $\vec{p}_{Tf} - \vec{p}_{Ti} = \vec{0}$ $\vec{p}_{Ti} = \vec{p}_{Tf}$ $\vec{p}_{iA} + \vec{p}_{iB} = \vec{p}_{fA} + \vec{p}_{fB}$ $m_A\vec{v}_{iA} + m_B\vec{v}_{iB} = m_A\vec{v}_{fA} + m_B\vec{v}_{fB}$

EXAMPLE

QUESTION 1

A man with mass 70 kg runs with velocity 3 m·s^{-1} to the right and jumps on a trolley of mass 5 kg which is moving at 0,5 m·s^{-1} to the left . After jumping the man stays on the trolley. The man-trolley system is isolated.



Before After

1.1 State the law of conservation of linear momentum in words (2)

1.2 Explain what is meant by an "isolated system" in Physics: (2)

1.3 Determine the combined speed of the man and the trolley after the man jumped on it. (5)

[9]

SOLUTION

1.1 The total linear momentum of an isolated system remains constant (is conserved). ✓✓ (2 or 0) (2)

1.2 An isolated system is one on which the <u>net external force</u> acting on the system <u>is zero</u>. ✓✓ (2 or 0) (2)

1.3 **OPTION 1**

Positive to the right

$$\sum \vec{p}_{\text{before}} = \sum \vec{p}_{\text{after}}$$
$$(\vec{p}_m + \vec{p}_T)_{\text{before}} = (\vec{p}_m + \vec{p}_T)_{\text{after}}$$
$$m_m\vec{v}_{m(before)} + m_T\vec{v}_{T(before)} = m_m\vec{v}_{m(after)} + m_T\vec{v}_{T(after)}$$
$$m_m\vec{v}_{m(before)} + m_T\vec{v}_{T(before)} = (m_m + m_T)\vec{v}_{sys(after)}$$

Any one ✓

$$(70)(+3)✓ + (5)(-0{,}5)✓ = (70+5)\vec{v}_{sys(after)}✓$$
$$v_{sys} = 2{,}77 \text{ m·s}^{-1}✓$$

OPTION 2/OPSIE 2
Positive to the left

$$\sum \vec{p}_{\text{before}} = \sum \vec{p}_{\text{after}}$$
$$(\vec{p}_m + \vec{p}_T)_{\text{before}} = (\vec{p}_m + \vec{p}_T)_{\text{after}}$$
$$m_m\vec{v}_{m(before)} + m_T\vec{v}_{T(before)} = m_m\vec{v}_{m(after)} + m_T\vec{v}_{T(after)}$$
$$m_m\vec{v}_{m(before)} + m_T\vec{v}_{T(before)} = (m_m + m_T)\vec{v}_{sys(after)}$$

Any one ✓

$$(70)(-3)✓ + (5)(+0,5)✓ = (70+5)\vec{v}_{sys(after)}✓$$
$$v_{sys} = -2,77 \text{ m·s}^{-1}$$
$$v_{sys} = 2,77 \text{ m·s}^{-1} ✓$$

(5)

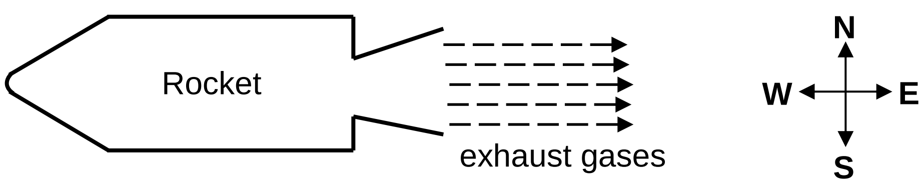
[9]

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 The simplified diagram below shows a rocket that has been fired horizontally, accelerating to the west.



Which ONE of the statements below best explains why the rocket accelerates?

A The speed of the exhaust gases is smaller than the speed of the rocket.

B The rocket pushes the exhaust gases to the east and the exhaust gases push the rocket to the west.

C The air outside the rocket exerts a greater force on the back of the rocket than at the front.

D The pressure of the atmosphere at the back of the rocket is less than at the front (2)

1.2 Airbags in modern cars provide more safety during an accident.
The statements below are made by a learner to explain how airbags can ensure better safety in a collision.

(i) The time of impact increases.

(ii) The impact force decreases.

(iii) The impulse increases.

Which of the statements above are CORRECT?

A (i) only

B (ii) only

C (ii) and (iii) only

D (i) and (ii) only (2)

1.3 A person drops a glass bottle onto a concrete floor from a certain height and the bottle breaks. The person then drops a second, identical glass bottle from the same height onto a thick, woollen carpet, but the bottle does not break.
Which ONE of the following is CORRECT for the second bottle compared to the first bottle for the same momentum change?

	AVERAGE FORCE ON SECOND BOTTLE	**TIME OF CONTACT WITH CARPET**
A	Smaller	Larger
B	Smaller	Smaller
C	Larger	Larger
D	Larger	Smaller

(2)

1.4 Net force is a measure of the …

A change in momentum

B change in energy.

C rate of change in momentum.

D rate of change in energy. (2)

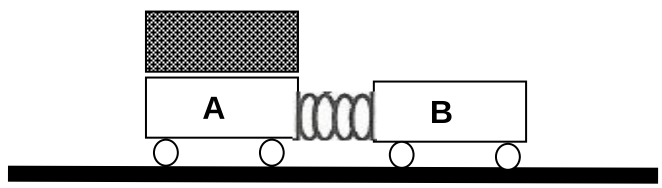
1.5 Two balls **A** and **B** with the same mass, move horizontally towards a man. Ball **A** is moving at twice the speed of ball **B**. The man applies the same force when he catches each ball.

Which ONE of the following is CORRECT for ball **A** compared to ball **B**?

	CHANGE IN MOMENTUM OF BALL A	**TIME TAKEN TO STOP BALL A**
A	The same	Longer
B	Larger	Longer
C	Larger	Shorter
D	Smaller	The same

(2)

1.6 Two trolleys A and B with the same mass are placed on a horizontal frictionless surface with a spring compress between them. A block with the same mass as that of one trolley is placed on top of block A as shown in the sketch below. When the spring is released the trolleys move apart due to the force exerted by the spring.



Which ONE of the following statements regarding the force exerted and the momentum gained respectively are CORRECT?

	FORCE EXERTED ON TROLLEY B IS:	**MOMENTUM GAINED BY TROLLEY B IS:**
A	Equal to the force exerted on trolley **A**	Equal to the momentum gained by trolley **A**
B	Double the force exerted on trolley **A**	Double the momentum gained by trolley **A**
C	Half the force exerted on trolley **A**	Half the momentum gained by trolley **A**
D	Four times the force exerted on trolley **A**	$1\frac{1}{2}$ times the momentum gained by trolley **A**

(2)

1.7 Which ONE of the physical quantities is equal to the rate of change in momentum?

A Power

B Impulse

C Acceleration

D Resultant force (2)

1.8 A tennis ball strikes a wall horizontally with linear momentum of magnitude 6 kg·m·s^{-1} and rebounds in the opposite direction with a linear momentum of magnitude 4 kg·m·s^{-1}. Which ONE of the vector diagrams correctly shows the initial momentum, final momentum and change in momentum vectors for the ball?

A

$\vec{p}_i = +6\ kg \cdot m \cdot s^{-1}$ (→)

$\vec{p}_f = -4\ kg \cdot m \cdot s^{-1}$ (←)

$\Delta\vec{p} = +10\ kg \cdot m \cdot s^{-1}$ (→)

B

$\vec{p}_i = +6\ kg \cdot m \cdot s^{-1}$ (→)

$\vec{p}_f = -4\ kg \cdot m \cdot s^{-1}$ (←)

$\Delta\vec{p} = -10\ kg \cdot m \cdot s^{-1}$ (←)

C

$\vec{p}_i = +6\ kg \cdot m \cdot s^{-1}$ (→)

$\vec{p}_f = -4\ kg \cdot m \cdot s^{-1}$ (←)

$\Delta\vec{p} = -2\ kg \cdot m \cdot s^{-1}$ (←)

D

$\vec{p}_i = +6\ kg \cdot m \cdot s^{-1}$ (→)

$\vec{p}_f = -4\ kg \cdot m \cdot s^{-1}$ (←)

$\Delta\vec{p} = +2\ kg \cdot m \cdot s^{-1}$ (→)

(2)

1.9 A trolley **A** of mass ***m*** moves to the right *with speed* $\boldsymbol{v}$. It collides head-on with a trolley **B** of mass **4*m*** moving to the left with speed $\frac{1}{4}\boldsymbol{v}$. After the collision the two trolleys stick together. Which ONE is the velocity of the system formed by the two trolleys?

A 0

B $\frac{1}{2}v$

C v

D $2v$ (2)

1.10 A ball with mass m, travelling west, hits a wall with a velocity of $\vec{v}$. It bounces back with a velocity $0{,}75v$ in an easterly direction. The change in momentum of the ball will be …

A 0,25 mv east

B 0,25 mv west

C 1,75 mv east

D 1,75 mv west (2)

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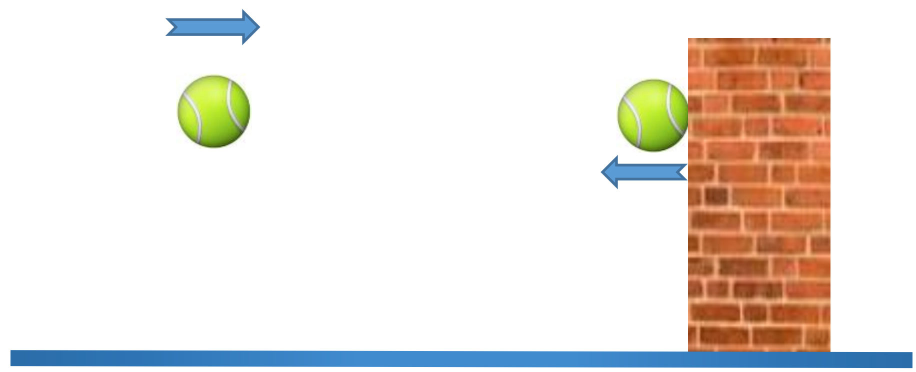
[20]

QUESTION 2

A 58,5 g tennis ball moves towards a wall at a speed of 8 m·s^{-1}. It bounces back in the opposite direction at a speed of 6 m·s^{-1}.



2.1 Define *linear momentum* in words. (2)

____

____

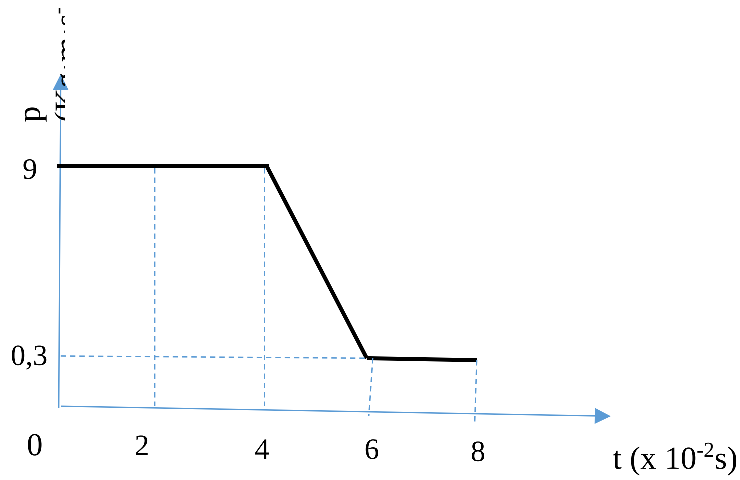
2.2 Calculate the change in momentum of the ball. (5)

2.3 Draw vector diagrams to illustrate the relationship between the initial momentum, the final momentum and the change in momentum. (3)

[10]

QUESTION 3

A bullet of mass 0.03 kg is fired into a stationary block and becomes embedded in the block. As it embeds in the block they move together at a constant velocity over a frictionless surface. The graph below represents the momentum of the bullet versus time for the entire motion.



3.1 State *Newton's second law* in terms of momentum in words. (2)

___

___

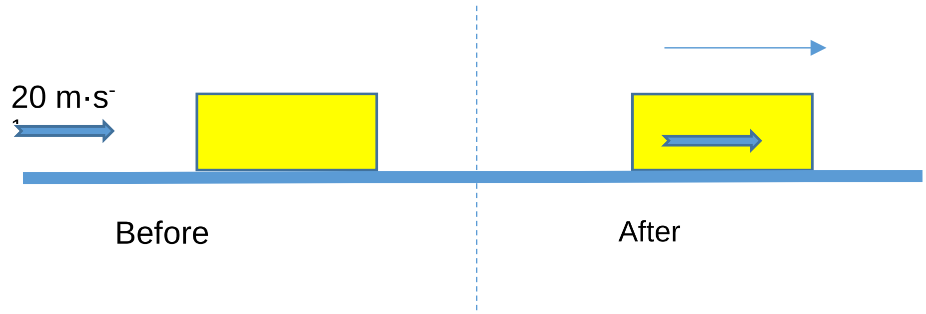
3.2 Calculate the final velocity of the bullet. (3)

3.3 Calculate the net force the block exerts on the bullet. (5)

[10]

QUESTION 4

An arrow of mass 200 g that moves at a speed of 20 m·s^{-1} is encrusted in a stationary wooden block of mass 2 kg, which is on a horizontal frictionless surface as shown in figure below.



4.1. State the *law of conservation of linear momentum* in words. (2)

____

____

____

4.2 Calculate the velocity of the system block-arrow after the impact. (5)

4.3 Calculate the impulse if the average force exerted by the block on the arrow. (3)

[10]

QUESTION 5

A football of mass 500 g approaches a player's foot at 4 $m \cdot s^{-1}$. The player kick it back along its original path, exerting a force of 45 N opposite the direction of approaching ball. His foot is in contact with the ball for 0,2 s. Ignore the effect of friction.

5.1. State Newton's second law of motion in terms of momentum. (2)

____

____

5.2. Calculate the velocity at which the ball leaves the player's foot. (3)

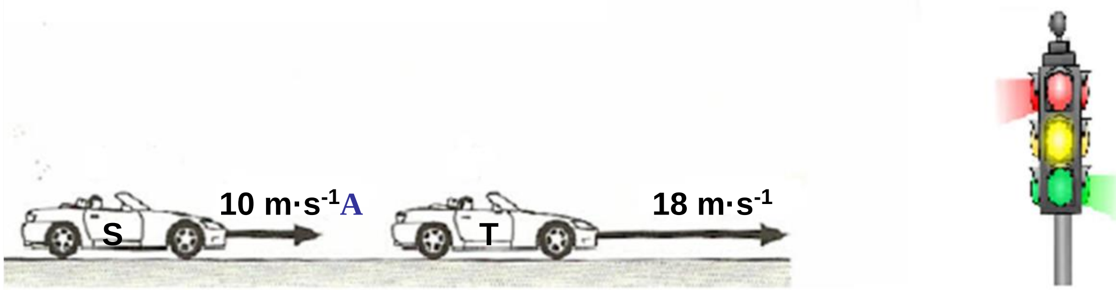
5.3. Calculate the change in momentum of the ball. (3)

5.4. Use vector diagram to illustrate this change. (3)

[11]

QUESTION 6 (Question 4 Trial 2014)

Two cars S and T travelling on a straight road approach a robot at velocities of 10 m·s^{-1} East and 18 m·s^{-1} East respectively as shown in the sketch below. Ignore the effect of friction.



Car T suddenly stops and car S collides with car T. After the collision the two cars move off together as a unit. The combined mass of each car with the driver is 1500 kg.

6.1 State the law of conservation of linear momentum in words. (2)

____

____

6.2 Calculate the speed of the two cars immediately after the collision. (4)

Research has shown that forces greater than 85 000 N during collisions may cause fatal injuries. The collision described above lasts for 0,08 s.

6.3 Determine, by means of calculations, whether the collision above could result in a fatal injury. (4)

The cars have crumple zones, seat belts, air bags and padded interiors that can reduce the chance of death or serious injury during accidents.

6.4 Use principles of Physics to explain how air bags can reduce the risk of injury or death. (3)

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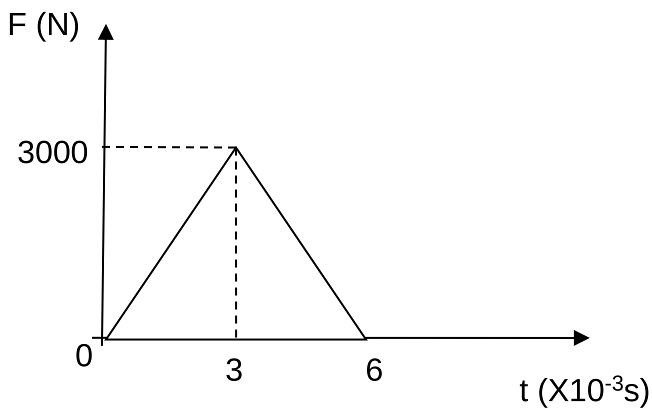
[13]

QUESTION 7

A 160 g cricket ball is thrown with a speed of 20 $m \cdot s^{-1}$. It is hit straight back toward the cricket pitcher. The contact time with the cricket bat was 6 x 10^{-3} s, before the ball bounced backwards. The graph below represent the force exerted by bat on the ball.



7.1 Define impulse of a force in words. (2)

____
____

7.2 What is the magnitude of the maximum force exerted by the ball on the bat? (1)

____

7.3 What does the area under the graph represent? (1)

____

7.4 Calculate the magnitude of the change in momentum of the ball. (3)

7.5 Calculate the speed with which the ball bounced back? (3)

7.6 While catching a ball the cricket fielder draws his arms in towards his body. Explain why this is done, by using a suitable physics theorem. (3)

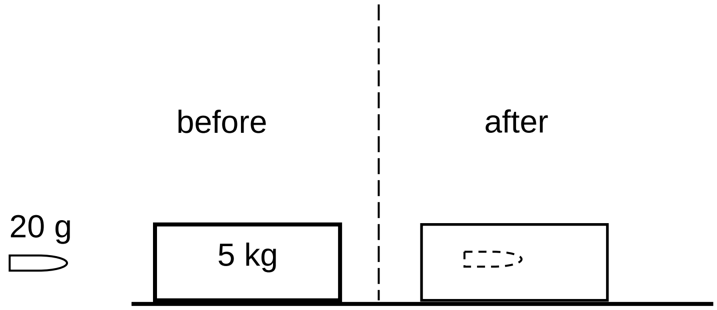
[13]

QUESTION 8 (DBE/November 2015)

A bullet of mass 20 g is fired from a stationary rifle of mass 3 kg. Assume that the bullet moves horizontally. Immediately after firing, the rifle recoils (moves back) with a velocity of 1,4 $m \cdot s^{-1}$.

8.1 Calculate the speed at which the bullet leaves the rifle. (4)

The bullet strikes a stationary 5 kg wooden block **fixed** to a flat, horizontal table. The bullet is brought to rest after travelling a distance of 0,4 m **into the block**. Refer to the diagram below.



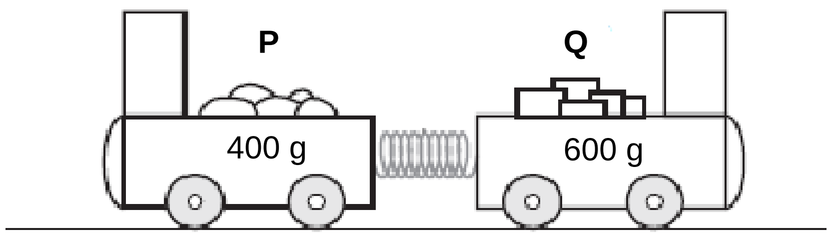
8.2 Calculate the magnitude of the average force exerted by the block on the bullet. (5)

8.3 How does the magnitude of the force calculated in QUESTION 8.2 compare to the magnitude of the force exerted by the bullet on the block? Write down only LARGER THAN, SMALLER THAN or THE SAME. (1)

[10]

QUESTION 9 (DBE/Feb.–March2016)

The diagram below shows two trolleys, **P** and **Q**, held together by means of a compressed spring on a flat, frictionless horizontal track. The masses of **P** and **Q** are 400 g and 600 g respectively.



When the trolleys are released, it takes 0,3 s for the spring to unwind to its natural length. Trolley **Q then** moves to the right at 4 $m \cdot s^{-1}$.

9.1 State the *principle of conservation of linear momentum* in words. (2)

____

____

____

9.2 Calculate the:

9.2.1 Velocity of trolley **P** after the trolleys are released (4)

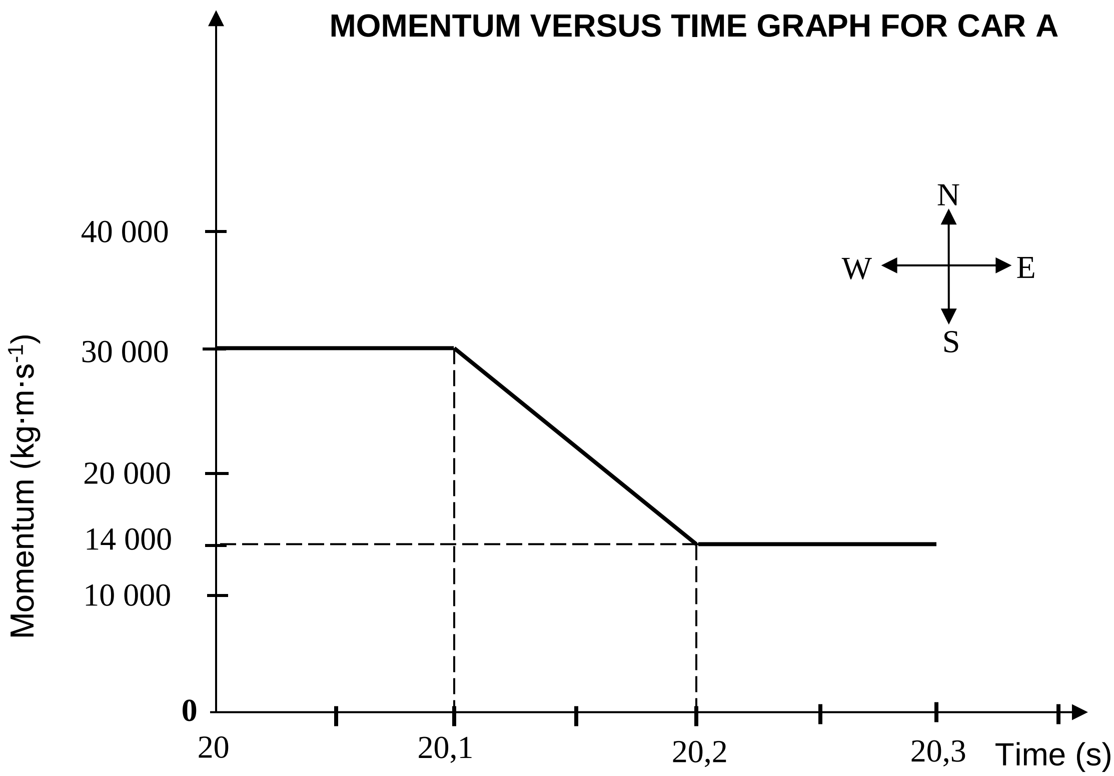
9.2.2 Magnitude of the average force exerted by the spring on trolley **Q** (4)

9.3 Is this an elastic collision? Only answer YES or NO. (1)

____ **[11]**

QUESTION 10 (DBE/November 2016)

The graph below shows how the momentum of car **A** changes with time *just before* and *just after* a head-on collision with car **B**.
Car **A** has a mass of 1 500 kg, while the mass of car **B** is 900 kg.
Car **B** was travelling at a constant velocity of 15 $m \cdot s^{-1}$ west before the collision.
Take east as positive and consider the system as isolated.



10.1 What do you understand by the term *isolated system* as used in physics?

____

____

____ (1)

Use the information in the graph to answer the following questions.

10.2 Calculate the:

10.2.1 Magnitude of the velocity of car (3)

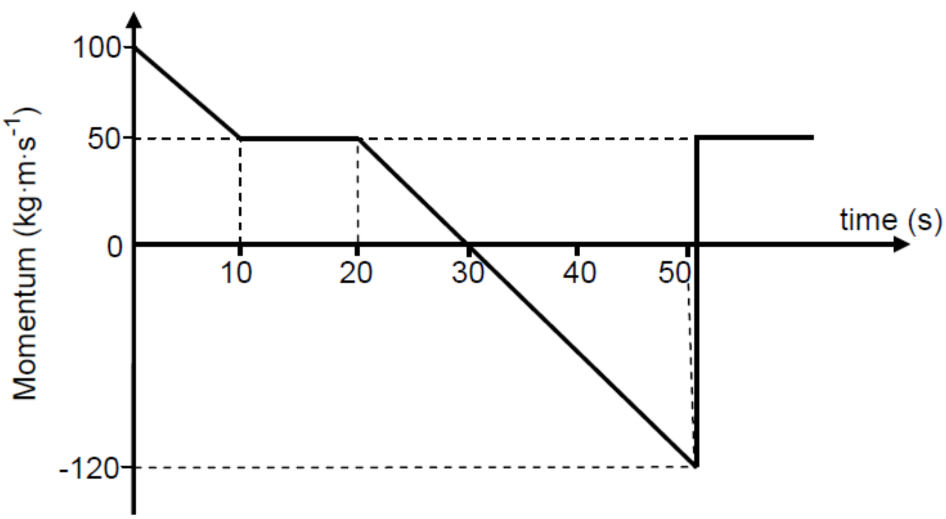
10.2.2 Velocity of car **B** just after the collision (5)

10.2.3 Magnitude of the net average force acting on car **A** during the collision (4)

[13]

QUESTION 11

The momentum versus time graph of object **A**, originally moving horizontally EAST, is shown below.



11.1 Write down the definition of *momentum* in words. (2)

11.2 *The net force acting on object **A** is zero between t = 10 s and t = 20 s.* Use the graph and a relevant equation to explain why this statement is TRUE. (2)

11.3 Calculate the magnitude of the impulse that object **A** experiences between t = 20 s and t = 50 s. (3)

11.4 At t = 50 s, object **A** collides with another object, **B**, which has a momentum of 70 kg·m·s^{-1} EAST.
Use the information from the graph and the relevant principle to calculate the momentum of object **B** after the collision. (5)

[12]

QUESTION 12

The mass of a cricket ball is 156 g and it is bowled at an average speed of 40,8 m·s^{-1}

12.1 Define *linear momentum* in words. (2)

____

____

12.2. Calculate the magnitude of the linear momentum of the cricket ball. (3)

12.3 A cricket ball strikes the bat at 40,8 $m \cdot s^{-1}$ and stays in contact with the bat for 1,2 s. The ball leaves the bat at a speed of 35 $m \cdot s^{-1}$ in the opposite direction.

12.3.1 Draw a vector diagram to illustrate the relationship between the initial and final momentum of the cricket ball, before and after striking the bat. Also show the change in momentum on your diagram. (3)
Use the labels p_i, p_f and Δp on your diagram.

12.3.2 Calculate the magnitude of the impulse experienced by the ball, while in contact with the bat

(3)

12.3.3 Calculate the magnitude of the net force exerted by the bat on the ball

(3)

12.4 While catching a ball the criket fielder draws his arms in towards his body. Explain why this is done, by using a suitable physics theorem. (3)

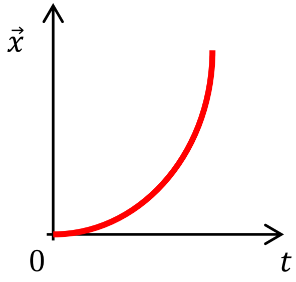
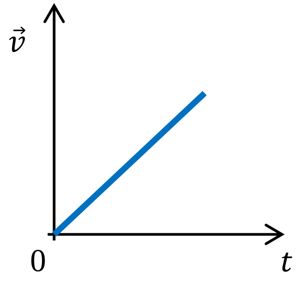
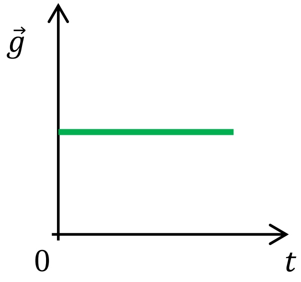
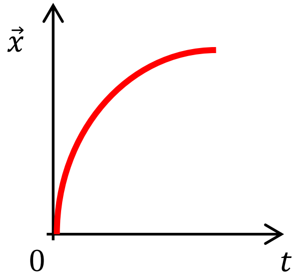
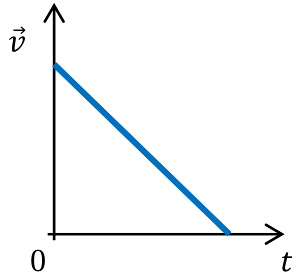
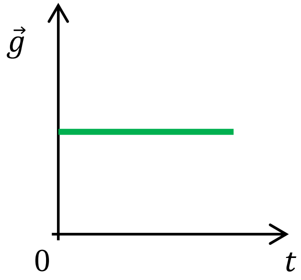
____
____
____
____
____
____

[17]

phys

TOPIC 1: MECHANICS

1.3. VERTICAL PROJECTILE MOTION IN ONE DIMENSION (1D)

Projectile	**Equations of motion**			
Projectile is an object upon which the only force acting is the force of gravity. The motion of a projectile is called ***free fall.***	**Position**	**Displacement**	**Velocity**	**Acceleration**
Free fall is the motion in which an object experiences negligible air resistance and constant acceleration due to gravitational force only.	$\vec{y}_f = \vec{y}_i + \Delta\vec{y}$ $\Delta\vec{y}$ – Displacement, which is the change in position.	$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $\Delta y = \frac{v_f^2 - v_i^2}{2a}$ $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$	$v_f = v_i + a\Delta t$ $v_f^2 = v_i^2 + 2a\Delta y$	Magnitude constant: $a = 9{,}8\ m \cdot s^{-2}$ Direction is always downwards (towards the centre of the Earth).
Free fall is the motion of an object upon which the only force acting is the force of gravity.		**Graphs**		
	Direction of motion	Position vs time	Velocity vs time	Acceleration vs time
	Vertically downwards (speed increases) (constant acceleration)			
	Vertically upwards (speed decreases) (constant acceleration)			

EXAMPLE

QUESTION 1

1. A boy standing on top of a building throws a ball vertically upwards from a position, 3.5 m above the ground with an initial velocity of 10 $m \cdot s^{-1}$. Ignore the effects of air resistance and answer the following questions.

1.1. What is the magnitude and direction of the acceleration of the ball?

1.2. Calculate the maximum height reached by the ball above the ground.

1.3. What was the velocity of the ball at its maximum height?

1.4. Calculate the time taken by the ball to reach its maximum height.

1.5. How much time did the ball take to reach its maximum position and back to the position from which it was thrown?

1.6. Calculate the total time taken by the ball to reach the ground.

1.7. Calculate the velocity with which the ball hits the ground.

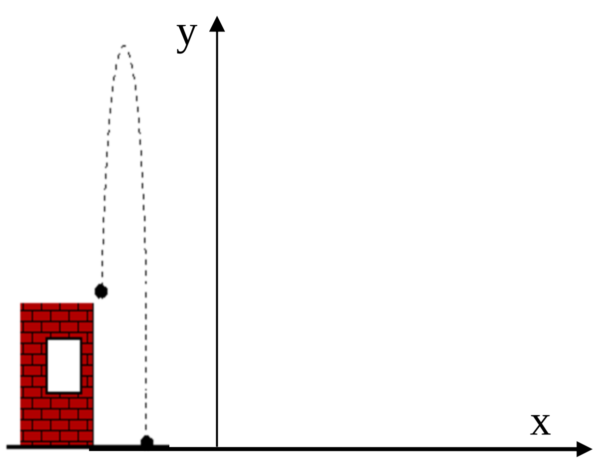
1.8. Draw a rough sketch of the velocity-time graph. Show relevant points on you velocity and time axis.

1.9. Draw a position-time graph.

1.10. Draw the acceleration time graph.

SOLUTION

It is important to make a sketch of the situation and to select positive direction. In this case let's go to use positive direction upwards.



1.1. $a = g = 9{,}8\ (m \cdot s^{-2})$ downwards.

1.2. $H = h_i + \Delta \mathbf{y}$

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

At the maximum height the velocity of the projectile is zero

$0^2 = (10)^2 + 2\,(-9{,}8)\Delta y$

$-100 = -\,(19{,}6)\ \Delta y$

$\Delta y = 5{,}10$ m

$H = 3{,}5 + 5{,}10 = 8{,}60$ m

1.3. Zero.

1.4. $v_f = v_i + g\,\Delta t$

$0 = 10 + (-9{,}8)\,\Delta t$

$-10 = (-9{,}8)\,\Delta t$

$\Delta t = 1{,}02$ s

1.5. $t = t_{up} + t_{down}$

$t_{up} = t_{down}$ when the ball reaches the projection point.

$t = 2t_{up}$

$t = 2 \times 1{,}02 = 2{,}04$ s

1.6. $\Delta y = v_i\Delta t + \frac{1}{2} g\,\Delta t^2$

From the maximum height to the ground

$-8{,}60 = (0 \times \Delta t) + \frac{1}{2}(-9{,}8)\,\Delta t^2$

$-8{,}60 = -4{,}9\,\Delta t^2$

$$\Delta t = \sqrt{\frac{8{,}60}{4{,}9}} = \sqrt{1{,}76} =$$

$\Delta t = 1{,}33$ s

$t_t = t_1$ (upwards) $+ t_2$ (downwards)

$t_t = 1{,}02 + 1{,}33 = 2{,}35$ s

1.7. $v_f = v_i + g\,\Delta t$

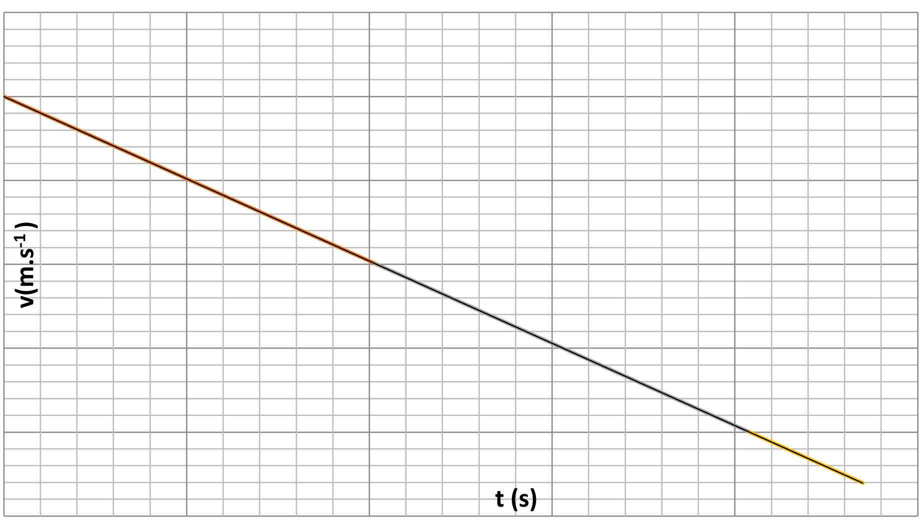
$v_f = 0 + (-9{,}8)1{,}33$

$v_f = 0 - 13{,}03$

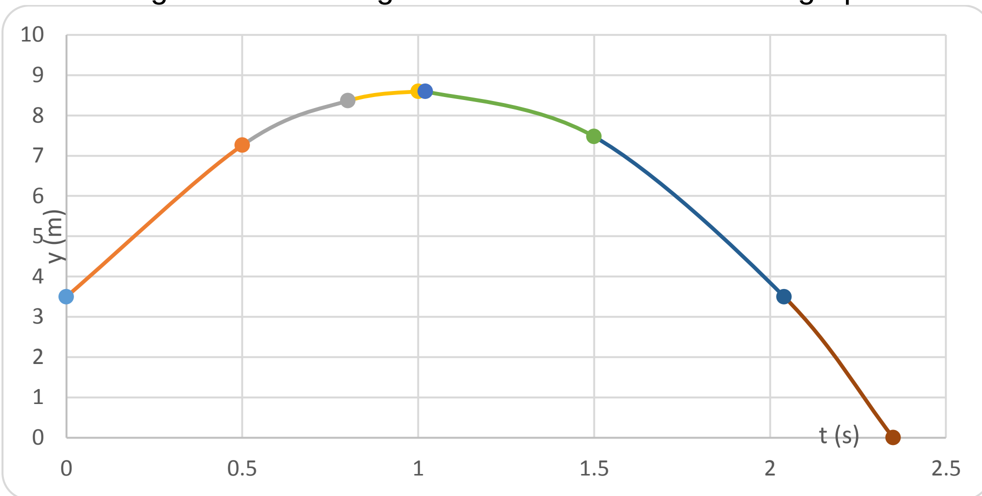
$v_f = -13{,}03\ m.s^{-1}$

$v_f = 13{,}03\ (m.s^{-1})$ downwards.

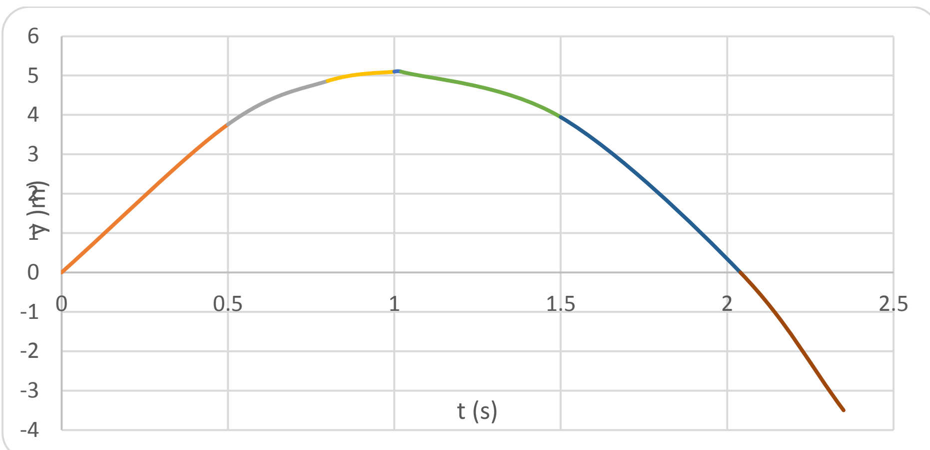
1.8



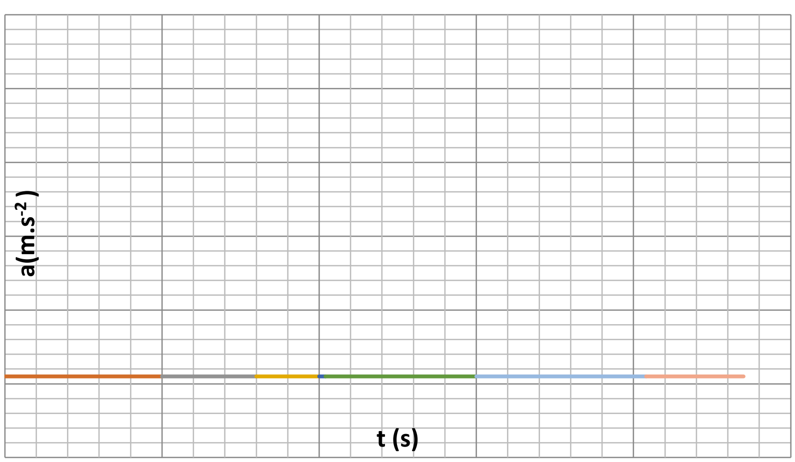
1.9. Let's go to select the ground as level zero then the graph will be the following.



Let's go to select the top of the building as level zero, the graph will be the following.



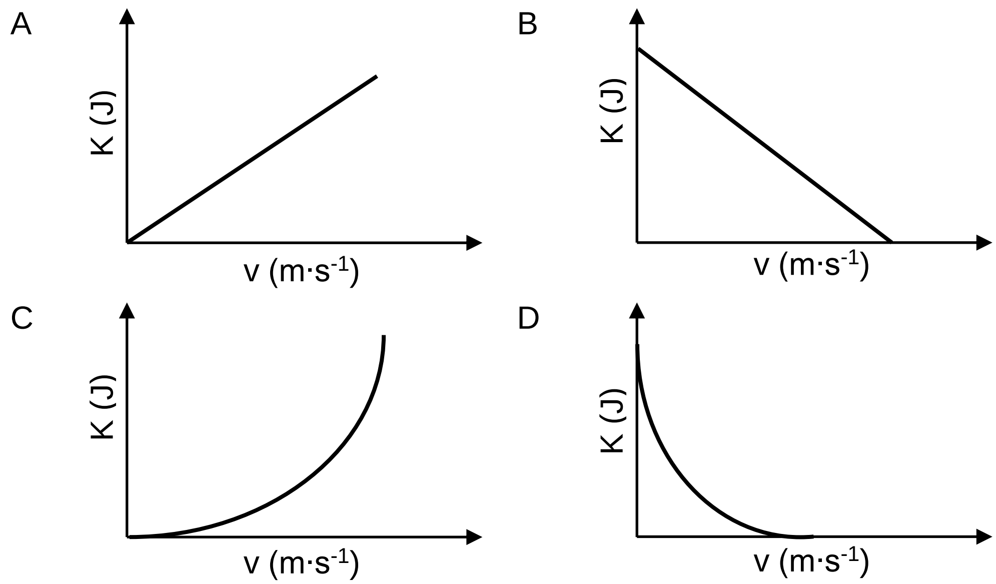
1.10



QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 Which ONE of the graphs below correctly represents the relationship between the kinetic energy (K) of a free-falling object and its speed (v)?



(2)

1.2 The statements below describe the motion of objects.

(i) A feather falls from a certain height inside a vacuum tube.
(ii) A box slides along a smooth horizontal surface at constant speed.
(iii) A steel ball falls through the air in the absence of air friction.

Which of the following describes UNIFORMLY ACCELERATED motion CORRECTLY?

A (i) and (ii) only
B (i) and (iii) only
C (ii) and (iii) only
D (i), (ii) and (iii) (2)

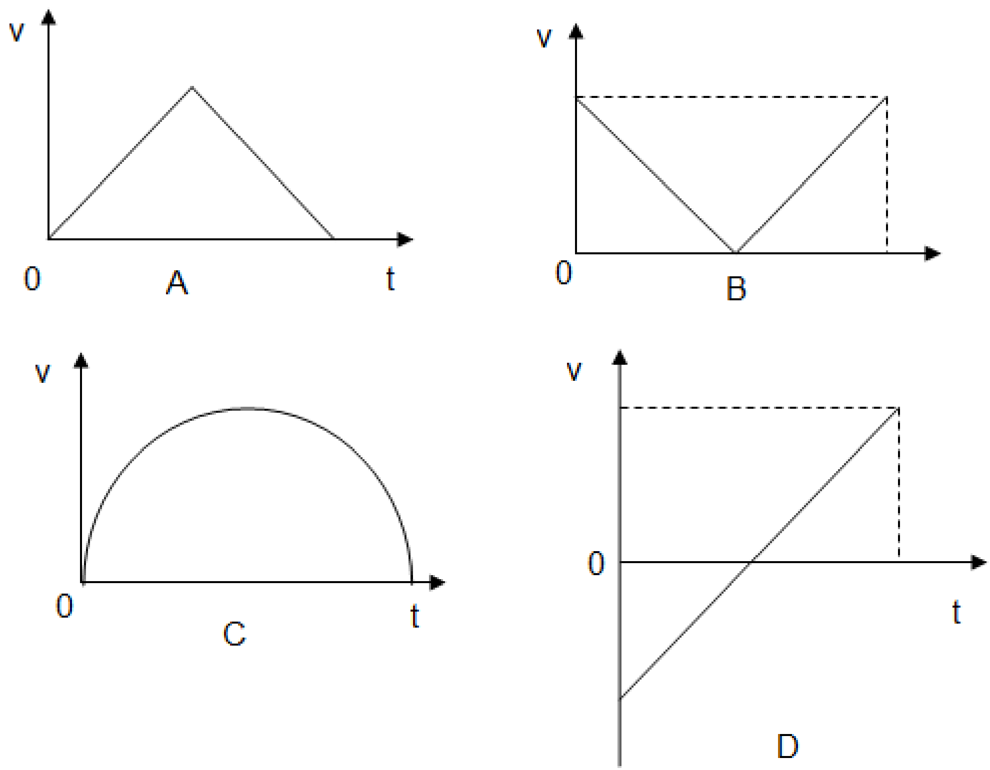
1.3 An object is thrown vertically upwards from the ground.

Which ONE of the following is CORRECT regarding the direction of the acceleration of the object as it moves upwards and then downwards? Ignore the effects of air resistance.

	OBJECT MOVING UPWARDS	OBJECT MOVING DOWNWARDS
A	Downwards	Upwards
B	Upwards	Downwards
C	Downwards	Downwards
D	Upwards	Upwards

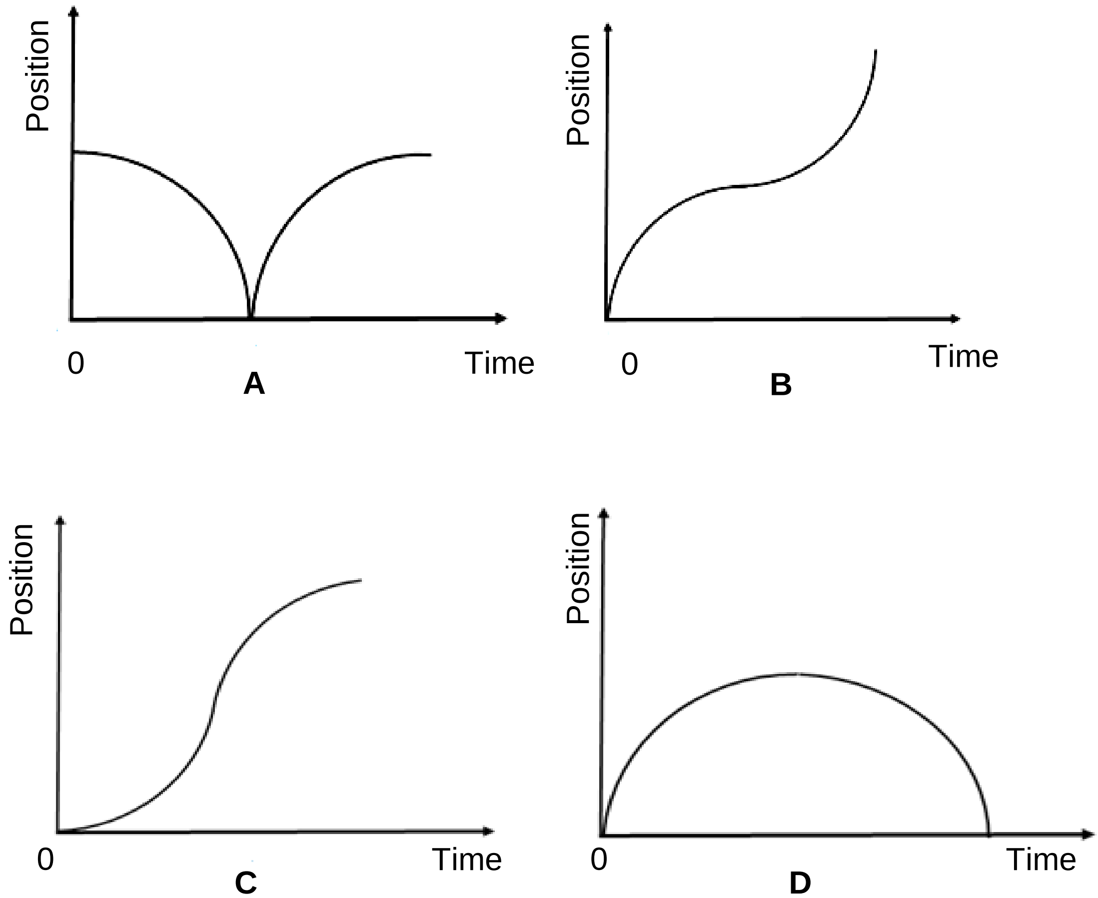
(2)

1.4 A boy throws a tennis ball vertically upwards, and after a time it returns to the boy's hands. Which ONE of the following velocity versus time graphs best represents the motion of the ball? Ignore air friction.



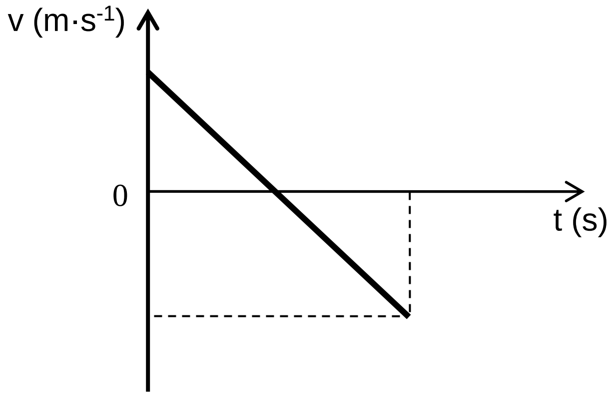
(2)

1.5 A ball dropped from a height, *h,* strikes the ground and bounces vertically upwards to its original height. Which ONE of the following position versus time graphs best represents the motion of the ball? Ignore the effects of air friction.



(2)

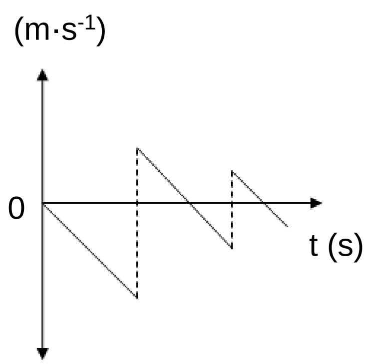
1.6 The velocity-time graph shows the motion of a ball which is thrown vertically upwards. Air friction is ignored.



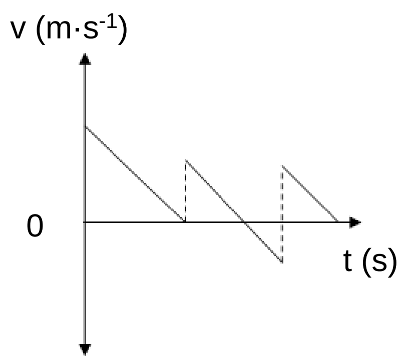
The area under the graph represents the…

A linear momentum of the ball.
B displacement of the ball.
C average velocity of the ball.
D acceleration of the ball. (2)

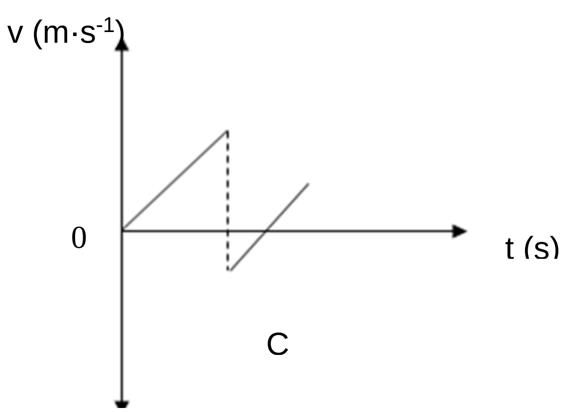
1.7 A ball is dropped from a height. Which ONE of the following velocity vs time graphs best represents the motion of the ball dropped and then bouncing vertically upwards twice?



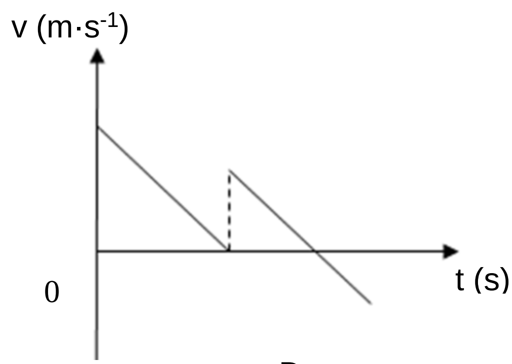
A



B



C



D (2)

1.8 A ball is thrown vertically upwards. Which ONE of the following quantities will be zero when it reaches maximum height?

A acceleration

B kinetic energy

C gravitational potential energy

D gravitational force (2)

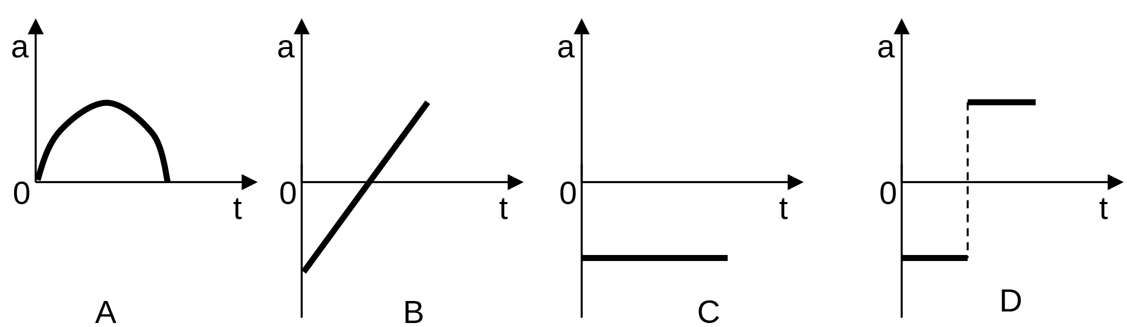
1.9 A ball is thrown vertically upwards at 9,8 $m \cdot s^{-1}$ and after 1 second it reaches the maximum height. Ignore air resistance.
Which ONE of the following statements regarding the acceleration and speed of the ball at the maximum height respectively are CORRECT?

	ACCELERATION OF THE BALL	**SPEED OF THE BALL**
A	Zero	Zero
B	9,8 $m \cdot s^{-2}$ upwards	9,8 $m \cdot s^{-1}$
C	9,8 $m \cdot s^{-2}$	9,8 $m \cdot s^{-1}$ Upwards
D	9,8 $m \cdot s^{-2}$ downwards	Zero

(2)

1.10 A ball is thrown vertically upwards. It takes 6 s to return to the thrower`s hand.

Which ONE of the following graphs can be used to represent the acceleration-time graph for the motion? Take up as positive.



(2)
[20]

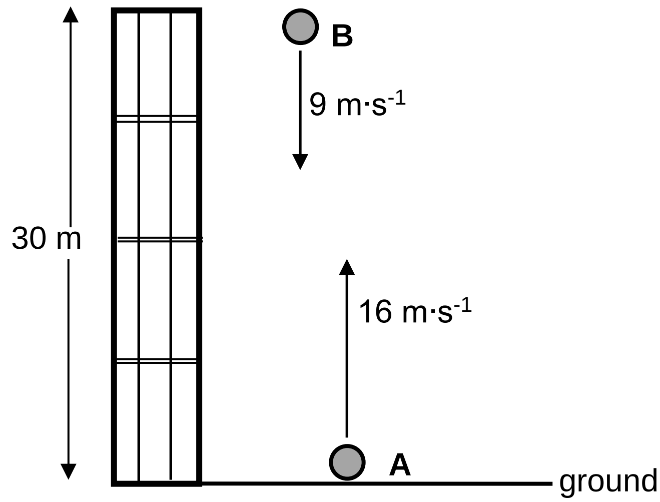
QUESTION 2 (DBE/November 2015)

Ball **A** is projected vertically upwards at a velocity of 16 $m \cdot s^{-1}$ from the ground. Ignore the effects of air resistance. **Use the ground as zero reference.**

2.1 Calculate the time taken by ball **A** to return to the ground. (4)

2.2 Sketch a velocity-time graph for ball **A**.
Show the following on the graph:
(a) Initial velocity of ball **A**
(b) Time taken to reach the highest point of the motion
(c) Time taken to return to the ground (3)

ONE SECOND after ball **A** is projected upwards, a second ball, **B**, is thrown vertically downwards at a velocity of 9 m·s^{-1} from a balcony 30 m above the ground. Refer to the diagram below.



2.3 Calculate how high above the ground ball **A** will be at the instant the two balls pass each other. (6)

[13]

QUESTION 3 (DBE/Feb.–Mar. 2016)

A man throws ball **A** downwards with a speed of 2 $m \cdot s^{-1}$ from the edge of a window, 45 m above a dam of water. One second later he throws a second ball, ball **B**, downwards and observes that both balls strike the surface of the water in the dam at the same time. Ignore air friction.

3.1 Calculate the:

3.1.1 Speed with which ball **A** hits the surface of the water (3)

3.1.2 Time it takes for ball **B** to hit the surface of the water (3)

3.1.3 Initial velocity of ball **B** (5)

phys

3.2 On the same set of axes, sketch a velocity versus time graph for the motion of balls **A** and **B**. Clearly indicate the following on your graph:

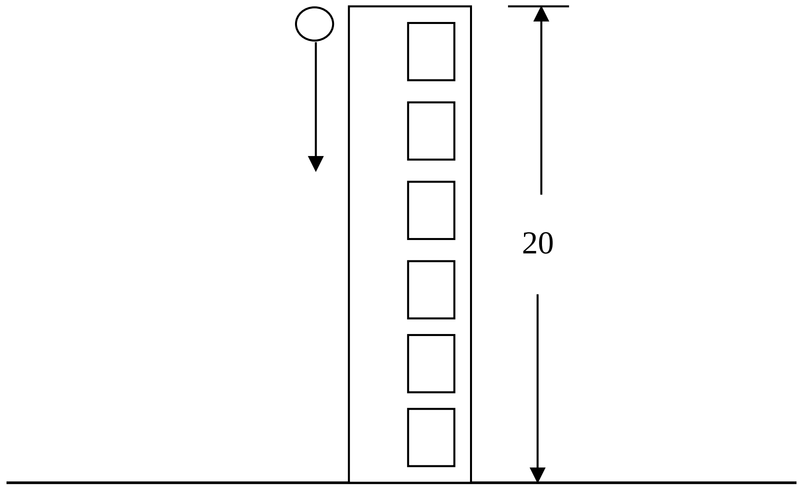
- Initial velocities of both balls **A** and **B**
- The time of release of ball **B**
- The time taken by both balls to hit the surface of the water

(5)
[16]

phys

QUESTION 4 (DBE/November 2016)

A ball is dropped from the top of a building 20 m high. Ignore the effects of air resistance.



4.1 Define the term *free fall*.

____

____ (2)

4.2 Calculate the:

4.2.1 Speed at which the ball hits the ground

(4)

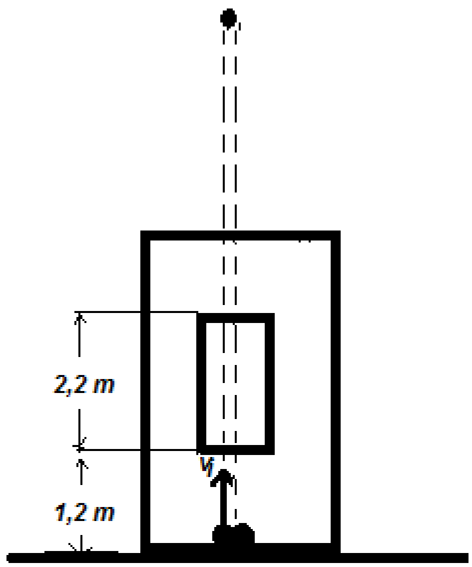
4.2.2 Time it takes the ball to reach the ground (3)

4.3 Sketch a velocity-time graph for the motion of the ball (no values required).

(2)
[11]

QUESTION 5

A ball is projected vertically upwards from the ground next to a building. The ball reaches maximum height above the ground before moving downwards. On its way down it passes a window 2,2 m high in the building in 0,2 s. The bottom of the window is 1,2 m above the ground. Ignore the effects of air friction.



5.1 Write down the acceleration of the ball at the maximum height. (2)

5.2 Write down the magnitude of the velocity of the ball at the maximum height. (1)

5.3 Calculate the velocity of the ball at the top of the window. (4)

5.4 Use equations of motion to calculate the initial speed of the ball. (4)

5.5 Calculate the time the ball takes to reach its maximum height above the ground.

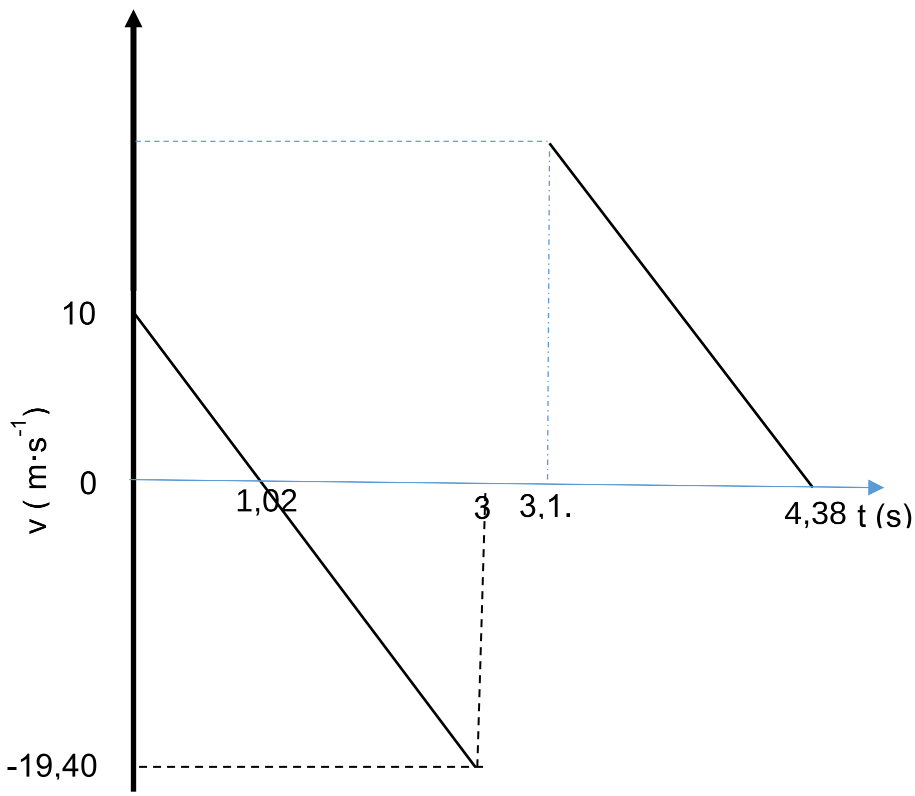
(3)

5.6 Sketch a velocity-time graph for the motion of the ball from the moment it was projected vertically upwards until it hits the ground for the first time. Indicate the respective time and velocity values on the graph. (3)

[17]

QUESTION 6

A ball is projected vertically upwards from the top edge of a building. The ball hits the ground after a time (*t*) and it is in contact with the ground for 0,1 s and then bounces vertically upwards reaching a maximum high (h) from the ground. (Air friction is being ignored)
The velocity-time graph below shows the motion of the ball during 4,38 s.



6.1. Why is the ball to be considered a projectile? (2)

____

____

6.2. What is the initial velocity of the ball? (2)

____

6.3. What is the velocity of the ball when it hits the ground? (2)

____

6.4. What is the physical quantity represented by the gradient of the graph? (1)

____

6.5. Calculate the:

6.5.1. Height of the building. (3)

6.5.2. Speed at which the ball leaves the ground. (3)

6.5.3. Maximum height reached by the ball after bouncing. (3)

6.6. Draw the position time graph for the projectile during 4,38 s. In your graph indicate the following:

- the position of the projectile at 1,02 s.
- the time the projectile reaches the projection point.
- position of the projectile at 4,38 s. (5)

[21]

QUESTION 7

Ball **A** is dropped from a height of 30 m at the same time as ball **B** is projected upwards at a speed of 20 m·s^{-1} from the ground below. The two balls pass each other after 1,5 s. Ignore the effect of air friction.

7.1 Calculate the velocity of **A** and **B** at the moment they pass each other. (5)

7.2. Sketch a velocity - time graph for ball **A** and **B**.

Show the following on the graph:

(a) Initial velocity of ball **A** and **B**.

(b) The velocity of the balls **A** and **B** at 1,5 s

(c) Time taken for the balls to pass each other (4)

phys

7.3 Calculate the displacement of ball **A** in 1,5 s. (3)

[12]

QUESTION 8

A ball is thrown vertically upwards with an initial velocity of 10 $m \cdot s^{-1}$. A photograph (shown) is taken when the ball is 1,5 m above the point of release. Ignore the effect of air friction.

8.1. Explain what is meant by a *projectile*. (2)

8.2. Calculate the time(s) when the ball will be at the position shown in the photograph. (4)

8.3. Calculate the position of the ball 0,1 s after it was thrown. (4)

[10]

QUESTION 9

Object **A** is dropped from a certain height and 5 s later object **B** is projected vertically downwards from the same height. Ignore air resistance.

9.1 Explain what is meant by a *projectile* in Physics. (2)

9.2 Use equations of motion to calculate the following:

9.2.1 Time taken by object **A** to reach a speed of 245 $m \cdot s^{-1}$ (3)

9.2.2 Initial velocity of object **B,** if object **A** has a velocity of 245 $m \cdot s^{-1}$ downwards when they meet. (4)

9.3 Sketch a velocity-time graph for object **B** from the moment it was projected until it reaches object **A**.
Indicate the following on the graph:

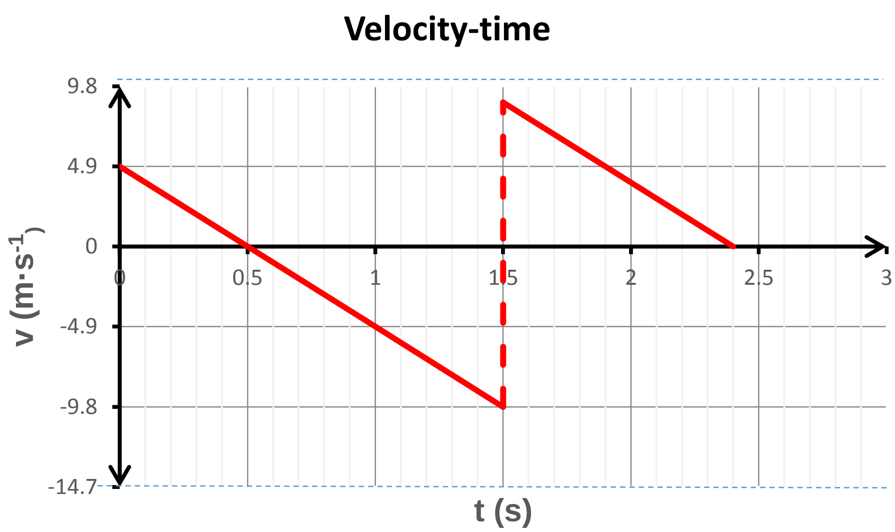
- Initial velocity
- Final velocity
- Time taken by object **B** to reach object **A**

(4)

[13]

QUESTION 10

A rubber ball is thrown vertically upwards from a balcony of a building. When the ball lands on the ground, it bounces vertically upwards. The velocity-time graph below represents the motion of the rubber ball.



10.1 Use the graph to determine :

10.4.1.1 Initial velocity of the ball. (1)

____

10.1.2 The time it takes for the ball to reach its maximum height once thrown upwards. (1)

____

10.1.3 The time at which the ball strikes the ground for the first time. (1)

____

10.2 Calculate the speed of the ball after 0,3 s of being thrown. (3)

10.3 The ball loses 10% of its velocity when it strikes the ground. Calculate the height to which the ball bounces after striking the ground. (5)

[11]

phys

TOPIC 1: MECHANICS

1.4. WORK, ENERGY AND POWER

Physical quantity						**Work-energy theorem and the principle of conservation of energy**	**Law of conservation of mechanical energy**
Work	**Kinetic energy**	**Potential energy**	**Mechanical energy**	**Power**	**Classification of forces**		
Work done by a constant force is defined as the *scalar quantity* equal to the *product of the force multiplied by the displacement* of the point of application of the force *by the cosine of the angle* formed by the line of action of the force and the direction of the displacement. $W = F\Delta x \cos\theta$ SI unit: **joule** [J]	**Kinetic energy** is the energy an object has due to its motion. $E_K = \frac{1}{2}mv^2$ SI unit: **joule** [J]	***Gravitational potential energy*** *is the energy an object has due to its position in a gravitational field relative to some reference point.* $E_p = mgh$ SI unit: **joule** [J]	**Total Mechanical energy** is equal to the sum of the gravitational potential energy plus the kinetic energy. $E_M = E_K + E_p$ SI unit: **joule** [J]	**Power** is the rate at which work is done or energy is expended. $P = \frac{W}{\Delta t}$ If the body possesses rectilinear uniform motion (v = constant), then: $P_{ave} = Fv_{ave}$ SI unit: **watt** [W]	**A conservative force** is a force for which the work done in moving an object between two points is independent of the path taken. Examples: gravitational force, electrostatic force and elastic force. **A non-conservative force** is a force for which the work done in moving an object between two points depends on the path taken. Examples: Frictional force, tension, etc	**Work- energy theorem: The work done by the resultant (net) force acting on an object is equal to the change in the kinetic energy of the object.** $W_{net} = \Delta E_K$ $W_{net} = E_{Kf} - E_{Ki}$ $W_{net} = W_c + W_{nc}$ Using the work- energy theorem: $W_c + W_{nc} = \Delta E_K$ But: $W_{cons} = -\Delta E_p$ $-\Delta E_p + W_{nc} = \Delta E_K$ Hence: $W_{nc} = \Delta E_K + \Delta E_p$ **This equation can be used to solve conservation of energy problems and is called the principle of conservation of energy.**	**Total mechanical energy in an isolated system remains constant (is conserved).** $E_{M(initial)} = E_{M(final)}$ ***In an isolated system, only conservative forces are acting.*** ***OR*** **The total mechanical energy of an object remains constant as the object moves, provided that the net work done by external non-conservative forces is zero.** $0 = \Delta E_K + \Delta E_p$

PROBLEM-SOLVING STRATEGY

STEP 1: MODEL. Draw a sketch of the situation if not given and identify which object(s) are parts of the system. Select the object(s) you will study and the environment. Some problems may need to be subdivided into two or more parts (scenarios).

STEP 2: VISUALIZE. Draw a free-body-diagram showing all the forces acting on the object(s). Identify the type of force (conservative or non-conservative).

STEP 3: SOLVE. Collect the data and write it in symbolic form. Select the equation, law (principle) or theorem you can apply to solve the problem.

- If the system is isolated and non-dissipative then the total mechanical energy is conserved:

$$E_{Ki} + E_{Pi} = E_{Kf} + E_{Pf} = E_M = constant$$

- If there are non-conservative forces acting (external or dissipative) then use equation:

$$W_{non-conservative} = \Delta E_K + \Delta E_p$$

- For both conservative and non-conservative forces acting, you can use the work energy theorem:

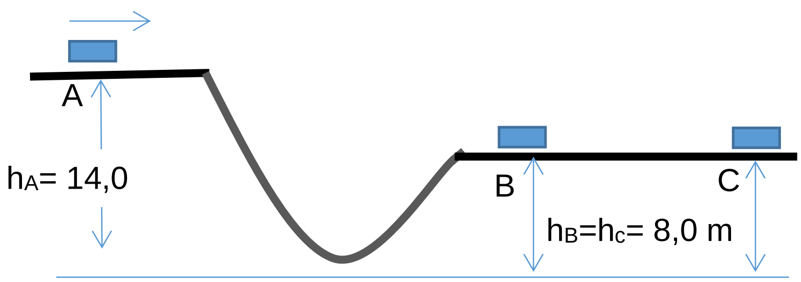
$$W_{net} = \Delta E_K$$

- Kinematics equations and some other laws could be needed for some problems.

STEP 4: ASSESS. Check that your result has the correct units, is reasonable and answers the question.

WORKED EXAMPLE

1. The sketch below shows a 2,0 kg block sliding from A to B along a frictionless surface. When the block reaches B, it continues to slide along a horizontal surface BC where a kinetic frictional force acts on the block. As a result, the block slows down, coming to rest at C. The kinetic energy of the block at A is 40,0 J, and the heights of A and B are 14,0 m and 8,0 m above the ground respectively.



1.1. Is the total mechanical energy of the block conserved as the block moves from A to B? Why or why not?

1.2. When the block reaches point B, has its kinetic energy INCREASED, DECREASED or REMAINED THE SAME? Provide a reason for your answer.

1.3. Calculate the speed of the block when it reaches B.

1.4. Is the total mechanical energy of the block conserved as the block slides from B to C? Justify your answer.

1.5. How much work does the kinetic frictional force do during the BC segment of the trip?

SOLUTION

STEP 1: MODEL

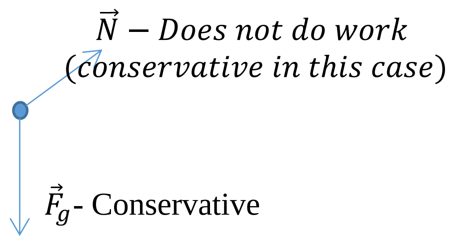
If there is a sketch of the situation then we do not need to draw it.
The block is interacting with the surface and the Earth.
System: Block- Surface- Earth
Object: Block
Enviroment: Earth and surface

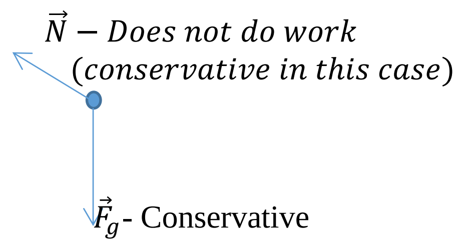
STEP 2: VISUALIZE

Free-body diagram
Part 1 (from A to B)

- Only two forces acting- gravitational force and normal force.
- From A to B only conservative forces acting then the system is isolated.

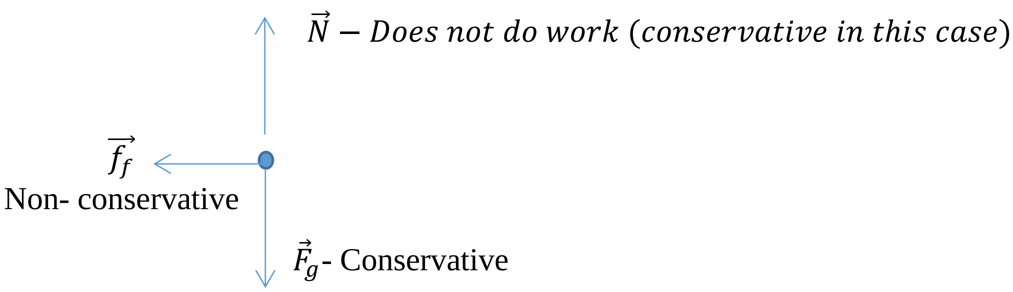
Moving down **Moving up**





Part 2 (from B to C)

- Sliding on a horizontal surface
- From B to C frictional force acting which is not conservative (system is not isolated)



STEP 3: SOLVE

<u>Data:</u>

m=2,0 kg
E_{KA}= 40 J
h_A= 14,0 m
h_B=h_c= 8,0 m
v_B-?
W_{ff}-?

1.1. The total mechanical energy is conserved if the net work done by the non-conservative forces is zero, or only conservative forces acting on the object, or W_{nc}= 0 J. Only two forces act on the block during its trip from A to B: the gravitational force which is conservative and the normal force which is conservative in this case. Thus we conclude that W_{nc}= 0 J, with the result that the total mechanical energy is conserved during the AB part of the trip.

1.2. As we have seen, the total mechanical energy is the sum of the kinetic and gravitational potential energy and remains constant from A to B. Therefore as one type of energy decreases, the other must increase for the sum to remain constant. Since B is lower than A, the gravitational potential energy at B is less than that at A. As a result, the kinetic energy at B must be greater than that at A.

1.3. From A to B total mechanical energy is conserved.

$$E_{Ki} + E_{Pi} = E_{Kf} + E_{Pf} = E_M = constant$$
$$E_{KA} + mgh_A = \frac{1}{2}\, mv_B^2 + mgh_B$$
$$E_{KA} + mgh_A = \frac{1}{2}\, mv_B^2 + mgh_B$$
$$40 + (2 \times 9{,}8 \times 14) = \frac{1}{2} \times 2 \times v_B^2 + (2 \times 9{,}8 \times 8)$$
$$40 + 274{,}4 = v_B^2 + 156{,}8$$
$$314{,}4 - 156{,}8 = v_B^2$$
$$v_B^2 = 157{,}6$$
$$v_B = \sqrt{157{,}6}$$
$$v_B = 12{,}55 \text{m·s}^{-1}$$

1.4. During the trip from B to C the frictional force acts on the block. This force is non-conservative, it does work on the block, consequently, the net work done by the non–conservative force is not zero ($W_{nc} \neq 0$), so the total mechanical energy is not conserved during this part of the trip.

1.5. During the BC part the total mechanical energy is not conserved because a kinetic frictional force is present.

$$W_{nc} = \Delta E_M$$
$$W_{nc} = \Delta E_K + \Delta E_p$$
$$W_{nc} = (E_{KC} - E_{KB} + mg(h_C - h_B)$$
$$W_{nc} = (\frac{1}{2}mv_C^2 - \frac{1}{2}mv_B^2 + mg(h_C - h_B)$$
$$W_{nc} = (\frac{1}{2}2 \times 0^2 - \frac{1}{2}2 \times (12{,}55)^2 + 2 \times 9{,}8 \times (8 - 8)$$
$$W_{nc} = 0 - (12{,}55)^2 + 0$$
$$W_{nc} = -157{,}50\, J$$

The work done by frictional force is –157,50 J because this force points in the opposite direction of the displacement.

ALTERNATIVE SOLUTION

Applying the work energy theorem:

$$W_{net} = \Delta E_K$$
$$W_{ff} + W_{Fg} + W_N = (E_{KC} - E_{KB})$$
$$W_{ff} + mgcos\, 90^0 + Ncos 90^0 = (\frac{1}{2}mv_C^2 - \frac{1}{2}mv_B^2)$$
$$W_{ff} + 0 + 0 = (\frac{1}{2}2 \times 0^2 - \frac{1}{2}2 \times (12{,}55)^2$$
$$W_{nc} = 0 - (12{,}55)^2$$
$$W_{nc} = -157{,}50\, J$$

The work done by frictional force is –157,50 J because this force points in the opposite direction of the displacement.

STEP 4: ***ASSESS***

The result has the correct units for speed (m·s^{-1}) and for work (J).

$$W_{nc} = [Kg \cdot m^2 \cdot s^{-2}] = J$$

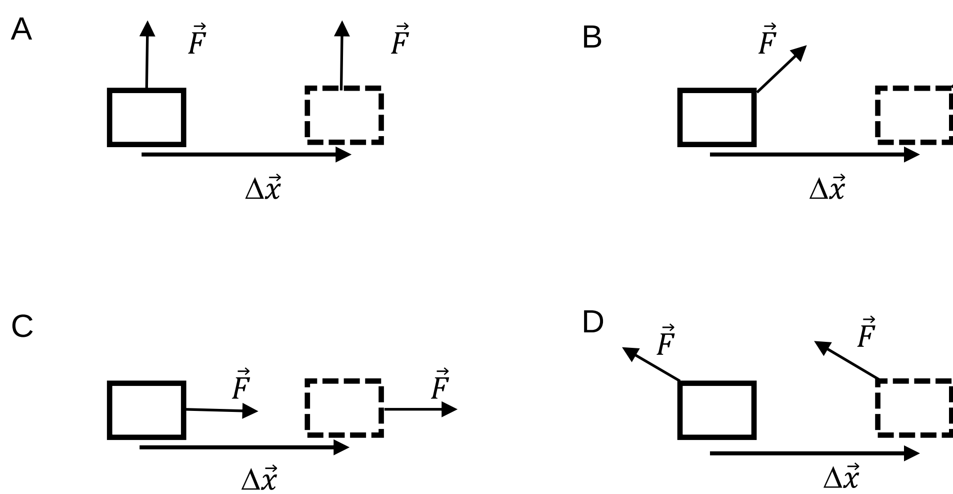
The result is reasonable and answers the questions.

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 The sketches below shows a block that moves to the right in the positive x-direction through the displacement Δx while under the influence of a force with the same magnitude F. In which of the cases will the amount of work done by the force $\vec{F}$ be the greatest?



(2)

1.2 A boy, of mass *m,* jumps from a tree branch at the same time that a girl, also of mass *m,* begins her descent down a frictionless slide. If they both start at the same height above the ground, which of the following is true about their kinetic energies as they reach the ground?

A Boy's kinetic energy is greater than girl's.

B Girl's kinetic energy is greater than Boy's.

C They have the same kinetic energy.

D The answer depends on the shape of the slide. (2)

1.3 The kinetic energy of a car moving at constant speed v is E_K. The speed of the car changes to $\frac{1}{2}v$. What is the new kinetic energy of the car?

A $\frac{1}{4}\ E_K$

B $\frac{1}{2}\ E_K$

C $2\ E_K$

D $4\ E_K$ (2)

1.4 A car with mass m moves at a constant velocity v and covers a distance Δx under the action of a constant frictional force f. The power required to keep the body in motion at this constant velocity is …

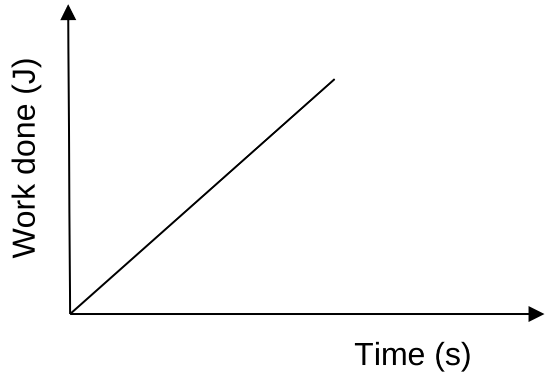
A $f\,\Delta x$.

B $f\,v$.

C $\frac{1}{2}mv^2$.

D $f\,\Delta t$. (2)

1.5 The graph below represents the relationship between the work done on an object and the time taken for this work to be done.



The gradient of the graph represents the …

A Acceleration.

B linear momentum.

C impulse.

D power. (2)

1.6 The work done by a constant force F applied to an object to increase the object's speed from v to $2v$ is W.

The work done by the same force to increase the speed of the object from 0 to v will be ...

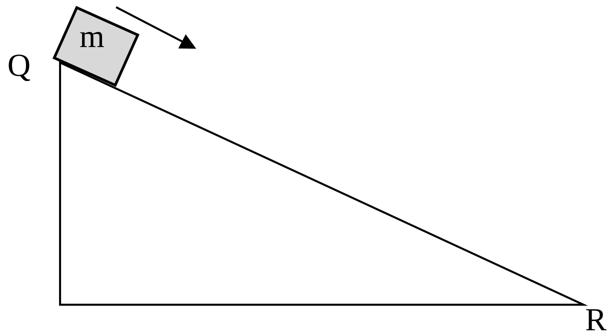
A ⅓W

B ½W

C 2W

D 3W (2)

1.7 A block of mass m is released from rest from the top of a frictionless inclined plane **QR**, as shown below.
The total mechanical energy of the block is E_Q at point **Q** and E_R at point **R**. The kinetic energy of the block at points **Q** and **R** is K_Q and K_R respectively.

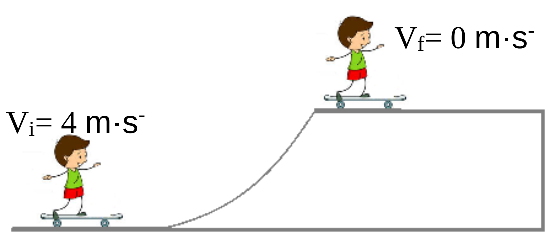


Which ONE of the statements regarding the total mechanical energy and the kinetic energy of the block at points **Q** and **R** respectively is CORRECT?

	TOTAL MECHANICAL ENERGY E	**KINETIC ENERGY** K
A	$E_Q > E_R$	$K_Q = K_R$
B	$E_Q = E_R$	$K_Q < K_R$
C	$E_Q = E_R$	$K_Q = K_R$
D	$E_Q < E_R$	$K_Q > K_R$

(2)

1.8 A skateboarder moves on a frictionless track that rises from one level to another. If the skateboarder's initial speed is 4 m·s^{-1}, the skateboarder just makes it to the upper level and comes to rest.



With an initial speed of 5 m·s^{-1}, the skateboarder will move to the right on the upper level with a final speed of …

A 1 m·s^{-1}.
B 2 m·s^{-1}.
C 3 m·s^{-1}.
D 4 m·s^{-1}. (2)

1.9 To lift a car with a hydraulic lift at a service station at constant speed requires work to be done. Lifting the car twice as high requires...

A twice the work done but the same power.

B twice the work done and half of the power.

C the same amount of work but twice the power.

D half of the work done and half of the power. (2)

1.10 A ball is dropped from rest, in the absence of air friction, from a height h with mechanical energy equal to E. When the ball reaches a height ⅓ h, the kinetic energy of the ball will be …

A $\frac{1}{3}E$

B $\frac{2}{3}E$

C E

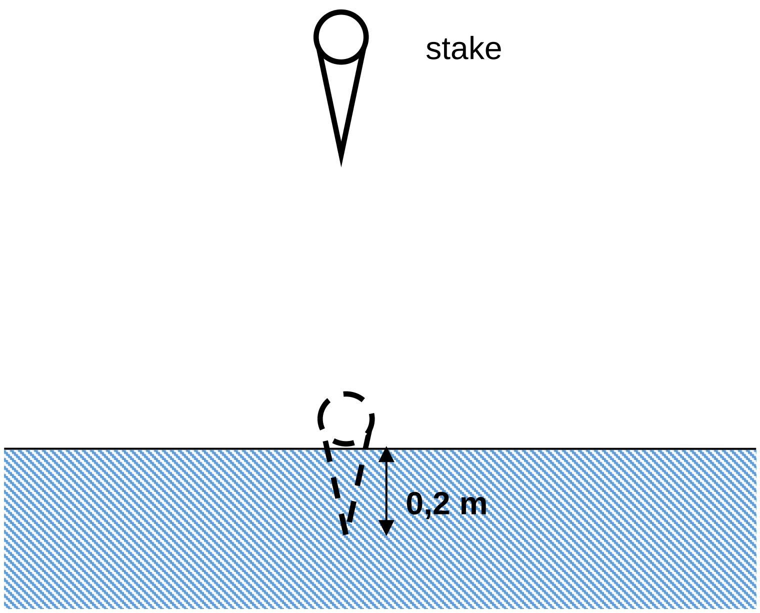
D $\frac{3}{2}E$ (2)

---

[20]

QUESTION 2

A stake of mass 1 kg falls from rest without rotating from a height of 240 m above the ground and penetrates into the ground a distance of 0,2 m. Ignore air resistance.



2.1 State the *principle of conservation of mechanical energy* in words: (2)

____

____

2.2 Is the resistance force exerted by the ground on the stake conservative or non-conservative?

Give a reason for the answer (2)

____

____

____

2.3 Calculate the work done by the gravitational force. (3)

2.4 Use the principle of conservation of mechanical energy to calculate the speed at which the stake hits the ground. (4)

2.5 State the work-energy theorem in words. (2)

____

____

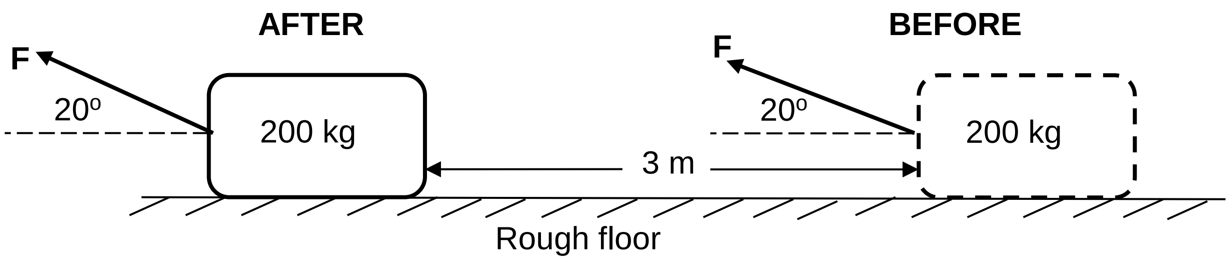
2.6 Use energy principles to calculate the resistance force of the ground on the stake. (5)

[18]

phys

QUESTION 3 (DBE/Feb.–Mar. 2016)

A constant force **F**, applied at an angle of 20° above the horizontal, pulls a 200 kg block, over a distance of 3 m, on a rough, horizontal floor as shown in the diagram below.



The coefficient of kinetic friction, μ_k, between the floor surface and the block is 0,2.

3.1 Give a reason why the coefficient of kinetic friction has no units.

____

____ (1)

3.2 State the work-energy theorem in words.

____

____ (2)

3.3 Draw a free-body diagram indicating ALL the forces acting on the block while it is being pulled. (4)

3.4 Show that the work done by the kinetic frictional force (W_{fk}) on the block can be written as W_{fk} = (-1 176 + 0,205 **F**) J. (4)

3.5 Calculate the magnitude of the force **F** that has to be applied so that the net work done by all forces on the block is zero. (4)

[15]

QUESTION 4

A 1×10^3 kg elevator car carries a maximum load of 8×10^2 kg. A constant frictional force of 4×10^3 N retards its motion upward. The elevator is lifted at constant speed of $3\ m \cdot s^{-1}$.

4.1 Define *power* in words (2)

4.2 Which one of the forces acting on the elevator is a conservative force? Give a reason for the answer. (2)

4.3 Calculate the power delivered by the motor to lift the fully loaded elevator. (6)

[10]

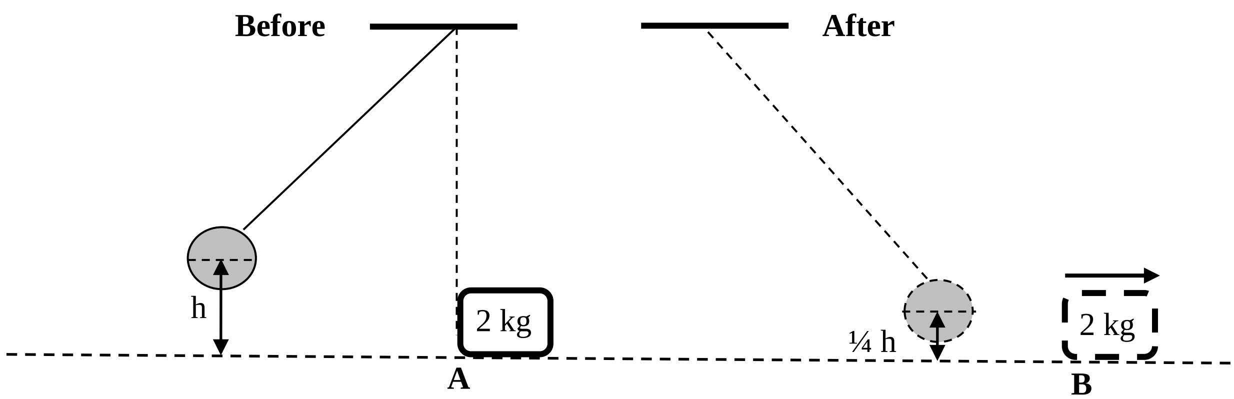
phys

QUESTION 5 (DBE/November 2016)

A pendulum with a bob of mass 5 kg is held stationary at a height h metres above the ground. When released, it collides with a block of mass 2 kg which is stationary at point **A**.

The bob swings past **A** and comes to rest momentarily at a position ¼ h above the ground.

The diagrams below are NOT drawn to scale.



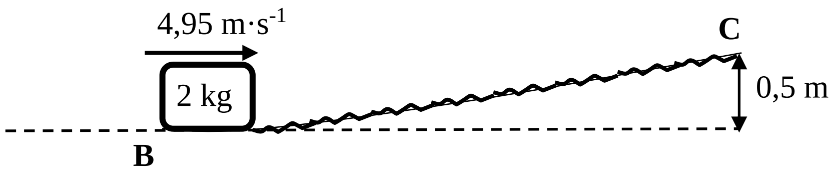
Immediately after the collision the 2 kg block begins to move from **A** to **B** at a constant speed of 4,95 $m \cdot s^{-1}$.
Ignore frictional effects and assume that no loss of mechanical energy occurs during the collision.

5.1 Calculate the:

5.1.1 Kinetic energy of the block immediately after the collision (3)

5.1.2 Height h (4)

The block moves from point **B** at a velocity of 4,95 $m\cdot s^{-1}$ up a rough inclined plane to point **C**. The speed of the block at point **C** is 2 $m\cdot s^{-1}$. Point **C** is 0,5 m above the horizontal, as shown in the diagram below.
During its motion from **B** to **C** a uniform frictional force acts on the block.



5.2 State the work-energy theorem in words.

____

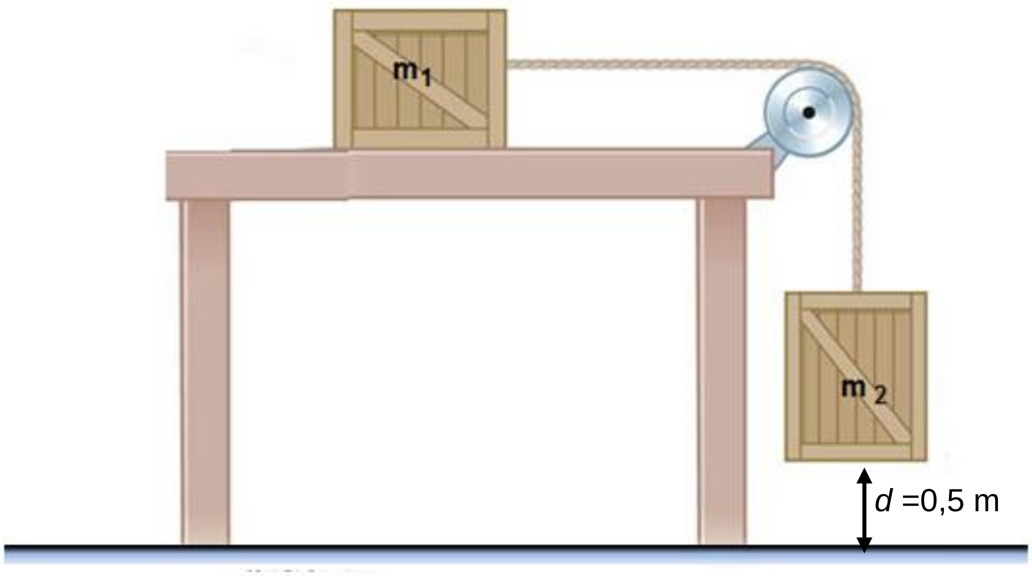
____ (2)

5.3 Use energy principles to calculate the work done by the frictional force when the 2 kg block moves from point **B** to point **C**. (4)

[13]

QUESTION 6

A block of mass, m_1 = 2,40 kg is connected to a second block of mass, m_2 = 1,80 kg as shown below. When the blocks are released from rest, they move through a distance d = 0,5 m at which point m_2 hits the floor. When block 2 hits the ground the speed of the blocks is 0,95 m·s^{-1}.



6.1 Gravitational force is a conservative force. Define the term *conservative force*.

____

____ (2)

6.2 Is the work done on block 2 by the tension force of the rope positive, negative or zero? Give a reason for the answer.

____

____

____ (2)

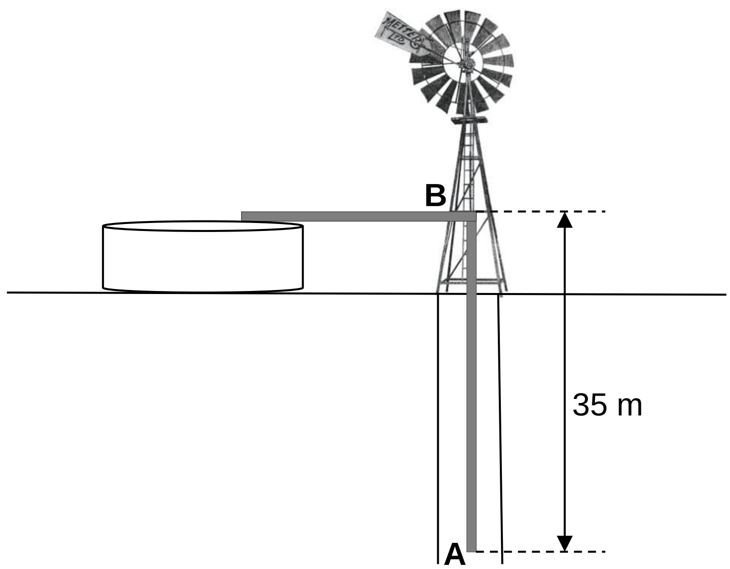
6.3 Use energy principles to calculate the coefficient of kinetic friction between block 1 and the horizontal surface. (5)

[9]

phys

QUESTION 7 (MP September 2015) ADAPTED

A windmill on a farm is used to pump stationary water, from point **A**, in a well. The water flows past point **B**, 35 m above point **A**, at a speed of 2,1 $m \cdot s^{-1}$.



7.1 Define the term *non-conservative force*.

____

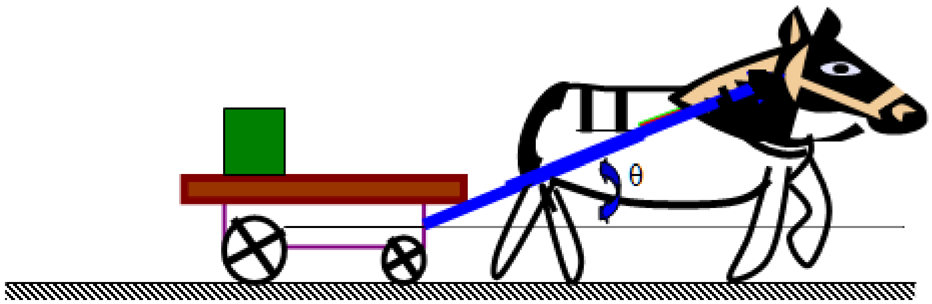
____ (2)

7.2 Calculate the maximum power delivered by the windmill if 87 kg water is pumped from the well per minute. (5)

[7]

QUESTION 8

A donkey pulls a cart of mass 600 kg from rest along a horizontal road. The donkey applies a constant force of magnitude 191,7 N at an angle of 30° to the horizontal. The cart accelerates and reaches a speed of 3 $m.s^{-1}$ in 5 minutes. The average frictional force that acts on the cart is 160,02 N. Neglect the effect of the rotation of the wheels of the cart.



8.1 State the *Work Energy- Theorem* in words.

____

____ (2)

8.2 Use the WORK ENERGY-THEOREM to calculate the distance covered by the cart in 5 minutes.

(5)

8.3 Calculate the power developed by the donkey in 5 minutes.

(3)

The donkey now applies a force of the same magnitude during the same time and the same distance, but at a SMALLER ANGLE to the horizontal, on the cart.

8.4 How does the power developed by the donkey now compare to the power developed by the donkey in QUESTION 8.3? Write down only GREATER THAN, SMALLER THAN or EQUAL TO.

Give a reason for the answer. (No calculations are required.)

___

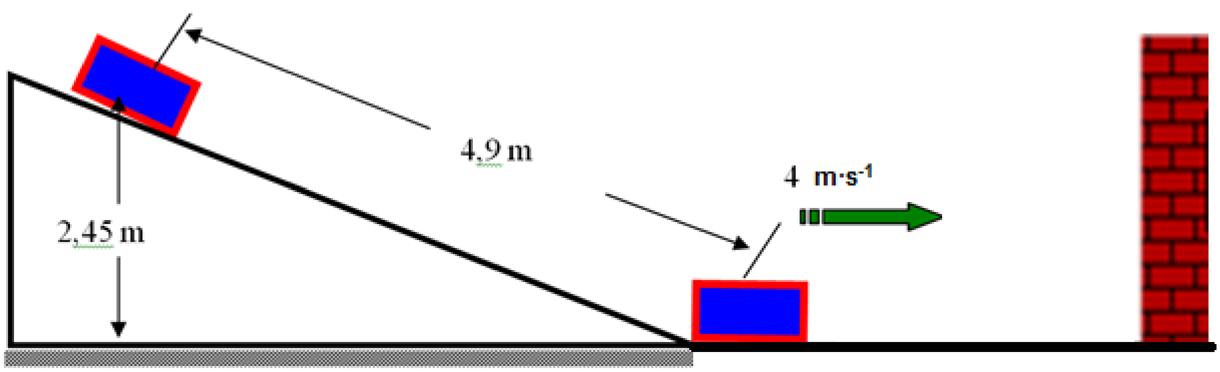
___

___ (2)

[12]

QUESTION 9

The sketch bellow shows a rigid block of 20 kg that is released from rest at a height of 2,45 m and moves downwards on an inclined plane, It reaches the base of the inclined plane with a speed of 4 $m \cdot s^{-1}$.



9.1 Draw a free-body diagram to show ALL the forces acting on the block **while it slides down the inclined plane.**

9.2 Is the mechanical energy conserved? Explain.

___

___

9.3 Calculate the work done by the frictional force and its magnitude if the length of the plane is 4,9 m.

9.4 Calculate the magnitude of the frictional force.

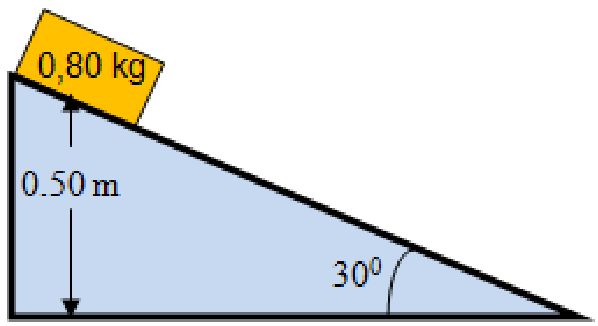
9.5 Calculate the work done by the net force applying WORK-ENERGY THEOREM.

9.6 The block moves on the horizontal frictionless surface and collides with a wall and comes to rest against the wall.

9.6.1 Calculate the change in kinetic energy of the block.

QUESTION 10

A block **A** of mass 0,80 kg with initial speed of 2 m·s^{-1} slides down a 30,0° hill from a vertical high of 0,50 m as shown in the sketch below. The coefficient of friction between the block and the surface of the hill is 0,737.



10.1 Draw a free body diagram to show all the forces acting on the block. (3)

10.2 Calculate the magnitude of the frictional force that acts on the block. (3)

10.3 State the WORK ENERGY- THEOREM in words. (2)

____

____

10.4 Use the WORK ENERGY- THEOREM to determine the distance the block slides down the hill. (5)

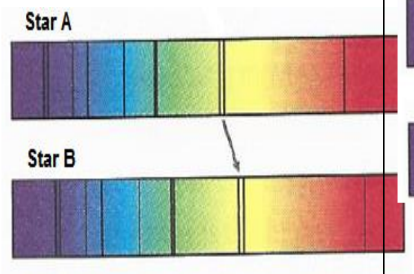
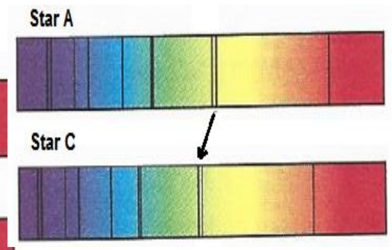
10.5 Now another block **B** is placed on block **A**. The system slides down with initial speed of 2 $m \cdot s^{-1}$. How will the distance covered by the system of blocks compare to the distance calculated in QUESTION 10.4? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. Show how you arrived to your answer. (3)

[16]

phys

TOPIC 2: WAVE SOUND AND LIGHT

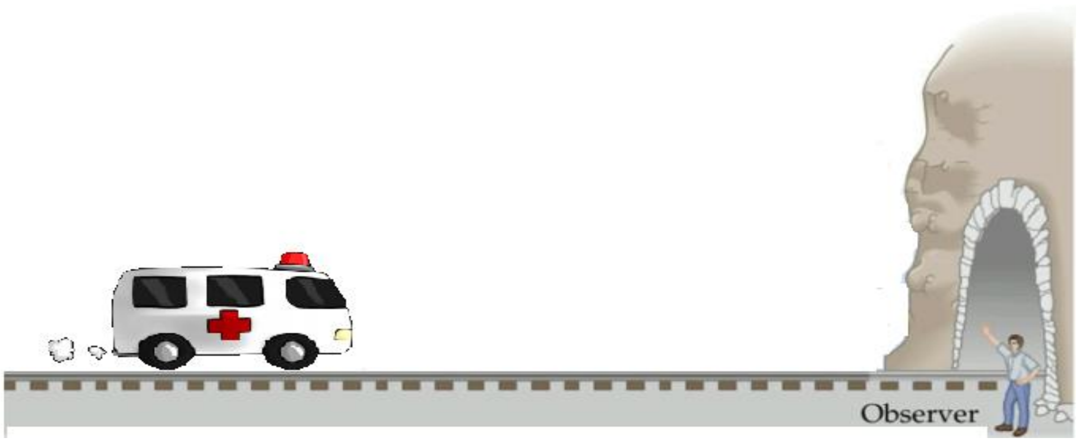
2.1. DOPPLER EFFECT

DOPPLER EFFECT				
Sound			Light	
Theory(DEFINITION)	**Equations**	**Applications**	**Red shift**	**Blue shift**
The *Doppler effect* is a change in frequency (or pitch) of sound detected by a listener because the sound source and the listener have different velocities relative to the medium of sound propagation. The frequency heard by the observer is higher than the frequency of the source when the source moves towards the observer and lower when the source moves away from the observer.	$f_L = \left(\frac{v \pm v_L}{v \pm v_s}\right) f_s$ where $v = f\lambda$ For a stationary listener $f_L = \left(\frac{v}{v \pm v_s}\right) f_s$ For a stationary source $f_L = \left(\frac{v \pm v_L}{v}\right) f_s$ For a source moving: • away $(v + v_s)$ • *towards* $(v - v_s)$ *Listener moving:* • *towards* $(v + v_L)$ • *away* $(v - v_L)$	• To find the rate of blood flow (Doppler scanning) • To see the unborn child (ultrasound scanning) • To hear the heartbeat of a foetus (ultrasound scanning)	If the light source is moving away from the observer (positive velocity), then the observed frequency is lower and the observed wavelength is greater (**red-shift**).  Red shifts are evidence that the Universe is expanding.	If the source is moving towards the observer (negative velocity), the observed frequency is higher and the wavelength is shorter (**blue-shift**). 

EXAMPLE

QUESTION 1

An ambulance approaches a tunnel in a mountain at a constant speed of 20 m·s^{-1}. The siren of the ambulance emits sound waves having a wavelength of 0,30 m. Take the speed of sound in air as 340 m·s^{-1}.



1.1 State the *Doppler effect* in words. (2)

1.2 Calculate the frequency of the sound waves emitted by the siren as heard by the ambulance's driver. (3)

1.3 Calculate the frequency of the sound waves heard by an observer standing near the tunnel entrance. (4)

1.4 How would the answer to QUESTION 7.3 change if the speed of the ambulance were GREATER THAN 20 m·s^{-1}? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

1.5 The sound from the siren reflects from the mountain back to the ambulance driver. Calculate the frequency heard by the ambulance driver. (3)

1.6 Write down ONE application of the Doppler Effect in medicine. (1)

[14]

SOLUTION
QUESTION 1

1.1 Doppler effect is the change in frequency (or pitch) of the sound detected by a listener ✓because the sound source and the listener have different velocities relative to the medium of sound propagation✓.
OR
The change in the observed frequency ✓when there is relative motion between the source and the observer.✓ (2)

1.2

$v = f\lambda$ ✓

$\underline{340 = f(0{,}30)}$✓

$f_s = 1\,133{,}33\text{ Hz}$ ✓ (3)

1.3 **OPTION 1**

$f_L = \left(\frac{v \pm v_L}{v \pm v_s}\right) f_s$✓ OR/*OF* $f_L = \left(\frac{v}{v \pm v_s}\right) f_s$

$f_L = \left(\frac{340}{340 - 20}\right)$ ✓1133,33✓

$f_L = 1204{,}16\text{ Hz}$✓

OPTION 2

$f_L = \frac{f_s}{1 - \frac{v_s}{v}}$ ✓

$f_L = \frac{1133{,}33}{1 - \frac{20}{340}}$ ✓ ✓

$f_L = 1204{,}16\text{ Hz}$✓

(4)

1.4 Increases ✓ (1)

1.5 $f_L = \left(\frac{v \pm v_L}{v \pm v_s}\right) f_s$ OR/OF $f_L = \left(\frac{v \pm v_L}{v}\right) f_s$

$f_L = \left(\frac{340 + 20}{340}\right)$ ✓1204,16✓

$f_L = 1274.99\text{ Hz}$✓

OR

$f_L = \left(1 + \frac{v_s}{v}\right) f_s$

$f_L = \left(1 + \frac{20}{340}\right)$✓$1204{,}16$✓

$f_L = 1274{,}99\ \text{Hz}$✓ (3)

7.6 **ANY ONE**✓

- It is used (in flow meters) in medical science to measure:
  - the speed and direction (velocity) of blood flow.
  - movement of the heart of a foetus.
- To find the rate of blood flow (Doppler scanning)
- To see the unborn child (Ultra sound scanning)
- To hear the heart of a foetus (Ultra sound scanning)
- It is used in medical sonography to generate images (and sounds) of flowing blood.
- To detect blood clotting (Doppler ultrasound test)

(1)

[14]

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 Light reaching the Earth from a galaxy moving away is shifted towards …

A greater velocities.

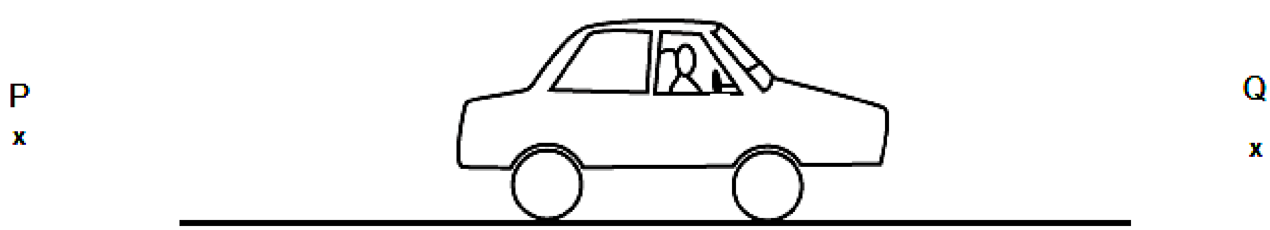
B higher frequencies.

C longer wavelengths.

D shorter wavelengths.

(2)

1.2 The diagram below shows the positions of two stationary listeners, **P** and **Q**, relative to a car moving at a constant velocity towards listener **Q**. The hooter on the car emits sound. Listeners **P** and **Q** and the driver all hear the sound of the hooter.

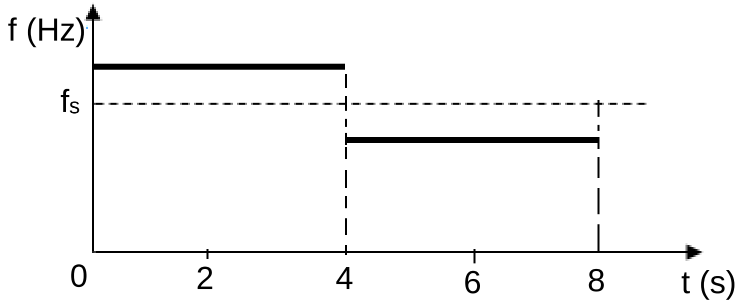


Which ONE of the following CORRECTLY describes the frequency of the sound heard by **P** and **Q**, *compared to that heard by the driver*?

	FREQUENCY OF THE SOUND HEARD BY P	FREQUENCY OF THE SOUND HEARD BY Q
A	Lower	Higher
B	Higher	Higher
C	Lower	Lower
D	Higher	Lower

(2)

1.3 The graph below represents the frequency of the siren of a police car observed by a stationary person standing next to the road.



Which ONE of the following describes the variation in the pitch (frequency) as observed by the person? The police car moves...

A towards the listener at constant speed and reaches him at 4 s. It then stops its motion.

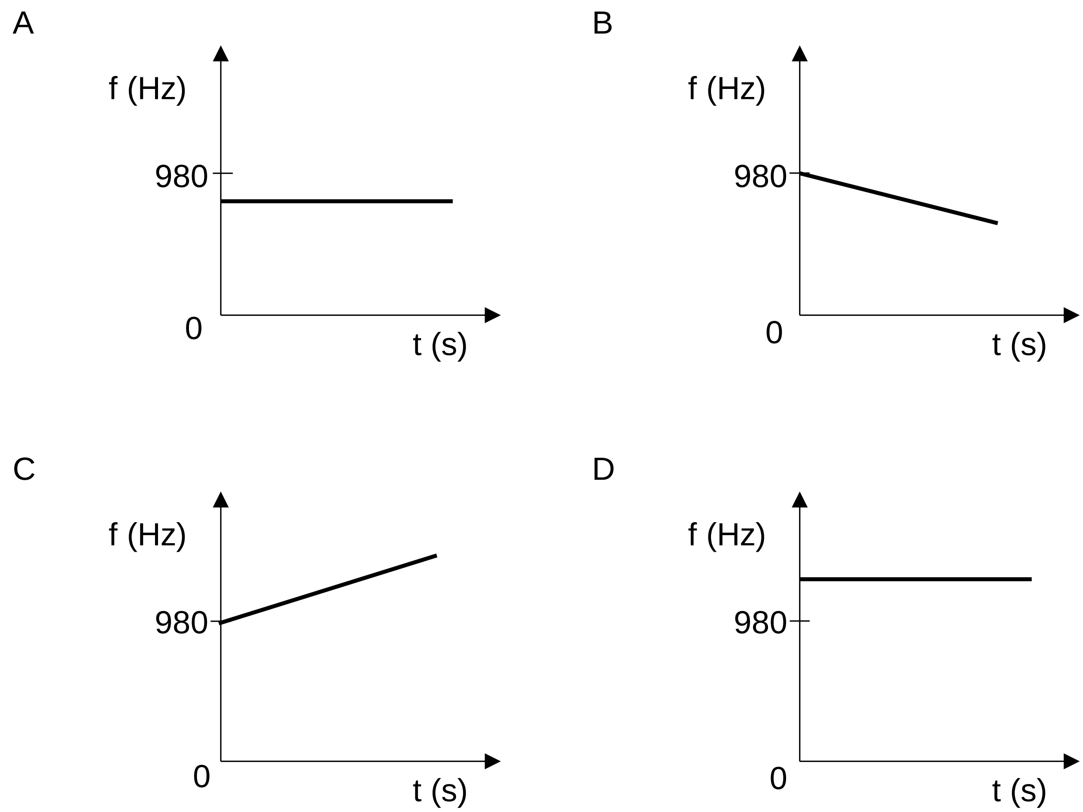
B away from the listener at constant speed. It reverses direction at 4 s and moves toward the listener at constant speed.

C towards the listener at constant speed and passes the listener at 4 s. It then moves away from the listener at the same constant speed.

D away from the listener at constant speed. It then decreases its speed at 4 s. (2)

1.4 An ambulance approaches an accident scene at a constant speed of 22,67 $m \cdot s^{-1}$. The siren of the ambulance emits sound waves at a frequency of 980 Hz. A stationary detector at the scene measures the frequency of the emitted sound waves.

Which ONE of the following frequency-time graphs shows the frequency measured by the detector?



(2)

1.5 The hooter of a vehicle travelling at constant speed towards a stationary observer, produces sound waves of frequency 400 Hz. Ignore the effects of wind. Which ONE of the following frequencies, in hertz, is most likely to be heard by the observer?

A 400

B 350

C 380

D 480 (2)

1.6 A listener moves at constant velocity towards a stationary source of sound. The frequency of the sound heard by the listener is higher than the frequency of the sound emitted by the source, because…

A The wavelength observed by the listener becomes shorter.

B More wave fronts reach the listener per second.

C The wavelength observed by the listener becomes longer.

D Less wave fronts reach the listener per second (2)

1.7 Which ONE of the statements below about the Doppler effect is CORRECT?

A The Doppler effect can be used to explain the expanding universe.

B The Doppler effect is only applicable to sound waves.

C A stationary listener hears a lower pitch of the sound from a siren of an approaching vehicle because of the Doppler effect.

D Electrons are ejected from a metal surface by means of the Doppler effect. (2)

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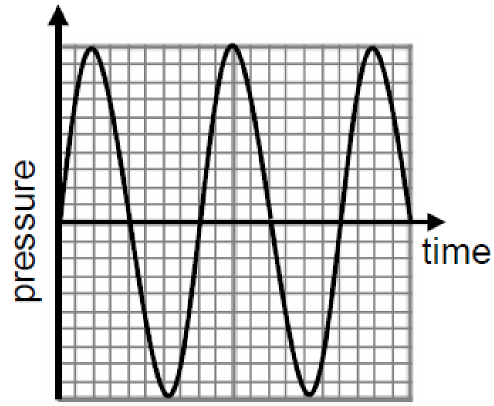
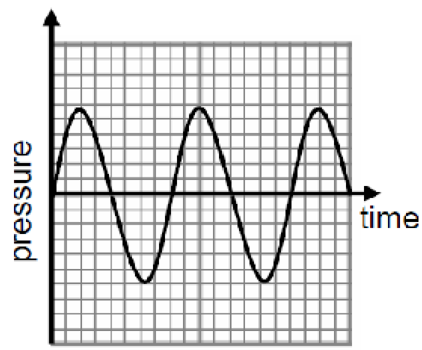
phys

1.8 The pressure versus time graph below represents a sound wave in air emitted by a stationary source.

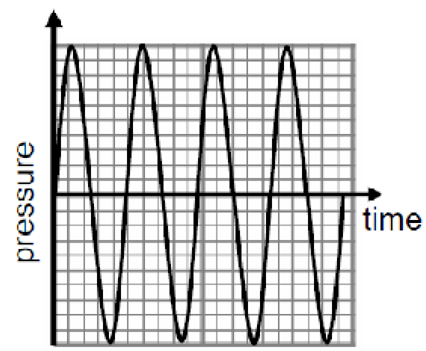


Which ONE of the following graphs best represents the sound wave, as observed by a stationary observer, if the source is moving towards the observer?

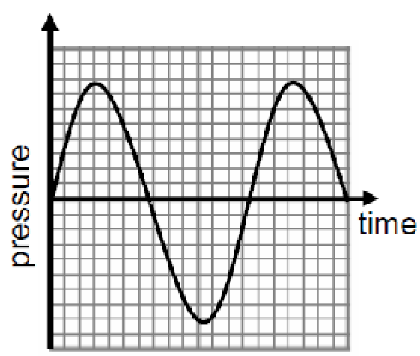
A



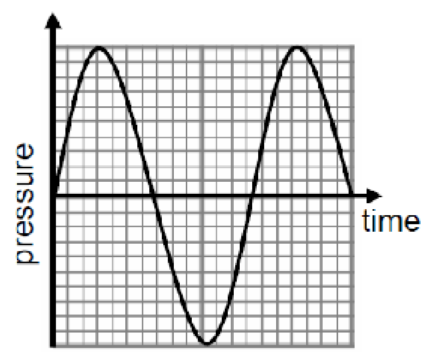
B



C



D



(2)

1.9 The wavelengths of light emitted by a distant star appear shorter when observed from Earth. From this we can conclude that the star is …

A moving towards Earth and the light is blue shifted.

B moving towards Earth and the light is red shifted.

C moving away from Earth and the light is red shifted.

D moving away from Earth and the light is blue shifted.

(2)

1.10 A police car, with its siren on, is travelling at a constant speed TOWARDS a stationary sound detector. The siren emits sound waves of frequency *f* and speed *v*.

Which ONE of the following combinations best describes the frequency and speed of the detected sound waves?

	FREQUENCY	SPEED
A	Less than *f*	*v*
B	Less than *f*	Less than *v*
C	Greater than *f*	Less than *v*
D	Greater than *f*	*v*

(2)

[20]

(

QUESTION 2 (DBE/November 2015)

2.1 The data below was obtained during an investigation into the relationship between the different velocities of a moving sound source and the frequencies detected by a stationary listener for **each** velocity. The effect of wind was ignored in this investigation.

Experiment number	1	2	3	4
Velocity of the sound source ($m \cdot s^{-1}$)	0	10	20	30
Frequency (Hz) of the sound detected by the stationary listener	900	874	850	827

2.1.1 Write down the dependent variable for this investigation. (1)

____

2.1.2 State the Doppler effect in words. (2)

____

____

____

____

2.1.3 Was the sound source moving TOWARDS or AWAY FROM the listener? Give a reason for the answer.

____

____ (2)

2.1.4 Use the information in the table to calculate the speed of sound during the investigation. (5)

2.2 The spectral lines of a distant star are shifted towards the longer wavelengths of light. Is the star moving TOWARDS or AWAY FROM the Earth? (1)

____

[11]

QUESTION 3 (DBE/Feb.–Mar. 2016)

Reflection of sound waves enables bats to hunt for moths. The sound wave produced by a bat has a frequency of 222 kHz and a wavelength of 1,5 x 10^{-3} m.

3.1 Calculate the speed of this sound wave through the air. (3)

3.2 A stationary bat sends out a sound signal and receives the same signal reflected from a moving moth at a frequency of 230,3 kHz.

3.2.1 Is the moth moving TOWARDS or AWAY FROM the bat? (1)

____

3.2.2 Calculate the magnitude of the velocity of the moth, assuming that the velocity is constant. (6)

[10]

phys

QUESTION 4 (DBE/November 2016)

4.1 An ambulance is moving towards a stationary listener at a constant speed of 30 m·s^{-1}. The siren of the ambulance emits sound waves having a wavelength of 0,28 m. Take the speed of sound in air as 340 m·s^{-1}.

4.1.1 State the Doppler effect in words. (2)

4.1.2 Calculate the frequency of the sound waves emitted by the siren as heard by the ambulance driver. (3)

4.1.3 Calculate the frequency of the sound waves emitted by the siren as heard by the listener. (5)

4.1.4 How would the answer to QUESTION 4.1.3 change if the speed of the ambulance were LESS THAN 30 m·s^{-1}? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

4.2 An observation of the spectrum of a distant star shows that it is moving away from the Earth.
Explain, in terms of the frequencies of the spectral lines, how it is possible to conclude that the star is moving away from the Earth. (2)

[13]

QUESTION 5

A whistle of a train emits sound waves at a frequency of 555 Hz. A person (listener) standing next to the train track hears a sound of the whistle with wavelength of 0,71 m. Assume that the speed of sound in air is 340 $m \cdot s^{-1}$.

5.1 Is the train approaching or moving away a person (listener)? Show how you arrived at the answer.

(4)

5.2 State the *Doppler effect* in words.

(2)

5.3 Calculate the speed of the train.

(5)

5.4 Write down TWO practical applications of the above phenomenon in the medical field.

(2)

Using large telescopes like the Southern African Large Telescope (SALT) in the Karoo, astronomers can measure the light from distant galaxies. In 1929 Edwin Hubble found that the light from distant galaxies is redshifted.

5.5 What does the redshifts tell us about the Universe? (2)

[15]

phys

QUESTION 6

A whistle of a locomotive, moving at a constant speed, emits a sound wave of 2 000 Hz. A man that stands on the side of the railroad hears a sound of frequency 1 836,0 Hz when the locomotive moves away from him. A girl that stands on the side of the railroad detects a sound of frequency 2 196,2 Hz when the locomotive approaches her. Use the speed of sound in air as 340 $m \cdot s^{-1}$.

6.1 State the *Doppler Effect* in words. (2)

6.2 Explain why the girl detects a sound of higher frequency as the locomotive approaches her. (3)

6.3 Will the frequency detected by the driver of the locomotive be GREATER THAN, EQUAL TO or SMALLER THAN 2 000 Hz? Give a reason for the answer. (2)

6.4 Calculate the speed of the locomotive. (5)

6.5 Write down ONE application of Doppler Effect in medicine. (1)

[13]

QUESTION 7

The siren of an ambulance emits sound of frequency 930 Hz as the ambulance approaches a stationary observer. The observer detects a frequency of 1000 Hz. Take the speed of sound in air as 340 $m \cdot s^{-1}$

7.1 State *Doppler effect* in words. (2)

____

____

____

____

7.2 Calculate the speed with which the ambulance approaches the observer. (5)

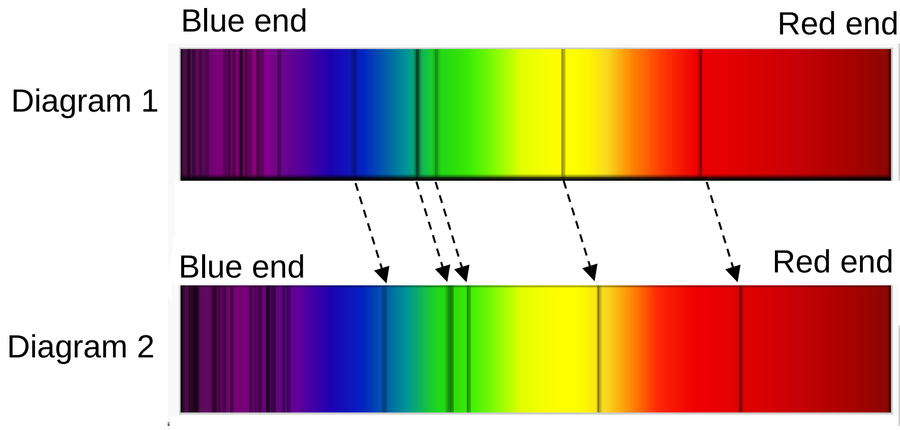
7.3 The ambulance is moving away from the observer. What effect will this have on the wavelength of the sound heard by the observer? Write down only INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

____

____

____

7.4 The Doppler effect could be used to explain the motion of stars and other heavenly bodies in our universe.
The two diagrams below represent the absorption spectra of a gas.
Diagram **1** represents the absorption lines in the optical spectrum of the Sun.
Diagram **2** represents the absorption lines in the optical spectrum of a supercluster of distant galaxies.



7.4.1 Are the stars moving *towards* or *away from* the Sun? Explain the answer by referring to the shifts in the spectral lines in the two diagrams above. (2)

____

____

7.4.2 From the comparison of the two diagrams above, what conclusion can be made about the Universe? (1)

____

[12]

phys

QUESTION 8

A commuter train passes a passenger platform at a constant speed of 40 m·s^{-1}. The train horn is sounded at its characteristic frequency of 320 Hz. An overall change in frequency is detected by a stationary person on the platform as train moves from approaching to receding. Consider the speed of sound in air as 343 m·s^{-1}.

8.1 State the Doppler effect in words. (2)

8.2 Does the stationary person detect a higher or lower wavelength while the train is approaching? Explain your answer. (4)

8.3 Calculate the overall change in frequency detected by the stationary person. (6)

8.4 A study of spectral lines obtained from various stars can provide valuable information about the movement of the stars.

The two diagrams below represents different spectral lines of an element.

Diagram 1 represents the spectrum of the element in a laboratory on Earth.

Diagram 2 represents the spectrum of the same element from a distant star.

Diagram 1

Diagram 2

Is the star moving *towards* or *away* from the earth? Explain the answers by referring to the shift in the spectral lines.

____

____

____ (2)

8.5 Name one application of Doppler effect. (1)

____ **[15]**

QUESTION 9

The siren of a stationary police car emits sound waves of frequency of 620 Hz. A stationary listener watches the police car approaching him at constant velocity on a straight road. The speed of the police car is 30 $m \cdot s^{-1}$. Assume that the speed of sound in air is 340 $m \cdot s^{-1}$.

9.1 How does the frequency of the sound waves heard by the listener compare to the frequency of the sound produced by the siren of the police car when it approaches the listener? Only write down HIGHER THAN, LOWER THAN or EQUAL TO. Explain your answer. (4)

___

___

___

___

9.2 Name and state the phenomenon observed in QUESTION 9.1. (3)

___

___

___

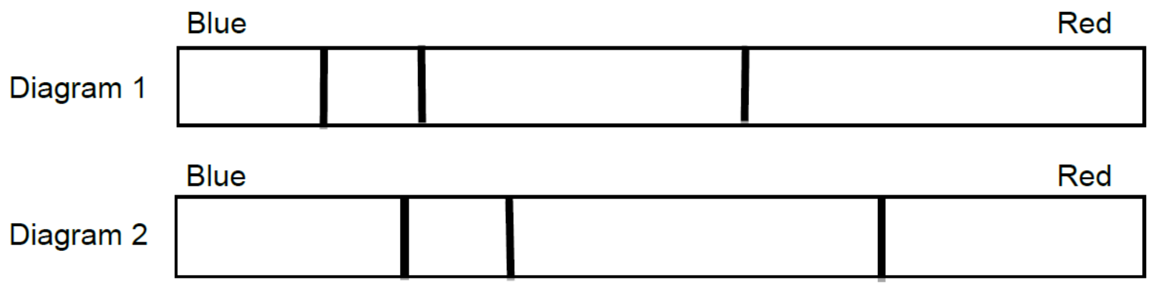
___

9.3 Calculate the frequency of the sound waves detected by the stationary listener. (4)

9.4 How will the answer to QUESTION 9.3 change if the police car moves away from the listener at 30 $m \cdot s^{-1}$? Write down HIGHER THAN, LOWER THAN or EQUAL TO. (1)

___

9.5 A study of spectral lines obtained from various stars can provide valuable information about the movement of the stars.
The two diagrams below represent different spectral lines of an element. Diagram **1** represents the spectrum of the element in a laboratory on Earth. Diagram **2** represents the spectrum of the same element from a distant star.



Is the star moving *towards* or *away from* the Earth? Explain the answer by referring to the shifts in the spectral lines in the two diagrams above. (2)

____

____

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[14]

QUESTION 10

Two identical Navy ships **A** and **B**, each having a sound of frequency 500 Hz, start to move at the same time in opposite directions away from a Lighthouse. A listener stationed in the lighthouse observes a frequency of 5% different from the actual frequency for Ship **A**, and a frequency of 450 Hz for ship **B**. Assume that the speed of sound in air is 340 $m \cdot s^{-1}$ and the speed of sound in water is 1 520 $m \cdot s^{-1}$

10.1 How different should the observed frequency of Ship **A** be compared to the actual frequency of the sound waves produced by **A**? Only write down HIGHER THAN, LOWER THAN or EQUAL TO. Explain your answer. (2)

____

____

____

10.2 Calculate the observed frequency for ship **A.** (2)

10.3 Name and define the phenomenon observed. (3)

____

____

____

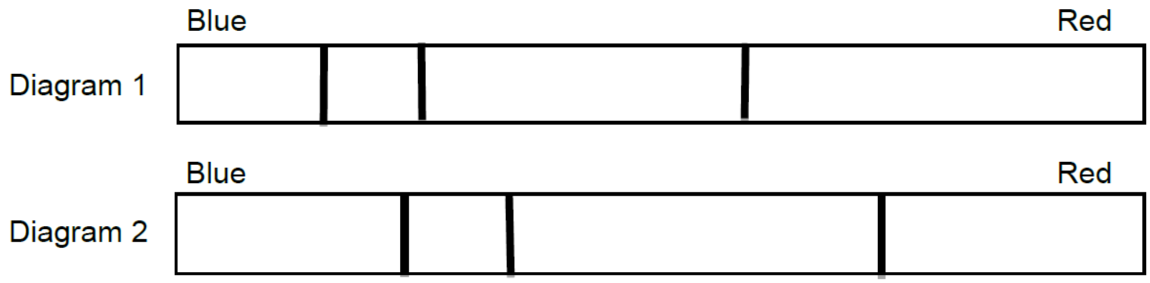
____

10.4 Calculate the distance between the two ships after they have moved at constant velocities for two minutes. (9)

phys

10.5 A study of spectral lines obtained from various stars can provide valuable information about the movement of the stars.

The two diagrams below represent different spectral lines of an element. Diagram **1** represents the spectrum of the element in a laboratory on Earth. Diagram **2** represents the spectrum of the same element from a distant star.



Is the star moving *towards* or *away from* the Earth? Explain the answer by referring to the shifts in the spectral lines in the two diagrams above. (2)

___

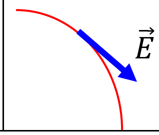
___

[18]

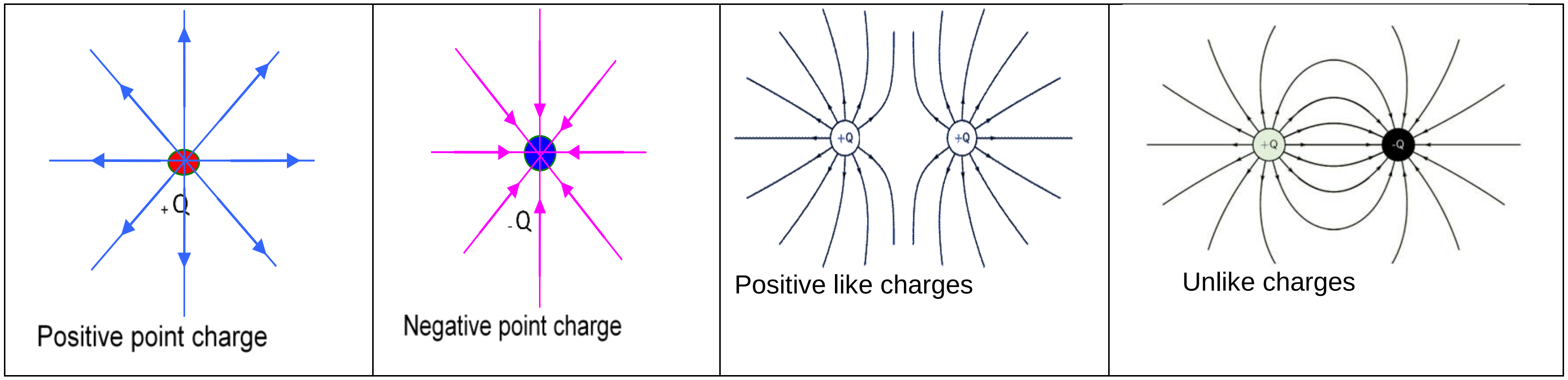
phys

TOPIC 3: ELECTRICITY AND MAGNETISM

3.1. ELECTROSTATICS

ELECTROSTATICS					
Electrostatics Force	Electric field	Electric field at a point	Lines	Principle of superposition of forces	Principle of superposition of fields
Coulomb`s law The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them: $F = \frac{KqQ}{r^2}$	***Electric field* is an area of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction in which a positive test charge would move if placed at that point.**	**The electric field at a point is the electrostatic force experienced per unit positive charge placed at that point.** $\vec{E} = \frac{\vec{F}}{q}$ **<u>For a point charge:</u>** $E = \frac{KQ}{r^2}$	Electric field lines are IMAGINARY LINES along which a small POSITIVE **test charge** would move. The force experienced by the positive **test charge** is always in the **direction** of the **tangent** to the field line They start on a positive **charge** and end on a negative **charge**. 	**The force that a system of point charges exerts on another point charge is equal to the vector addition of all the forces each one exerts on it.** $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + ... + \vec{F}_n$	**The electric field strength at a point due to a system of point charges is equal to the vector addition of all the electric field strengths of each one at a specific point.** $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + ... + \vec{E}_n$

Electric field pattern



PROBLEM SOLVING STRATEGY FOR ELECTROSTATIC FORCES AND COULOMB'S LAW

- **MODEL:** Identify point charges or objects that can be modelled as point charges.
- **VISUALISE:** Use a pictorial representation to establish a coordinate system, show the position of the charges, show the force vectors on the charge, define distance and angles and identify what the problem is trying to find. This is the process of translating words to symbols.
- **SOLVE:** The mathematical representation is based on Coulomb's law:

  $$F = \frac{KqQ}{r^2}$$

  - Show the direction of the forces- repulsive for like charges, attractive for opposite charges- on the pictorial representation.
  - When possible, do graphical vector addition on the pictorial representation. While not exact, it tells you the type of answer you should expect.
  - Write each force vector in terms of its x- and y- components, then add the components to fine the net force. Use the pictorial representation to determine which components are positive and which are negative.
- **ASSESS:** Check that your result has the correct units, is reasonable and that is answers the question.(Night R. 2008)

PROBLEM-SOLVING STRATEGY: THE ELECTRIC FIELD OF MULTIPLE POINT CHARGES.

STEP 1: MODEL: Model charged objects as point charges.

STEP 2: VISUALIZE: Make a pictorial representation (drawing/sketch).

For the pictorial representation:

- Stablish a coordinate system
- Identify the point P at which you want to calculate the electric field.
- Draw the electric field of each charge at point P.
- Use symmetry to identify if any components of $\vec{E}_{\text{net}}$ are zero.

STEP3: SOLVE: Apply the principle of superposition of fields. The mathematical representation is $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \cdots \vec{E}_n$

OR

$$\vec{E}_{net} = \sum \vec{E}_i$$

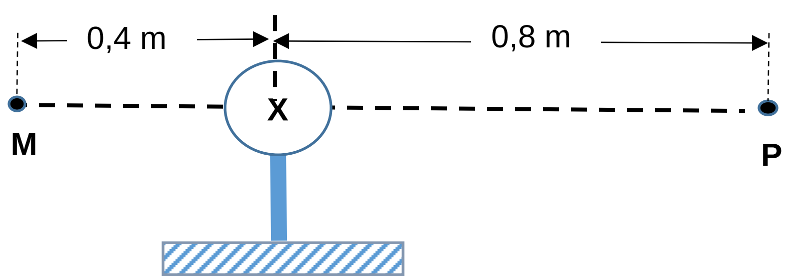
- For each charge, determine its distance from point P.
- Calculate the electric field strength (magnitude) of each charge at point P.
- Sum all the electric fields at point P to determine $\vec{E}_{net}$
- If needed, determine the magnitude and direction of $\vec{E}_{net}$.

STEP 4: ASSES: Check that your result has the correct unit, is reasonable, and agrees with any known limiting cases.

EXAMPLES

QUESTION 1

The diagram below shows a metal sphere **X** of negligible mass on an insulated stand in a vacuum. $3{,}125 \times 10^{10}$ electrons have been removed from the sphere.



1.1 Draw the electric field pattern associated with sphere **X**. (2)

1.2 Describe an *electric field*. (2)

1.3 Calculate the net charge on the sphere. (3)

1.4 Calculate the electric field at point **P**. (3)

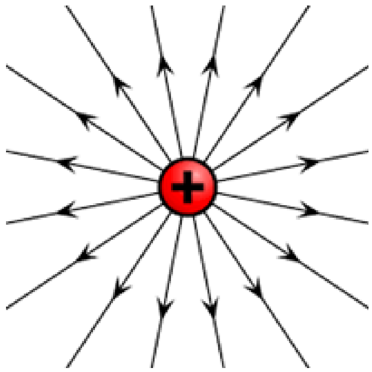
1.5 How does the magnitude of the electric field at point **M** compare with the value calculated in QUESTION 1.4? Write down only GREATER THAN, EQUAL TO or SMALLER THAN. Give a reason for the answer. (2)

1.6 A metal sphere **Y,** on an insulated stand carrying a charge of -4 nC, is now placed at point **M**. Show by calculations where a positive point charge **Q** should be placed so that it is in equilibrium. (4)

[16]

SOLUTION

1.1



Shape (radial)✓

Correct direction ✓

(2)

1.2 An *electric field* is a region of space in which an electric charge experiences a force✓. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.✓ (2)

1.3 Q=ne✓

$Q=(3{,}125 \times 10^{10})(1{,}6 \times 10^{-19})$✓

$Q=+5\times10^{-9}$ C✓ (3)

1.4 **POSITIVE MARKING FROM 1.3**

$E=\frac{kQ}{r^2}$✓

$E=\frac{(9{,}0\times10^{9})(5\times10^{-9})}{(0{,}8)^2}$✓

$E=70{,}31\ N\cdot C^{-1}$ away from the charge✓ (3)

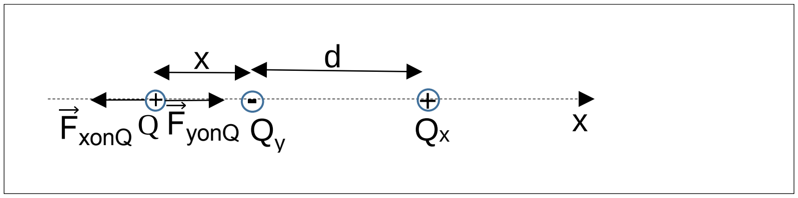
1.5 GREATER THAN ✓

The <u>electric field</u> at a point due to a point charge is <u>inversely proportional to the square of the distance</u> between the point and the charge/($E \propto \frac{1}{r^2}$) ✓

OR

The distance from <u>the charge to point **M** is smaller than the distance from the charge to point **P**</u>. ✓ (2)

1.6



OPTION 1

$\vec{F}_{x\ on\ Q}+\vec{F}_{y\ on\ Q}=\vec{0}$ **OR** $-F_{x\ on\ Q}+F_{y\ on\ Q}=0$ **OR** $F_{x\ on\ Q}=F_{y\ on\ Q}$

$k\frac{Q_xQ}{(d+x)^2}=k\frac{Q_yQ}{x^2}$ **OR** $\sqrt{\frac{Q_x}{(d+x)^2}}=\sqrt{\frac{Q_y}{x^2}}$ **OR** $\frac{\sqrt{Q_x}}{d+x}=\frac{\sqrt{Q_y}}{x}$ } ✓Any one

$\frac{\sqrt{(5\times10^{-9})}}{0,4+x}$ ✓ $=\frac{\sqrt{(4\times10^{-9})}}{x}$ ✓

$x=3,39\ m$ ✓

OPTION 2

$\vec{F}_{x\ on\ Q}+\vec{F}_{y\ on\ Q}=\vec{0}$ ✓ **OR** $-F_{x\ on\ Q}+F_{y\ on\ Q}=0$ **OR** $F_{x\ on\ Q}=F_{yon\ Q}$

$k\frac{Q_xQ}{(d+x)^2}=k\frac{Q_yQ}{x^2}$ **OR** $Q_xx^2=Q_y(d+x)^2$

OR

$Q_xx^2=Q_yd^2+2Q_ydx+Q_yx^2$

OR

$Q_xx^2-Q_yd^2-2Q_ydx-Q_yx^2=0$

OR

$(Q_x-Q_y)x^2-2Q_ydx-Q_yd^2=0$ } ✓Any one/

$(5\times10^{-9}-4\times10^{-9})x^2$ ✓ $-2(4\times10^{-9})(0,4)x-4\times10^{-9}(0,4)^2=0$ ✓

OR

$(10^{-9})x^2$ ✓ $-(3,2\times10^{-9})x+0,64\times10^{-9}=0$ ✓

OR

x^2 ✓ $-3,2x-0,64=0$ ✓

OR

$x=\frac{3,2\pm\sqrt{(3,2)^2-4(1)(-0,64)}}{2}$ ✓✓ **OR** $x=\frac{3,2\pm\sqrt{(3,2)^2+4(1)(0,64)}}{2}$

$x = 3,39\ m$ ✓

OPTION 3

$\vec{F}_{net}=\vec{0}$

$\vec{F}_{x\ on\ Q}+\vec{F}_{y\ on\ Q}=\vec{0}$ **OR** $-F_{x\ on\ Q}+F_{y\ on\ Q}=0$ **OR** $F_{x\ on\ Q}=F_{y\ on\ Q}$

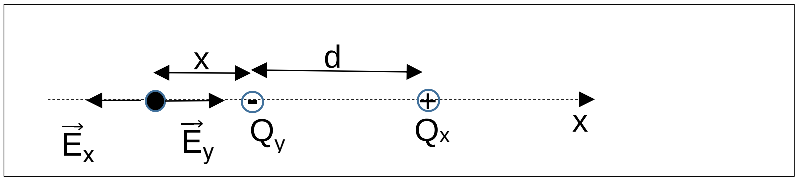
$Q\vec{E}_x+Q\vec{E}_y=\vec{0}$ **OR** $-QE_x+QE_y=0$ **OR** $QE_x=QE_y$

$k\frac{Q_x}{(d+x)^2}=k\frac{Q_y}{x^2}$ **OR** $\sqrt{\frac{Q_x}{(d+x)^2}}=\sqrt{\frac{Q_y}{x^2}}$ **OR** $\frac{\sqrt{Q_x}}{d+x}=\frac{\sqrt{Q_y}}{x}$ } ✓Any one/

$\frac{\sqrt{(5\times10^{-9})}}{0,4+x}$ ✓ $= \frac{\sqrt{(4\times10^{-9})}}{x}$ ✓

x=3,39 m✓

OPTION 4



$\vec{F}_{net}=\vec{0}$

$\vec{F}_{net}=q\vec{E}_{net}=0$

Therefore

$\vec{E}_{net}=\vec{0}$

$\vec{E}_x+\vec{E}_y=\vec{0}$ **OR** $-E_x+E_y=0$ **OR** $E_x=E_y$

$k\frac{Q_x}{(d+x)^2}=k\frac{Q_y}{x^2}$ **OR** $\sqrt{\frac{Q_x}{(d+x)^2}}=\sqrt{\frac{Q_y}{x^2}}$ **OR** $\frac{\sqrt{Q_x}}{d+x}=\frac{\sqrt{Q_y}}{x}$

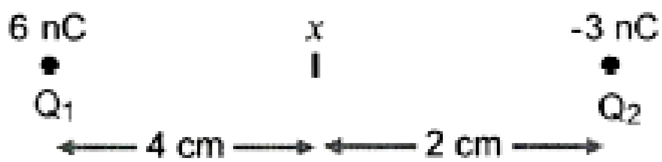
$\frac{\sqrt{(5\times10^{-9})}}{0,4+x}$ ✓ $= \frac{\sqrt{(4\times10^{-9})}}{x}$ ✓ (4)

x=3,39 m✓

[16]

EXAMPLE 2

Two charges, Q_1 = 6 nC and Q_2 = -3nC, are placed 6 cm apart in a horizontal line, as shown below.



2.1. Calculate the magnitude of the electric field at *x* as a result of charge Q1 only.

2.2. Calculate the magnitude of the electric field at *x* as a result of charge Q_2 only.

2.3. Calculate the net electric field at *X* as a result of the presence of both Q_1, and Q_2.

2.4. Calculate the magnitude and direction of the force that will experience a charge of 4 μC at point *x.*

SOLUTION

2.1. $E = \frac{KQ}{r^2}$

$$E = \frac{9\times10^{9}\times6\times10^{-9}}{(0{,}04)^2} = 33750 N\cdot C^{-1}$$

2.2. $E = \frac{KQ}{r^2}$

$$E = \frac{9\times10^{9}\times3\times10^{-9}}{(0{,}02)^2} = 67500 N\cdot C^{-1}$$

2.3. $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$

$E_{net\ at\ x}$= E_1 + E_2

$E_{net\ at\ x}$= 33750 + 67500=101 250 N·C^{-1}

2.4. F=qE

F= 4 x 10^{-6} x 101 250 = 405 000 x10^{-6} = 0,405 N to the right/in the direction of Q_2.

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 Two charged spheres of magnitudes 2Q and Q respectively are placed a distance r apart on insulating stands.

If the sphere of charge Q experiences a force **F** to the east, then the sphere of charge 2Q will experience a force …

A **F** to the west.

B **F** to the east.

C 2**F** to the west.

D 2**F** to the east. (2)

1.2 P, Q and R are three charged spheres. When P and Q are brought near each other, they experience an attractive force. When Q and R are brought near each other, they experience a repulsive force.

Which ONE of the following is TRUE?

A P and R have charges with the same sign.

B P and R have charges with opposite signs.

C P, Q and R have charges with the same sign.

D P, Q and R have equal charges. (2)

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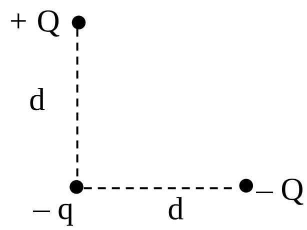
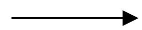
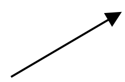
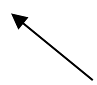
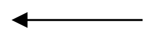
phys

1.3 Two charges, + Q and – Q, are placed a distance d from a negative charge – q. The charges, + Q and – Q, are located along lines that are perpendicular to each other as shown in the diagram below.



Which ONE of the following arrows CORRECTLY shows the direction of the net force acting on charge – q due to the presence of charges + Q and – Q?

A	
B	
C	
D	

(2)

1.4 Two identical conducting spheres are charged such that sphere 1 has a charge of 4 C and sphere 2 has a charge of −4 C. A third identical sphere is initially uncharged. If sphere 3 touches sphere 1 and separates, then touches sphere 2 and separates. The final charge on sphere 3 is…

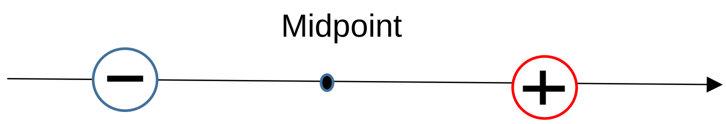
A -1 C

B + 1C

C - 2 C

D + 2 C (2)

1.5 The sketch below shows a negative and a positive point charge. The magnitude of the positive charge is greater than that of the negative charge.



Where on the line that passes through the charges is the total electric field zero?

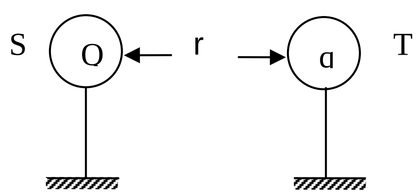
A To the right of the positive charge.

B To the left of the negative charge.

C Between the charges, to the left of the midpoint.

D Between the charges, to the right of the midpoint. (2)

1.6 Two spheres **S** and **T** on isolated stands carry charges **Q** and **q** respectively and their centres are a distance **r** apart.



The magnitude of the electrostatic force exerted by **S** on **T** is **F**. If the distance between them is doubled the new electrostatic force is:

A 2 F

B 1/2 F

C 1/4 F

D 4 F

(2)

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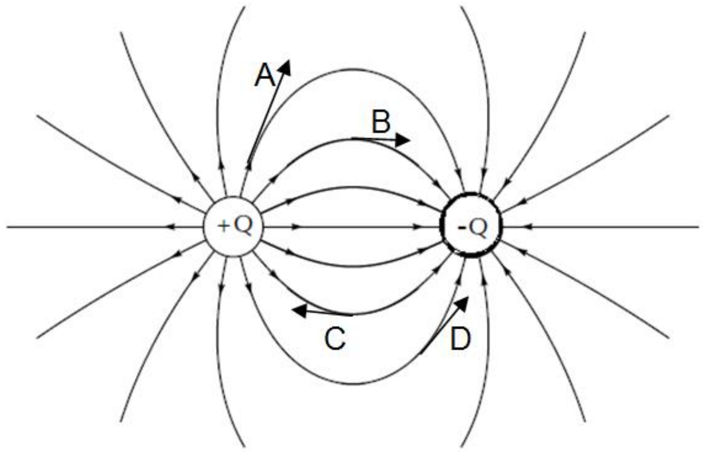
phys

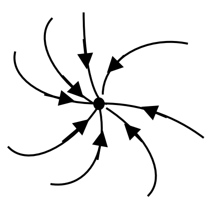
1.7 A learner drew a diagram shown below to show the electric field pattern due to two point charges and the electric field strength at different points.



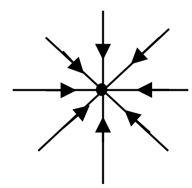
Which ONE of the vectors that show the electric field strength at a point was represented incorrectly? (2)

1.8 Which ONE of the sketches below correctly represents the electric field lines of a positive point charge?

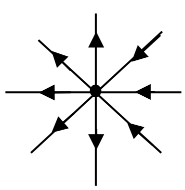
A



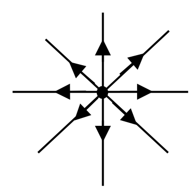
B



C

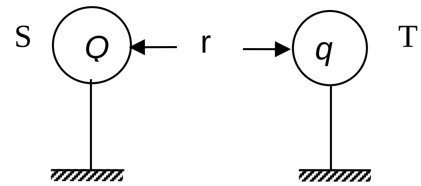


D



(2)

1.9 Two spheres **S** and **T** on isolated stands carry charges *Q* and *q* respectively and their centres are a distance *r* apart. The magnitude of the electrostatic force exerted by **S** on **T** is *F*.



If the distance between them is tripled the new electrostatic force is …

A $\frac{1}{9}F$

B $\frac{1}{3}F$

C F

D $9F$

(2)

1.10 Which ONE of the following combinations is CORRECT regarding the properties of electric field lines?

	Direction	Strength of field
A	Positive to negative	Strongest where the lines are the most dense
B	Negative to positive	Weakest where the lines are the least dense
C	North to south	Strongest where the lines are the most dense
D	North to south	Weakest where the lines are the least dense

(2)

---

[20]

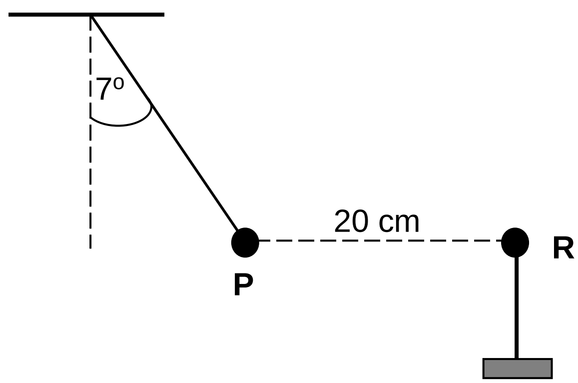
phys

QUESTION 2 (DBE/November 2015)

A very small graphite-coated sphere **P** is rubbed with a cloth. It is found that the sphere acquires a charge of + 0,5 μC.

2.1 Calculate the number of electrons removed from sphere **P** during the charging process. (3)

Now the charged sphere **P** is suspended from a light, inextensible string. Another sphere, **R**, with a charge of – 0,9 μC, on an insulated stand, is brought close to sphere **P**. As a result sphere **P** moves to a position where it is 20 cm from sphere **R**, as shown below. The system is in equilibrium and the angle between the string and the vertical is 7°.



2.2 Draw a labelled free-body diagram showing ALL the forces acting on sphere **P**. (3)

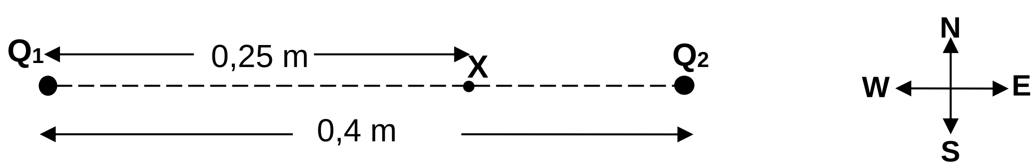
2.3 State Coulomb's law in words. (2)

2.4 Calculate the magnitude of the tension in the string. (5)

[13]

QUESTION 3 (DBE/November 2015)

Two charged particles, $\mathbf{Q_1}$ and $\mathbf{Q_2}$, are placed 0,4 m apart along a straight line. The charge on $\mathbf{Q_1}$ is + 2 x 10^{-5} C, and the charge on $\mathbf{Q_2}$ is – 8 x 10^{-6} C. Point **X** is 0,25 m **east** of $\mathbf{Q_1}$, as shown in the diagram below.



Calculate the:

3.1 Net electric field at point **X** due to the two charges (6)

3.2 Electrostatic force that a – 2 x 10^{-9} C charge will experience at point **X** (4)

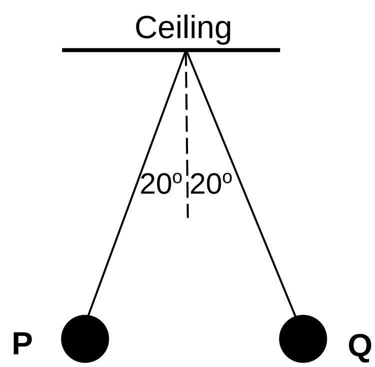
The – 2 x 10^{-9} C charge is replaced with a charge of – 4 x 10^{-9} C at point **X**.

3.3 **Without any further calculation**, determine the magnitude of the force that the – 4 x 10^{-9} C charge will experience at point **X**.

(1)
[11]

QUESTION 4 DBE/Feb.–Mar. 2016)

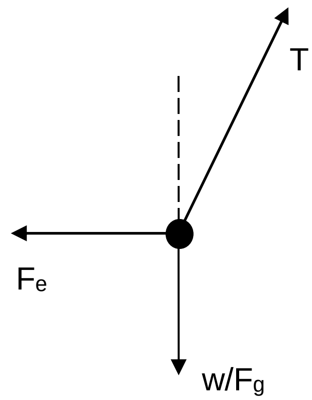
Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of +250 nC. The balls come to rest in the positions shown in the diagram below.



4.1 In the diagram, the angles between each string and the vertical are the same. Give a reason why the angles are the same. (1)

4.2 State Coulomb's law in words. (2)

4.3 The free-body diagram, not drawn to scale, of the forces acting on ball **P** is shown below.



Calculate the:

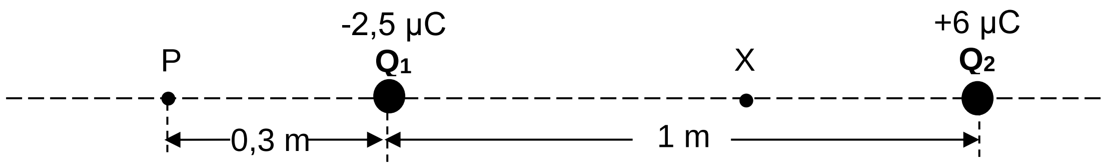
4.3.1 Magnitude of the tension (T) in the string (3)

4.3.2 Distance between balls **P** and **Q** (5)

[11]

QUESTION 5 (DBE/Feb.–Mar. 2016)

A sphere $\mathbf{Q_1}$, with a charge of -2,5 µC, is placed 1 m away from a second sphere $\mathbf{Q_2}$, with a charge +6 µC. The spheres lie along a straight line, as shown in the diagram below. Point **P** is located a distance of 0,3 m to the left of sphere $\mathbf{Q_1}$, while point **X** is located between $\mathbf{Q_1}$ and $\mathbf{Q_2}$. The diagram is not drawn to scale.



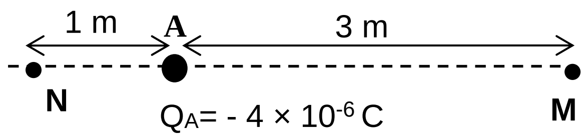
5.1 Show, with the aid of a VECTOR DIAGRAM, why the net electric field at point **X** *cannot be zero.* (4)

5.2 Calculate the net electric field at point **P**, due to the two charged spheres $\mathbf{Q_1}$ and $\mathbf{Q_2}$. (6)

[10]

QUESTION 6

The diagram below shows a point charge **A** with a charge of - 4 × 10^{-6} C and two points **M** and **N.**



6.1 Define *electric field at a point* in words (2)

____

____

6.2 Draw the electric field pattern due to point charge **A.** (2)

6.3 At what point, **M** or **N,** is the magnitude of the electric field due to the point charge **A** greater? Explain the answer. (3)

____

____

____

____

6.4 A positive point charge **B** with charge + 8 x 10^{-6} C is placed at point **M.** Point charges **A** and **B** exerts forces on each other.

6.4.1 State *Coulomb's law* in words. (2)

____

____

____

____

6.4.2 Calculate the electrostatic force exerted by charge **A** on charge **B.** (4)

6.4.3 Calculate the net electric field at point N. (5)

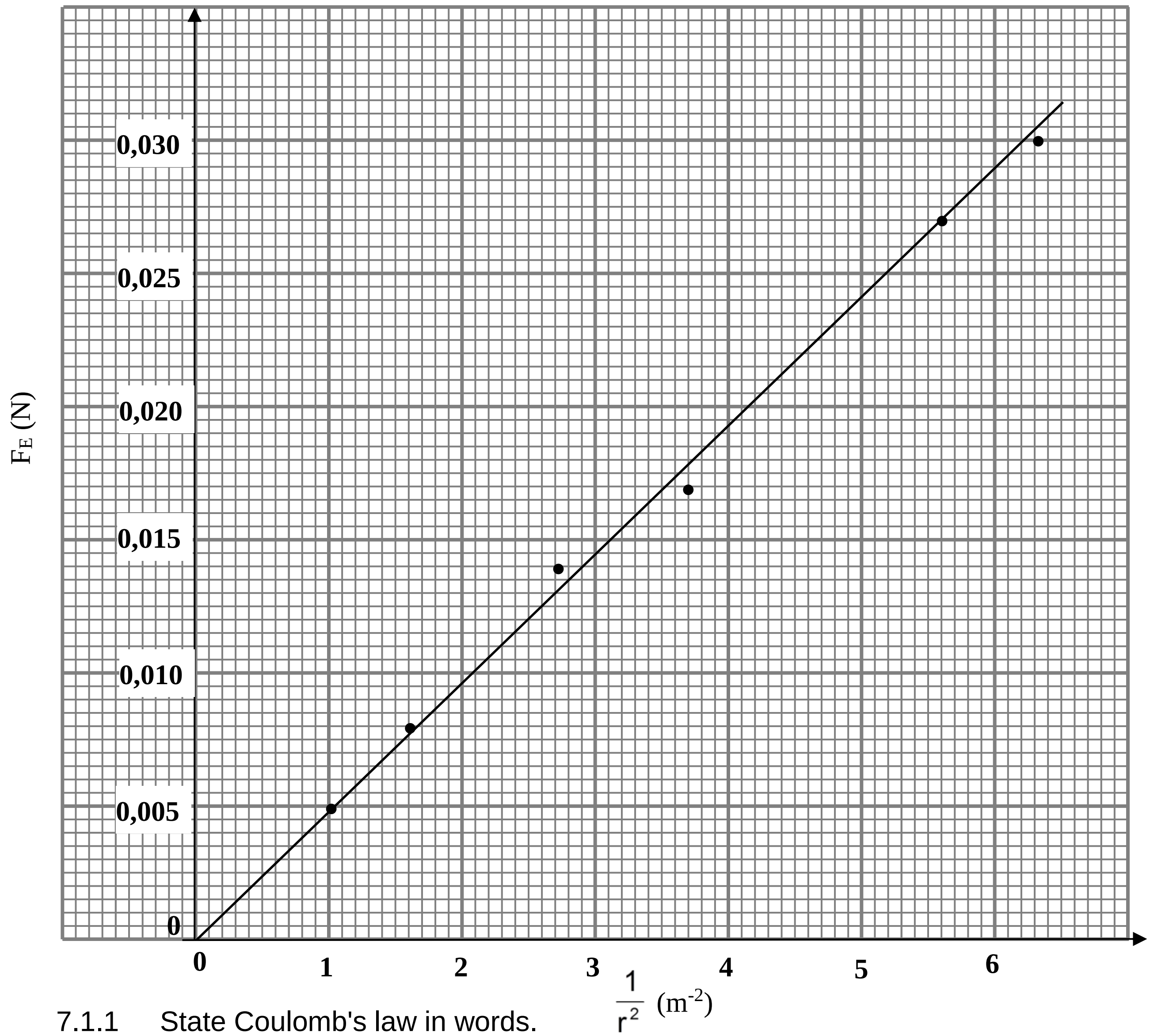
[18]

phys

QUESTION 7 (DBE/November 2016))

7.1 In an experiment to verify the relationship between the electrostatic force, F_E, and distance, r, between two **identical**, positively charged spheres, the graph below was obtained.

GRAPH OF F_E VERSUS $\frac{1}{r^2}$



7.1.1 State Coulomb's law in words. (2)

____

____

____

____

7.1.2 Write down the dependent variable of the experiment. (1)

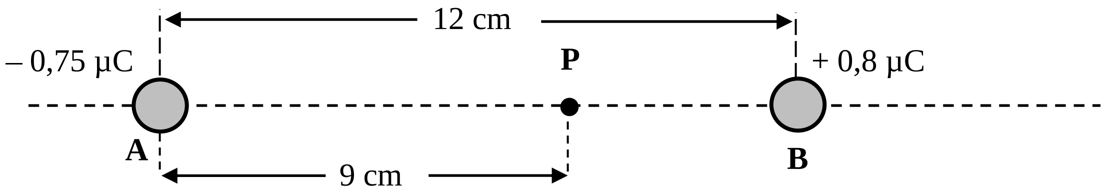
7.1.3 What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph? (1)

7.1.4 Use the information in the graph to calculate the charge on each sphere. (6)

7.2 A charged sphere, **A**, carries a charge of – 0,75 µC.

7.2.1 Draw a diagram showing the electric field lines surrounding sphere **A**. (2)

Sphere **A** is placed 12 cm away from another charged sphere, **B**, along a straight line in a vacuum, as shown below. Sphere **B** carries a charge of +0,8 µC. Point **P** is located 9 cm to the right of sphere **A**.

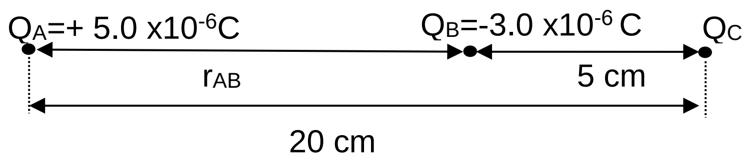


7.2.2 Calculate the magnitude of the net electric field at point **P**. (5)

[17]

QUESTION 8

Three point charges Q_A, Q_B and Q_C are placed in vacuum as shown in the sketch below. The distance between point charges Q_A and Q_C is 20 cm while that between Q_B and Q_C is 5 cm.



8.1 State Coulomb's Law in words. (2)

____

____

____

____

8.2 How does the magnitude of the electrostatic force exerted by point charge Q_A on point charge Q_B compare with the magnitude of the electrostatic force exerted by point charge Q_B on point charge Q_A ? Write down only GREATER THAN, SMALLER THAN or EQUAL TO.

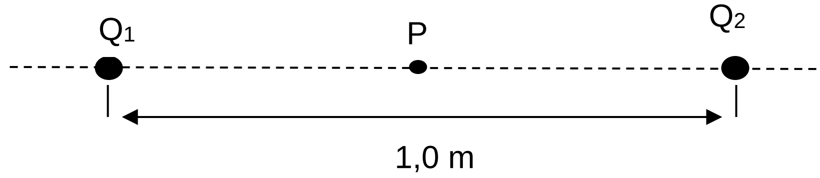
____ (1)

8.3 Determine the nature (positive or negative) and calculate the number of protons or electrons in charge Q_c so that the net electrostatic force on Q_B is zero. (8)

[11]

QUESTION 9

Two point charges Q_1= +5,0 µC and Q_2= -3,0 µC 1 m apart, are placed in vacuum as shown in the sketch below .



9.1 Define the term *electric field* at a point.

____

____

____

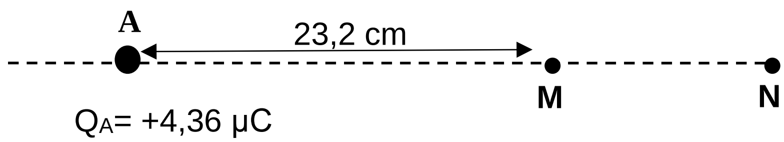
(2)

9.2 Calculate the net electric field at point P located at the middle of the distance between the point charges Q_1 and Q_2. (6)

[8]

QUESTION 10

The diagram below shows a point charge **A** with a charge +4,36 μC and two points **M** and **N.**



10.1 Define *electric field at a point* in words (2)

10.2 Draw the electric field pattern due to point charge **A.** (2)

10.3 At what point, **M** or **N,** is the magnitude of the electric field due to the point charge **A** greater? Explain the answer. (3)

10.4 A negative point charge **B** with charge – 7 x 10^{-6} C is placed at point **M.** Point charges **A** and **B** exerts forces on each other.

10.4.1 State *Coulomb's law* in words. (2)

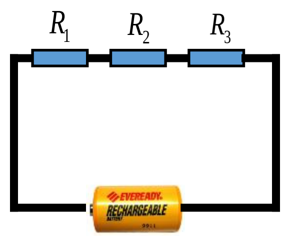
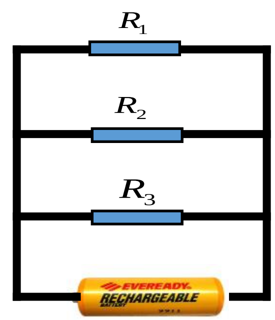
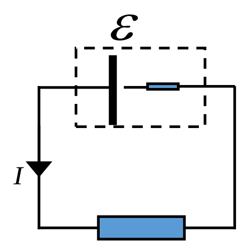
10.4.2 Calculate the magnitude of the electrostatic force exerted by charge **A** on charge **B.** (4)

10.4.3 Calculate the distance from charge sphere **A** along the line that passes through the point charges where the net electric field is zero. (5)

[18]

TOPIC 3: ELECTRICITY AND MAGNETISM

3.2. ELECTRIC CIRCUITS

CURRENT	*EMF &* POTENTIAL DIFFERENCE	Resistors in Series	Resistors in Parallel	Ohm's Law	Internal Resistance	Work (energy transferred)	Power
The total charge that passes through a conductor per unit of time. $I = \frac{Q}{\Delta t}$ Measured in amperes (A)	Emf is the work done (energy transferred) per unit charge to move the charge from the negative electrode to the positive electrode in the battery. $\varepsilon = \frac{W}{q}$ ***Potential defference*** is the work done per unit charge between two points in a circuit. $V = \frac{W}{Q}$ Measured in volts (V)	 $R_T = R_1 + R_2 + R_3$ $I_1 = I_2 = I_3$ $V_T = V_1 + V_2 + V_3$ (Resistors act as potential dividers.)	 $\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ $V_1 = V_2 = V_3$ $I_T = I_1 + I_2 + I_3$ (Resistors act as current dividers.)	**Ohm's Law** ***states that the potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.*** $R = \frac{V}{I}$ ***Whole circuit:***  *A real battery has internal resistance.* $I = \frac{\varepsilon}{R + r}$	When current flows through a voltage source (battery/generator) a resistance to current flow arises due to the resistance of the materials (chemicals/conductors) from which the source is made. **Internal resistance is the resistance offered to the electron flow by the electrolyte/medium of the cell/generator** Measured in ohms (Ω)	General: $W = VIt$ Series: $W = I^2 Rt$ Parallel: $W = \frac{V^2}{R} t$ **Whole circuit:** $W = \varepsilon It$ Measured in joules (J)	**The rate at which electrical work is done or electrical energy is transferred.** $\boldsymbol{P = \frac{W}{\Delta t}}$ $\boldsymbol{P = VI}$ $\boldsymbol{P = \frac{V^2}{R}}$ $\boldsymbol{P = I^2 R}$ Measured in watts (W)

phys

STRATEGY TO SOLVE PROBLEMS ON ELECTRIC CIRCUITS

- Read the problem carefully as many times as you need.
- If not given, draw a circuit diagram.
- Write down the data in symbolic form.
- Indicate the conventional direction of the current from high-potential to low-potential (+ to -).
- Re-draw the circuit diagram to simplify it if necessary.
- Identify the type of connection (series/parallel).
- Analysing circuits

  1 – The algebraic sum of the changes in potential in a complete transversal of any loop of a circuit must be zero. ($\varepsilon = IR + Ir$)

  2. The sum of the currents entering any junction must be equal to the sum of the currents leaving that junction. ($I = I_1 + I_2 + \ldots + I_n$)

- Write down the formula/ equation that solves the question.
- Find the unknowns if needed (multi-concept problems)
- Do the calculations and write down the final answer.
- Check your answer

  1- Does it have the correct dimensions (units)?

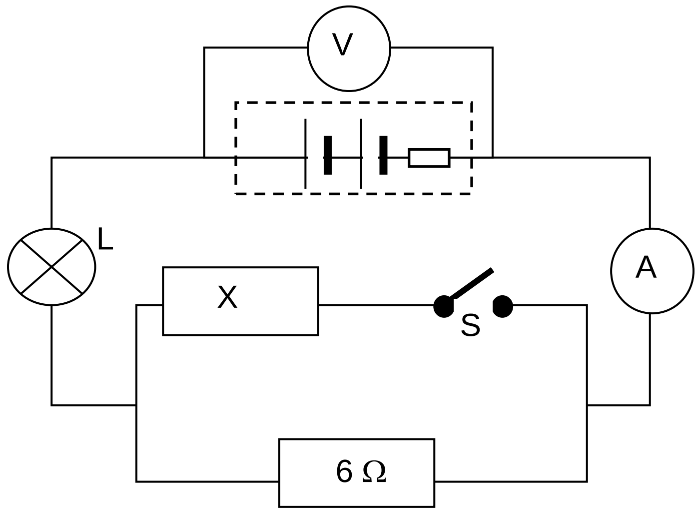
  2- Is the numerical value reasonable?

phys

EXAMPLE

QUESTION 1

In the circuit represented the battery has an emf of 24 V and an unknown internal resistance, r. The resistance of resistor X is also unknown.



When switch S is open the ammeter has a reading of 1,5 A.

1.1 Calculate the resistance of bulb L if the power dissipated in it is equal to 18 W.

1.2 Calculate the internal resistance of the battery.

When switch S is closed the ammeter has a reading of 2,0 A.

1.3 Calculate the reading on voltmeter V.

1.4 Calculate the resistance of resistor X.

SOLUTION

Remember

emf is the maximum amount of energy a battery can transfer per coulomb charge (V=W/q). It is the voltmeter reading across the battery when the battery is NOT delivering current (with the switch open). The emf of a battery does not change – it is a property of a battery.

When the battery is delivering current to a circuit, the voltmeter reading across the battery drops. This is as a result of the internal resistance in the battery.

Consider the equation:

emf = I (R + r)

Total external resistance → $\varepsilon = IR$

Internal resistance → $+ Ir$

$\varepsilon = IR + Ir$

$\varepsilon = V_{external} + V_{\text{"internal resistance"}}$

1.1 $P = I^2R$

$18 = (1,5)^2R$

$R = 18/1,5^2 = 8\ \Omega$

> 1.1 The current in a series circuit is everywhere the same

1.2 $emf = I(R + r)$

$24 = (1,5)(8+6) + (1,5)(r)$

$= 21 + 1,5r$

$r = 2\ \Omega$

> 1.2 The resistance of the battery is the internal resistance, r. Remember R in this formula is TOTAL external resistance.
> From this calculation you can see that the $V_{external}$ is 21 V and the V_{int} is (1,5)(2) =3 Ω

1.3 $emf = V_{ext} + Ir$

$24 = V_{ext} + (2)(2)$

$V_{ext} = 24 – 4$

$= 20\ V$

> 1.3 Remember that the emf of the battery remains 24 V and its internal resistance remains 2 Ω, irrespective what is done to the circuit!! Why does the current increase from 1,5 A to 2 A? Because now we have a parallel connection of resistors, which lowers the external resistance, increasing the current.

1.4 $V_{over\ L} = IR = 2(8) = 16\ V$

$V_{over\ //\ comp} = 20 - 16 = 4\ V$

$R_{//} = V/I = 4/2 = 2\ \Omega$

$1/R_{//} = 1/x + 1/6$

$½ = 1/x + 1/6$

$1/x = ½ - 1/6 = (3-1)/6 = 2/6$

$x = 6/2 = 3\ \Omega$

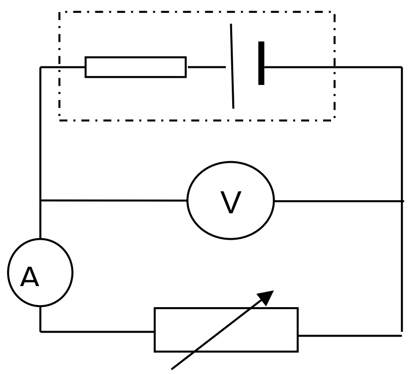
> 1.4 Potential difference relationships!

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 In the circuit represented below, the resistance of the variable resistor is decreased. How does this affect the reading of the ammeter and voltmeter?



	AMMETER READING	VOLTMETER READING
A	Unchanged	decreases
B	increases	decreases
C	decreases	decreases
D	decreases	increases

(2)

1.2 The minimum value of the resistance that can be obtained by connecting two 4 Ω resistors is ...

A 8 Ω.

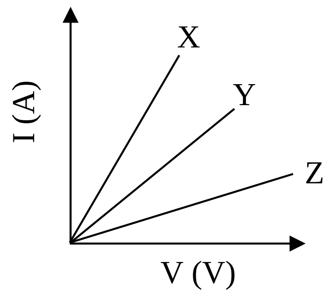
B 4 Ω.

C 2 Ω.

D 1 Ω. (2)

1.3 Learners investigate the relationship between current (I) and potential difference (V) at a constant temperature for three different resistors, **X**, **Y** and **Z**.

They obtain the graphs shown below.



The resistances of **X**, **Y** and **Z** are R_X, R_Y and R_Z respectively.

Which ONE of the following conclusions regarding the resistances of the resistors is CORRECT?

A $R_Z > R_Y > R_X$

B $R_X = R_Y = R_Z$

C $R_X > R_Y > R_Z$

D $R_X > R_Y$ and $R_Y < R_Z$ (2)

1.4 When a resistor of resistance R is connected to a battery of emf ε and negligible internal resistance, the power dissipated in the resistor is P.

If the resistor is replaced with a resistor of resistance 2R, without changing the battery, the power dissipated will be …

A ¼P

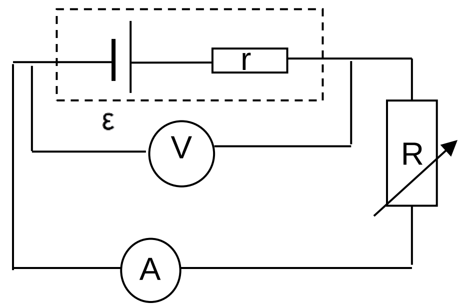
B ½P

C 2P

D 4P

(2)

1.5 In the circuit represented below, the resistance of the variable resistor is decreased.



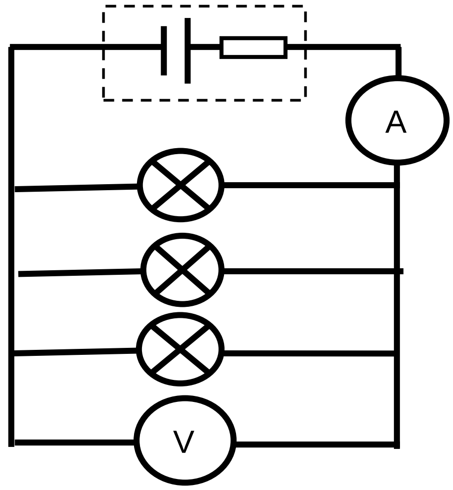
How would this decrease affect the readings on the voltmeter and ammeter?

	Voltmeter reading	**Ammeter reading**
A	unchanged	unchanged
B	decreases	increases
C	decreases	unchanged
D	increases	increases

(3)

phys

1.6 Consider the following circuit diagram with three identical bulbs connected as shown below.

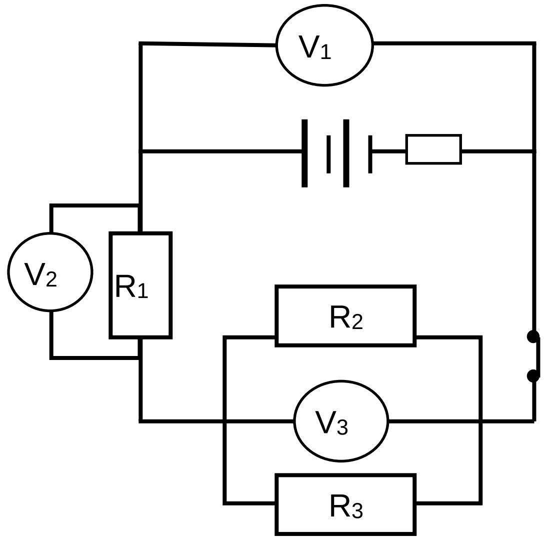


If one of the bulbs is burnt out. How would this change affect the readings on the voltmeter and ammeter?

	AMMETER READING	VOLTMETER READING
A	decreases	unchanged
B	decreases	decreases
C	increases	unchanged
D	decreases	increases

(2)

1.7 In the given circuit the internal resistance of the cell CANNOT be ignored. The resistance of the resistors are all equal.



Which one of the following statements is true concerning the voltmeter readings?

A $V_1 = V_2 + V_3$

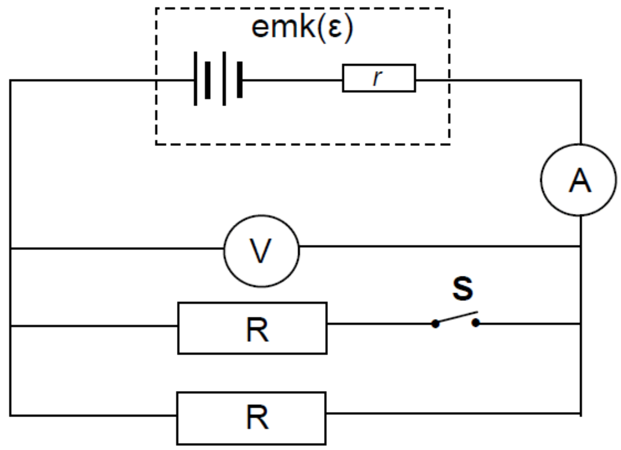
B $emf = V_1 + V_2 + V_3$

C $emf = V_1$

D $V_1 = V_3$

(2)

1.8 In the circuit below the battery has an emf (ε) and internal resistance *r*. With switch **S** open, readings are registered on the ammeter and voltmeter.

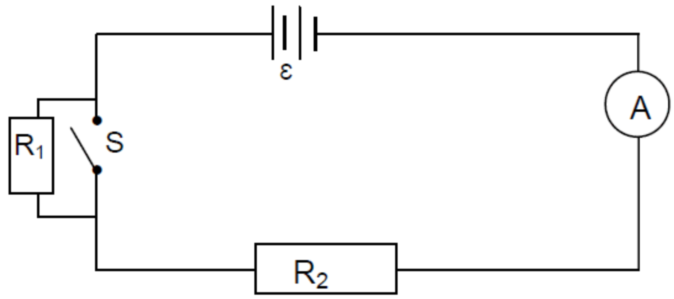


Switch **S** is now closed. How do the readings on the ammeter and voltmeter change?

	AMMETER READING	VOLTMETER READING
A	Increases	Remains the same
B	Increases	Decreases
C	Decreases	Remains the same
D	Decreases	Decreases

(2)

1.9 A battery of emf Ɛ and negligible internal resistance is connected in a circuit, as shown below. The resistances of R_1 and R_2 are high.

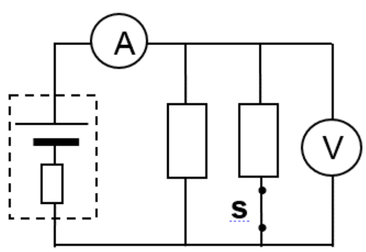


Which ONE of the following combinations about the ammeter readings will be CORRECT when switch S is open and when switch S is closed?

	SWITCH OPEN	SWITCH CLOSED
A	Ammeter reads only the current in R_1	Ammeter reads only the current in R_2
B	Ammeter reads only the current in R_2	Ammeter reads the current in both R_1 and R_2
C	Ammeter reads the current in both R_1 and R_2	Ammeter reads the current in both R_1 and R_2
D	Ammeter reads the current in both R_1 and R_2	Ammeter reads the current in R_2 only

(2)

1.10 A circuit with two parallel resistors is shown below.



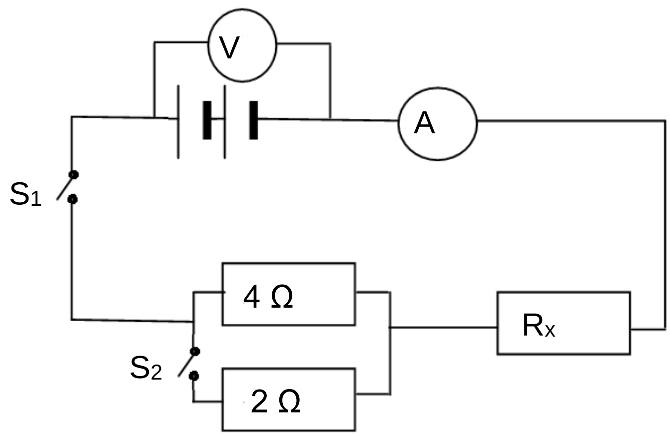
How will the ammeter and voltmeter readings be affected if switch **S** is opened?

	AMMETER READING	VOLTMETER READING
A	Increase	Decrease
B	Decrease	Increase
C	Stays the same	Stays the same
D	Decrease	Decrease

(2)
[20]

QUESTION 2

Three resistors, 2 Ω, 4 Ω and R_x are connected to a battery as shown in the circuit diagram below. With switch S_1 open and S_2 closed the reading on the voltmeter is 10 V. With both switches closed the reading on the voltmeter is 8 V and the ammeter is 1 A.



2.1 Write down the value of the emf of the battery. (1)

____

2.2 Calculate the:

2.2.1 resistance of the unknown resistor $\mathbf{R_x}$. (7)

2.2.2 internal resistance of the battery. (3)

2.3 How will the reading on the voltmeter be affected if the switch S_1 is closed while S_2 is opened. (4)
Write down only INCREASES, DECREASES or REMAINS THE SAME.
Briefly explain the answer.

____

____

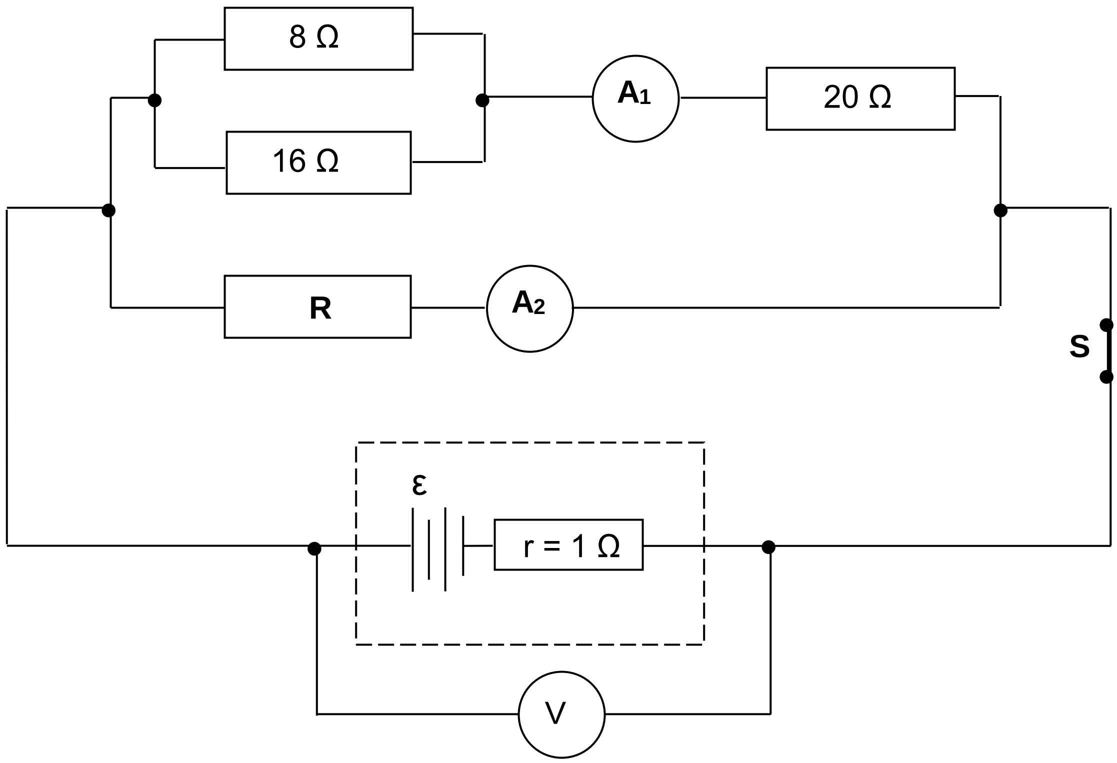
____

____

[15]

QUESTION 3 (DBE/November 2015)

A battery with an internal resistance of 1 Ω and an unknown emf (ε) is connected in a circuit, as shown below. A high-resistance voltmeter (V) is connected across the battery. **A_1** and **A_2** represent ammeters of negligible resistance.



With switch **S** closed, the current passing through the 8 Ω resistor is 0,5 A.

3.1 State Ohm's law in words.

____

____

____ (2)

3.2 Calculate the reading on ammeter **A_1**. (4)

3.3 If device **R** delivers power of 12 W, calculate the reading on ammeter **A_2**. (5)

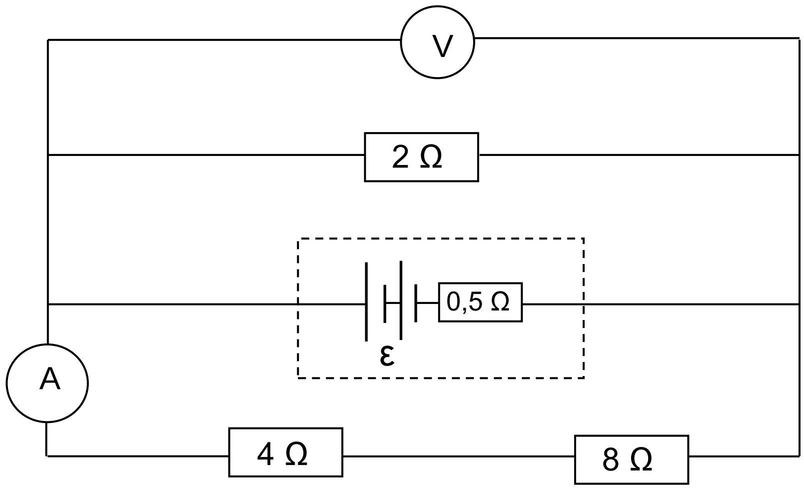
3.4 Calculate the reading on the voltmeter when switch **S** is open. (3)

[14]

phys

QUESTION 4 (DBE/Feb.–Mar. 2016)

A battery of an unknown emf and an internal resistance of 0,5 Ω is connected to three resistors, a high-resistance voltmeter and an ammeter of negligible resistance, as shown below.



The reading on the ammeter is 0,2 A.

4.1 Calculate the:

4.1.1 Reading on the voltmeter (3)

4.1.2 Total current supplied by the battery (4)

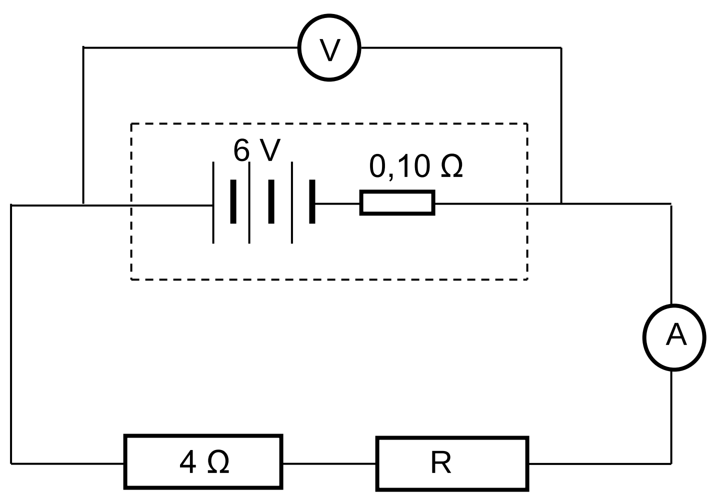
4.1.3 Emf of the battery (5)

4.2 How would the voltmeter reading change if the 2 Ω resistor is removed from the circuit? Write down INCREASE, DECREASE or REMAIN THE SAME. Explain the answer.

(3)
[15]

QUESTION 5

In the circuit diagram below the emf of the battery is 6 V and its internal resistance is 0,10 Ω. The resistance R is UNKNOWN.



5.1 Explain the term *internal resistance.* (2)

phys

5.2 Write down an equation for the terminal potential difference using the values given. (2)

8.3 Draw a sketch graph of terminal potential difference versus current. Indicate the following in the graph: (3)

- The value of the emf
- Current at which terminal potential difference is zero.

5.4 The energy dissipated in 4 Ω resistance is 40 J and the energy dissipated in resistance R is 60 J.

Calculate the:

5.4.1 Resistance R (4)

5.4.2 Total current in the circuit (3)

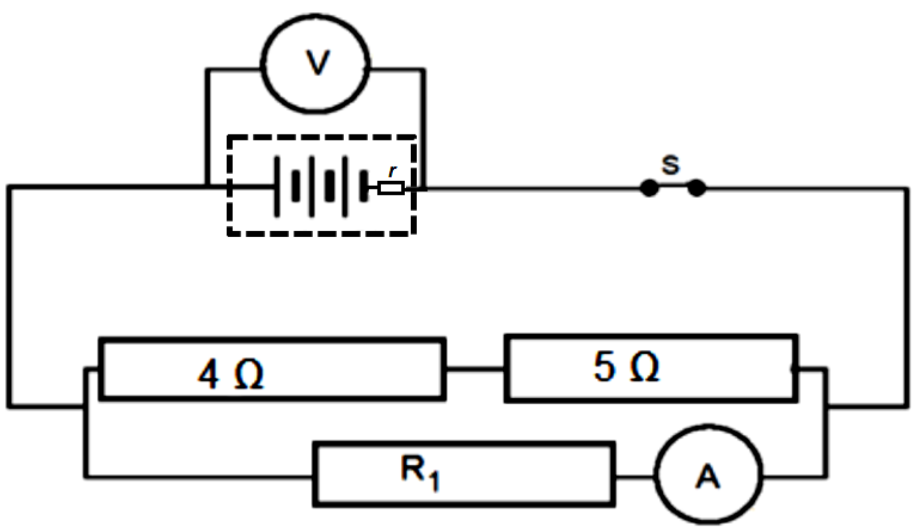
5.4.3 Reading of the voltmeter (3)

5.5 A 7 Ω resistor is now connected in parallel to the 4 Ω resistor. How will this action affect the reading of the voltmeter? Write down only INCREASES, DECREASES or REMAINS THE SAME. Briefly explain the answer. (4)

[21]

QUESTION 6

The circuit diagram below shows two resistors of resistance 4 Ω and 5 Ω each connected in parallel to resistor R_1 of unknown resistance. The battery has an emf of 15 V and an unknown internal resistance (r).



6.1 State *Ohm's law* in words. (2)

The reading on the ammeter is 1,5 A and the voltmeter reading is 12,9 V.

Calculate the:

6.2 resistance of resistor R_1. (3)

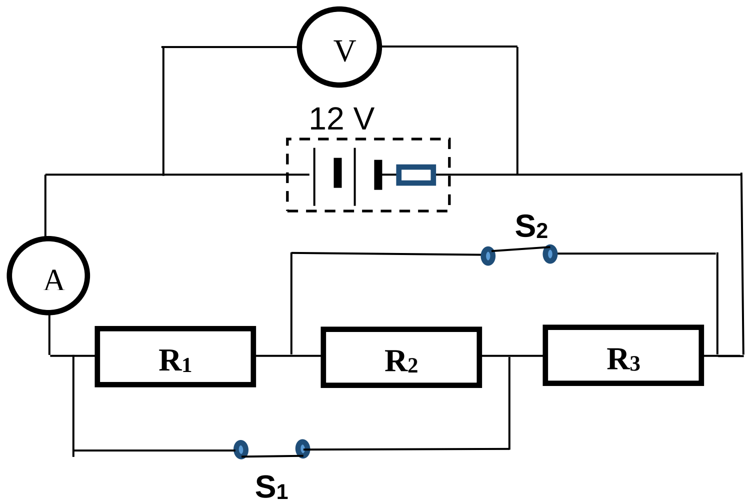
6.3 equivalent resistance of the parallel connection (combination). (3)

6.4 internal resistance of the battery. (4)

[12]

QUESTION 7

In the circuit diagram below the *emf* of the battery is 12 V and the internal resistance is 0,4 Ω. Switches **S_1** and **S_2** are closed.The ammeter reading is 3 A. The resistance of the three resistors is the same. Ignore the resistance of the wires.



7.1 Write down TWO differences between electromotive force (emf) and terminal potential difference. (2)

7.2 State *Ohm's law* in words. (2)

7.3 Calculate the current passing through resistor **R_2**. (4)

7.4 Determine the reading of the voltmeter. (4)

7.5 The switches $\mathbf{S}_1$ and $\mathbf{S}_2$ are now open.

7.5.1 How will the reading on the ammeter be affected? Write down only INCREASEs, DECREASEs or REMAINs THE SAME. (1)

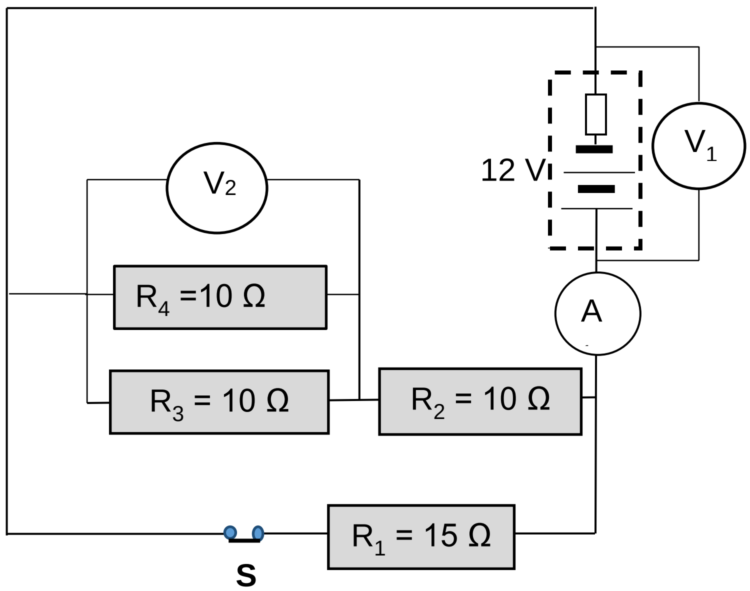
7.5.2 How will the reading on the voltmeter be affected? Write down only INCREASES, DECREASES or REMAINS THE SAME.

Explain the answer. (4)

[17]

QUESTION 8 (Start on a new page.)

In the circuit diagram below the resistance of the conductors and the ammeter are negligible. The *emf* of the battery is 12 V and the internal resistance is 0,5 Ω. The switch **S** is closed.



8.1 State *Ohm's law* in words. (2)

____

____

.2 Calculate the:

8.21 Reading on ammeter $\mathbf{A_1}$ (6)

8.2.2 Power dissipated in the 15 Ω resistor (4)

phys

8.2.3 Reading on voltmeter $\mathbf{V_2}$ (3)

8.3 Switch **S** is now opened.

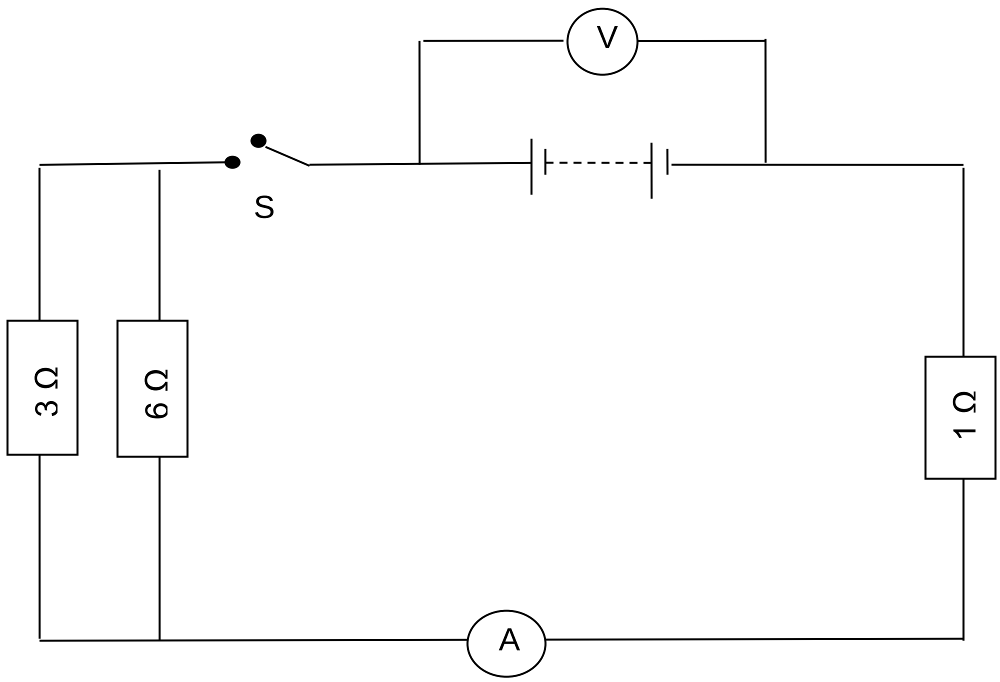
8.3.1 How will the reading on the ammeter $\mathbf{A_1}$ be affected? Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

8.3.2 How will the reading on voltmeter $\mathbf{V_1}$ be affected? Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

[21]

QUESTION 9

The battery in the circuit diagram below has an emf (ε) of 12 V and an unknown internal resistance **r**. The resistance of the connecting wires and the ammeter is negligible.



9.1 Write down the reading on voltmeter **V** when switch **S** is open. (2)

___

Switch **S** is now closed. The reading on voltmeter **V** changes to 9 V.

9.2 Calculate the total external resistance of the circuit. (5)

9.3 Calculate the internal resistance, **r** , of the battery. (6)

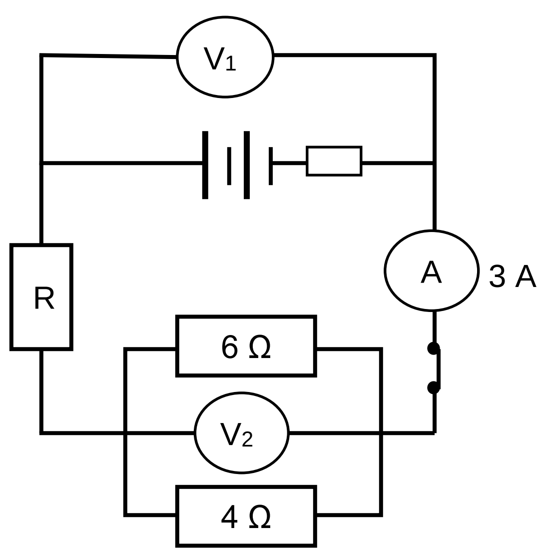
9.4 Calculate the power for 1 Ω resistor. (4)

9.5 Calculate the energy dissipated in 1 Ω resistor in 20 s. (4)

[21]

QUESTION 10

When the switch in the circuit is opened the voltmeter 1 reads 12.V. When the switch is closed the reading drops to 10 V and the ammeter reading is 3 A.



10.1 What is the reading of the ammeter when the switch is open? (1)

10.2 What is the emf (ε) of the battery?

(1)
(3)

10.3 Calculate the equivalent resistance of the resistors connected in parallel.

(3)

10.4 What is the reading of voltmeter V_2?

10.5 Determine the internal resistance of the battery.

(3)

10.6 What is the total external resistance of the circuit?

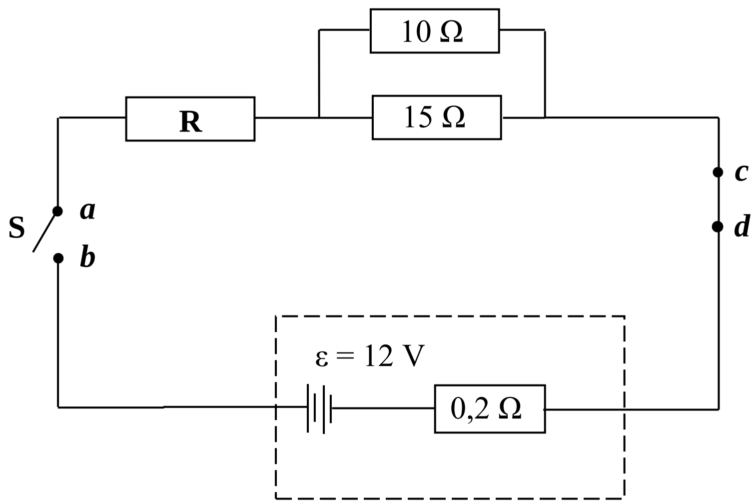
(3)

10.7 If the resistor of 6 Ω burns out. How does this affect the reading of the ammeter and the reading of voltmeter **1**? Explain the answer. (4)

[18]

QUESTION 11 (DBE/November 2016)

11.1 In the circuit below the battery has an emf (ε) of 12 V and an internal resistance of 0,2 Ω. The resistances of the connecting wires are negligible.



11.1.1 Define the term *emf of a battery.* (2)

____

____

____

11.1.2 Switch **S** is open. A high-resistance voltmeter is connected across points ***a*** and ***b***.
What will the reading on the voltmeter be? (1)

____

11.1.3 Switch **S** is now closed. The same voltmeter is now connected across points ***c*** and ***d***.
What will the reading on the voltmeter be?

____ (1)

When switch **S** is closed, the potential difference across the terminals of the battery is 11,7 V.
Calculate the:

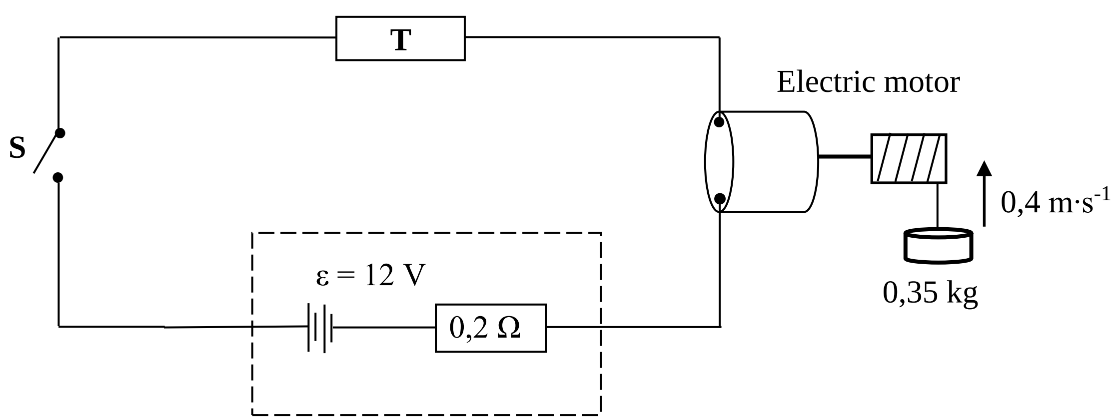
11.1.4 Current in the battery (3)

11.1.5 Effective resistance of the **parallel** branch (2)

11.1.6 Resistance of resistor **R** (4)

11.2 A battery with an emf of 12 V and an internal resistance of 0,2 Ω are connected in series to a very small electric motor and a resistor, **T**, of unknown resistance, as shown in the circuit below.

The motor is rated **X** watts, 3 volts, and operates at optimal conditions.



When switch **S** is closed, the motor lifts a 0,35 kg mass vertically upwards at a constant speed of 0,4 $m \cdot s^{-1}$. Assume that there is no energy conversion into heat and sound.

Calculate the value of:

11.2.1 **X** (3)

11.2.2 The resistance of resistor **T** (5)

[21]

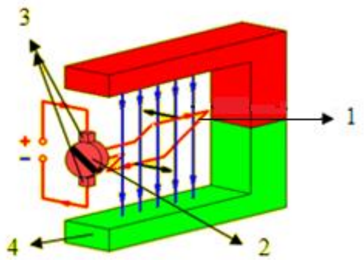
TOPIC 3: ELECTRICITY AND MAGNETISM

3.3. ELECTRODYNAMICS

3.3.1 ELECTRICAL MACHINES

Direct current motor (DC–motor)

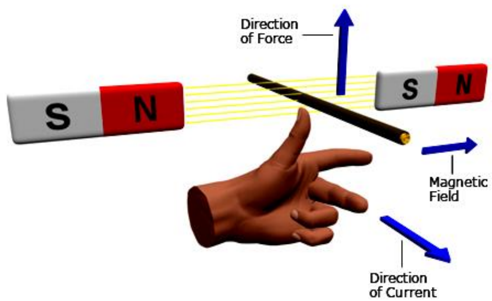
<u>Motors convert electrical energy into (rotational) mechanical energy.</u>



<u>Elements of the DC-motor:</u>

1. Coil.
2. Split-ring (commutator).
3. Carbon brushes.
4. Two poles of magnet (permanent magnets)

Fleming's left hand (motor) rule



The thumb shows the direction of the force, the first finger shows the direction of current and the second finger shows the direction of the magnetic field. The thumb, the first finger and the second finger must be at a right angle to (90^0) each other.

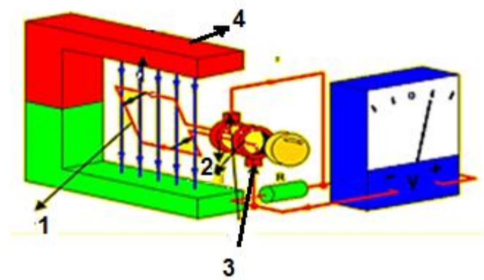
AC and DC Generators

AC Generators

<u>Generators convert mechanical energy into electrical energy.</u>

The generator is based on the principle of "electromagnetic induction"

<u>Elements of the AC generator:</u>

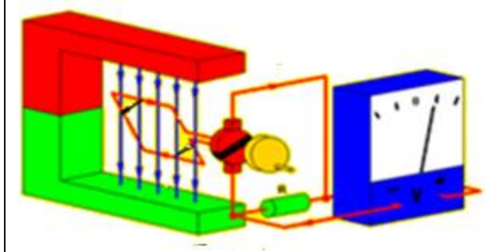


1

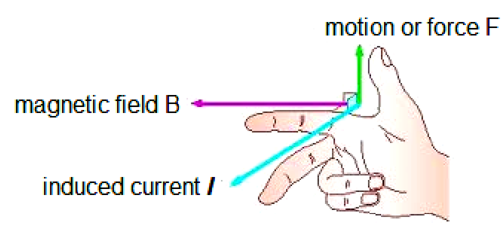
1-Coil.
2-Slip-rings.
3-Carbon brushes.
4-Two poles of magnet (permanent magnets).

The DC generator (Dynamo)

The DC generator or dynamo is similar to the AC generator, but the slip rings are replaced by split ring (commutator) to get direct current (current that flows in one direction).



Fleming's right hand (dynamo) rule (for generators)

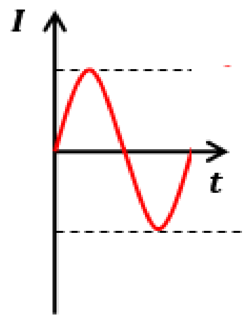
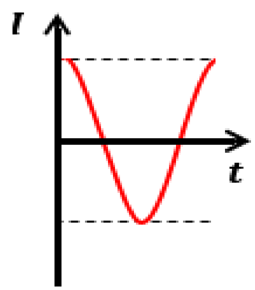
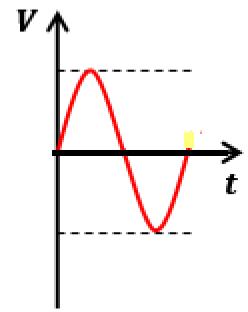
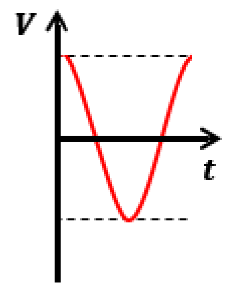


The thumb represents the direction of motion of the conductor.
The first finger represents the direction of the magnetic field (north to south).
The second finger represents the direction of the induced or generated current (the direction of the induced current will be the direction of conventional current - from positive to negative).

phys

3.3.2. ALTERNATING CURRENT

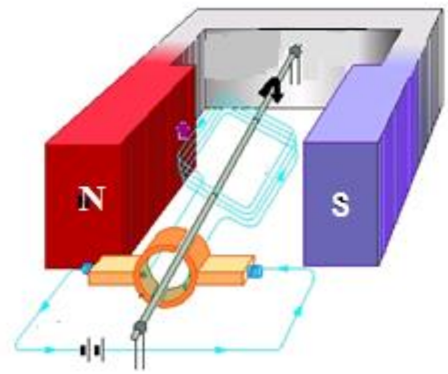
Alternating current ***(AC) is an oscillating electric current that varies*** **sinusoidally with time,** ***reversing its direction of flow periodically.***

Advantages of AC over DC	Graphs a		rms values		Average power
	Current versus time	Voltage versus time	Current	Voltage	
Easy to be transformed (step up or step down using a transformer). Easier to convert from AC to DC than from DC to AC. Easier to generate. It can be transmitted at high voltage and low current over long distances with less energy lost. High frequency used in AC makes it suitable for motors.	For one complete cycle  OR 	For one complete cycle  OR 	***The root-mean-square current*** ***is the value of the voltage/current in an AC circuit that will have the same heating effect as a DC circuit.*** $I_{rms} = \frac{I_{max}}{\sqrt{2}}$ $I_{max} = \frac{V_{max}}{R}$	***The root-mean-square voltage*** ***is the value of the voltage/current in an AC circuit that will have the same heating effect as a DC circuit.*** $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ Where $V_{max} = I_{max}R$	$P_{ave} = I_{rms}V_{rms}$ $I_{rms} = \frac{V_{rms}}{R}$ OR $V_{rms} = I_{rms}R$ **For series connection:** $P_{ave} = (I_{rms})^2R$ For parallel connection: $P_{ave} = \frac{V_{rms}^2}{R}$

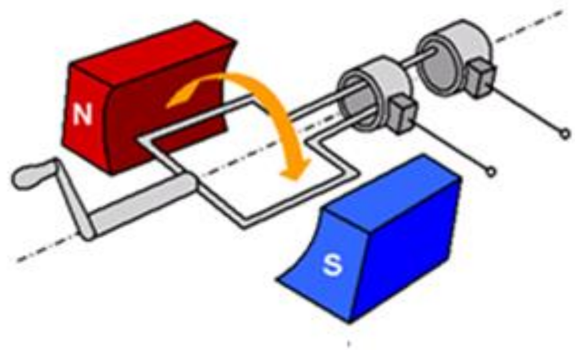
EXAMPLE

QUESTION 1

The simplified diagrams below represent an electric motor and a generator.



X



Y

1.1 Which ONE of the diagrams above represents a simplified diagram of an electric motor? Give a reason for your answer. (2)

1.2 What type of generator (AC or DC) is represented in the simplified diagrams above? Give a reason for your answer. (2)

1.3 State ONE method of increasing the induced emf of this generator. (1)

1.4 Write down ONE use of electric motors. (1)

1.5 The maximum potential difference produced by this generator is 12 V and the frequency is 50 Hz.

1.5.1. Sketch a graph of the induced potential difference versus time. (3)

1.5.2. Calculate the induced rms potential difference. (3)

1.5.3. Calculate the average power dissipated if a 5 Ω resistor is connected to this generator. (3)

[15]

SOLUTION

QUESTION 1

1.1 X ✓. It converts electrical energy into mechanical energy.✓ (2)

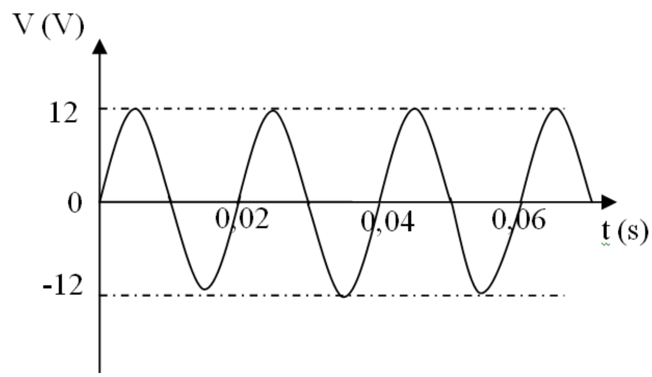
1.2 AC generator✓. It has slip rings.✓ (2)

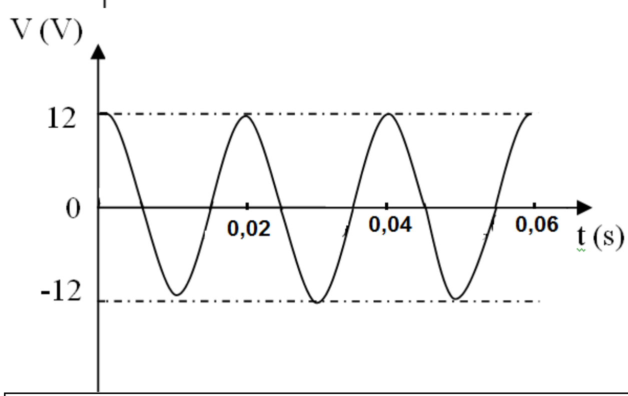
1.3 ANY ONE✓
Increasing the speed/frequency of rotation
Increasing the number of coils
Increasing the strength of the magnetic field
Insert a soft iron core
(1)

1.4 ANY ONE✓
- Pumps
- Fans
- Compressors
- Hair dryers

(1)

1.5.1





Criteria for marking the graph	
Any correct shape (sine or cosine) at least one cycle (one oscillation)	✓
Maximum voltage (12V and -12 V)	✓
Correct time (at least 0,02 s)	✓

(3)

1.5.2 $V_{rms}=\frac{V_{max}}{\sqrt{2}}$✓

$V_{rms}=\frac{12}{\sqrt{2}}$✓

$V_{rms}=8,49\ V$✓

(3)

1.5.3 **Option 1**

$P_{ave}=\frac{V_{rms}^2}{R}$✓

$P_{ave}=\frac{(8,49)^2}{5}$✓

$P_{ave}=14,42\ W$✓

Option 2

$I_{rms}=\frac{V_{rms}}{R}$

$I_{rms}=\frac{8,49}{5}$

$I_{rms}=1,698\ A$

$P_{ave}=I_{rms}^2R$✓

$=(1,698)^2(5)$✓

$P_{ave}=14,42\ W$ ✓

Option 3

$I_{rms}=\frac{V_{rms}}{R}$

$I_{rms}=\frac{8,49}{5}$

$I_{rms}=1,698\ A$

$P_{ave}=V_{rms}\ I_{rms}$✓

$=(8,49)(1,698)$✓

$P_{ave}=14,42\ W$ ✓

(3)
[15]

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 An electrical machine that uses a commutator and converts mechanical energy into electrical energy.

A DC generator

B AC generator

C DC motor

D AC motor (2)

1.2 The device that uses electrical energy to produce mechanical energy is called.

A Dynamo

B Alternator

C Electric motor

D Generator (2)

1.3 The basic physics principle on which an electric motor operates is known as …

A electromagnetic induction.

B Faraday's law of electromagnetic induction.

C Lenz's law.

D motor effect. (2)

1.4 The component of a DC motor that ensures that the coil rotates continuously in ONE DIRECTION is the ...

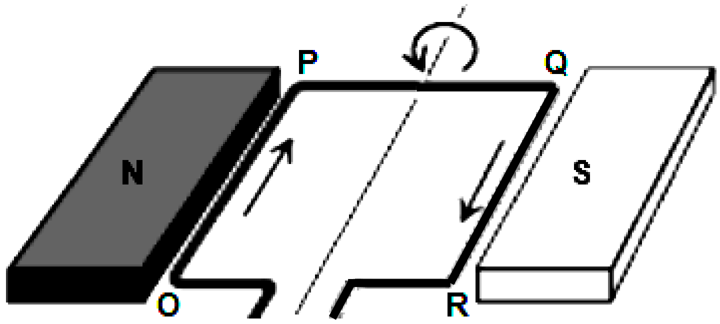
A slip rings.

B split ring.

C carbon brushes.

D battery. (2)

1.5 A DC current passes through a rectangular wire loop OPQR placed between two pole pieces of a magnet, as shown below.



Which TWO segments of the loop will experience an electromagnetic force when the loop is in the position above?

A OP and PQ

B QR and RO

C OP and QR

D RO and OP

____ (2)

1.6 Which ONE of the following changes may lead to an increase in the emf of an AC generator without changing its frequency?

A Decrease the area of the coil..

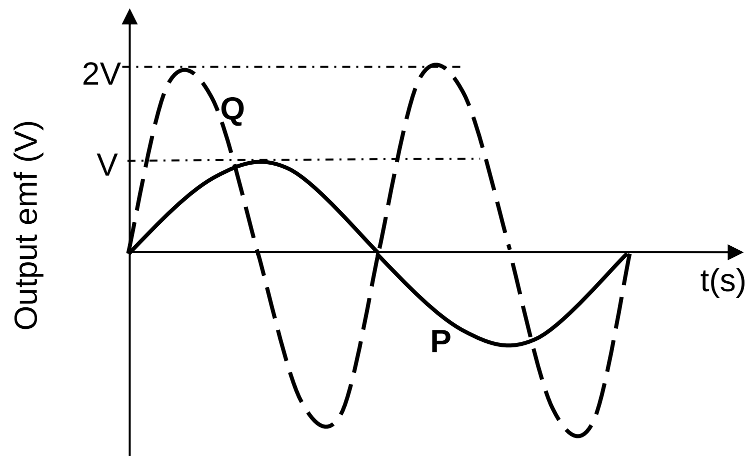
B Increase the area of the coil.

C Increase the resistance of the coil.

D Decrease the speed of rotation.

____ (2)

1.7 Graph **P** represents the output emf of an AC generator. Graph **Q** is the output emf after a change has been made using the SAME generator.



Which ONE of the following changes has been made to the generator to produce graph **Q**?

A The number of turns of the coil has been doubled.

B The surface area of the coil has been doubled.

C The speed of rotation has been doubled.

D The strength of the magnetic field has been doubled.

____ (2)

1.8 When electrical energy must be transported over long distances, the energy loss can be minimized if:

A the current is high and the voltage is low.

B the voltage is high and the current is low

C both the current and voltage is low.

D both the current and voltage is high.

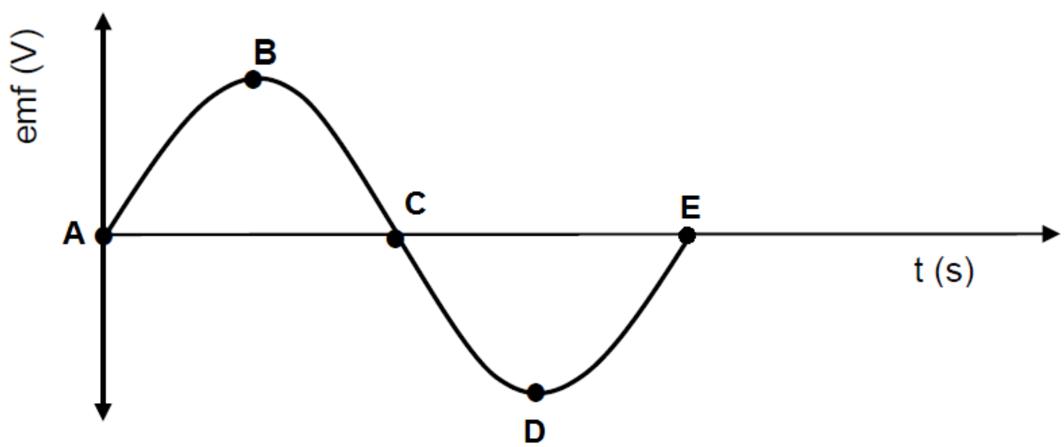
____ (2)

1.9 The speed of rotation of the coils in an AC generator is increased. Which ONE of the following combinations of frequency and output voltage for the generator will occur as a result of the change?

	FREQUENCY	**OUTPUT VOLTAGE**
A	Increases	Increases
B	No change	Increases
C	Decreases	Decreases
D	Increases	No change

(2)

1.10 The coil of an AC generator make one complete rotation. The resulting graph for the output emf is shown below.



The value of the induced emf **B** on the graph is obtained when the normal to the plane of the coil is at an angle (θ) of …

A 0º

B 90º

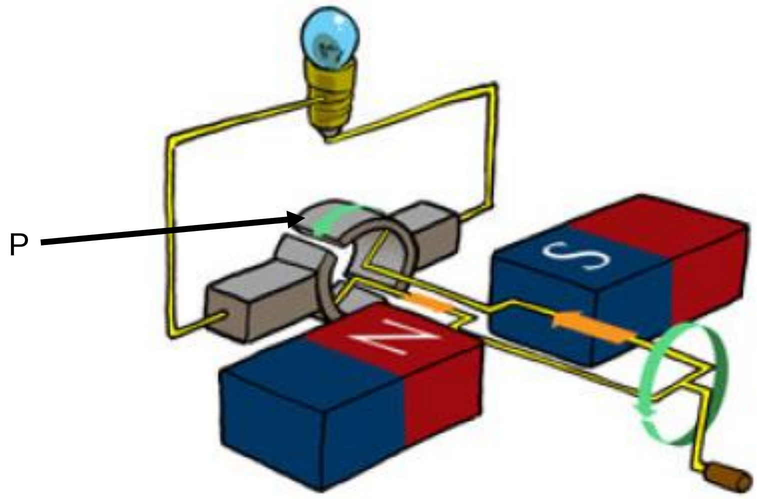
C 180º

D 270º

(2)
[20]

QUESTION 2

The diagram below represents and electrical machine and P is a split ring commutator.



2.1 Identify the type of electrical machine and write down the energy conversion that takes place in this electrical machine. (2)

____

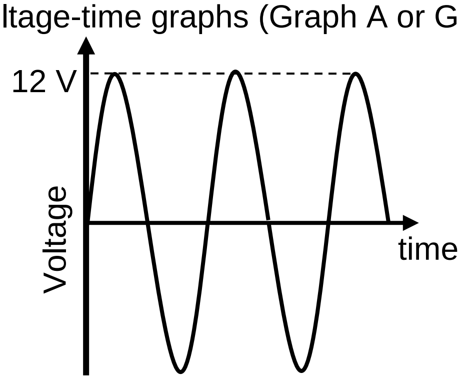
____

2.2 Identify the type of electrical machine and write down the energy conversion that takes place in this electrical machine. (2)

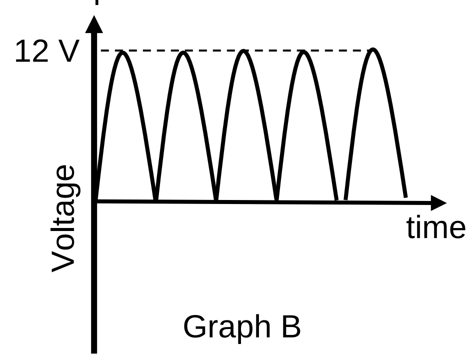
____

____

2.3 The split ring commutator is replaced by slip rings. Which ONE of the following voltage-time graphs (Graph A or Graph B) corresponds with the above change?



Graph A



Graph B

Explain the answer.

____

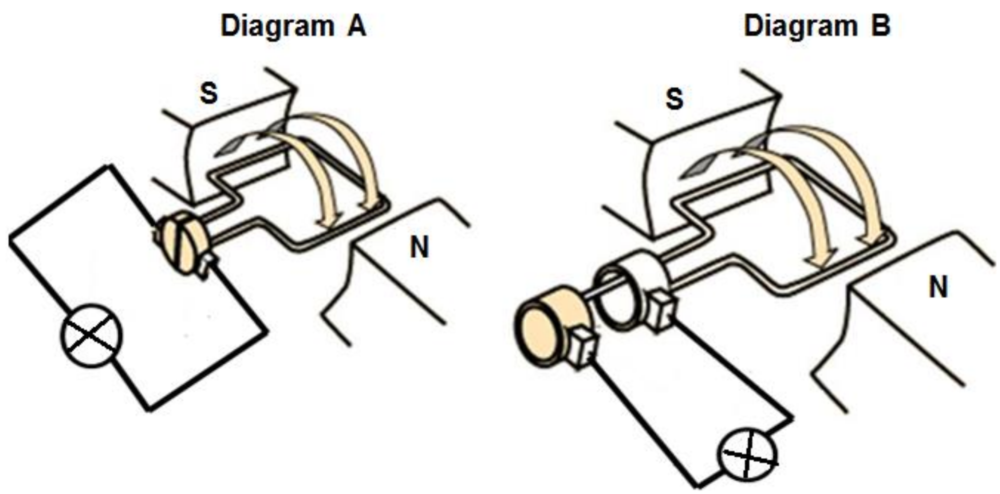
____ (3)

2.4 The light bulb shown in the circuit dissipates energy of 6 J per second. An identical light bulb is connected in parallel to it. Calculate the rms current in the circuit under the new conditions. Assume the emf remains unchanged. (5)

[12]

QUESTION 3

The following diagrams show two types of generators.



3.1 Which type of generator is represented by diagram A? (1)

____

3.2 Which type of generator is represented by diagram B? (1)

____

3.3 How do the generators shown above differ? Refer to the components they consist of. (2)

____

____

3.4. The generator in diagram **B** induces an rms voltage of 220 V. (3)

3.4.1 Calculate the maximum (peak) voltage induced.

3.4.2 Draw a graph of voltage versus time for one cycle (one complete rotation) in diagram B. Indicate in the graph the values of:

- rms voltage
- maximum (peak) voltage (4)

3.5 Write down two examples of the use of generators. (2)

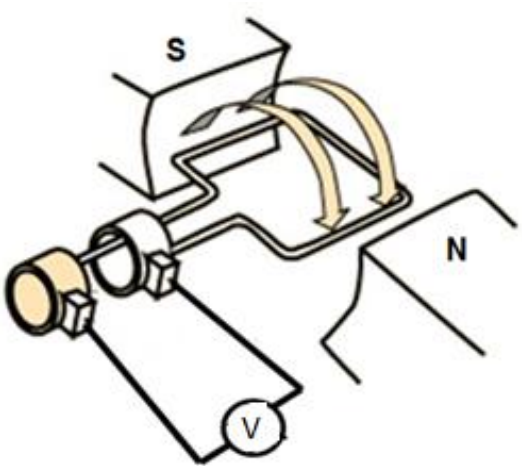
____

____

[13]

QUESTION 4

The basic components of an electric generator are shown in the diagram below.



4.1 Explain the basic operating principle of a generator? (2)

____

____

4.2 Explain the function of the slip rings in an AC generator. (1)

____

____

4.3 This generator with a maximum voltage of 24 V and frequency 50 Hz is connected to a resistor with a resistance of 265 Ω.

. Calculate

4.3.1 The rms current. (5)

4.3.2 The average power dissipated in the resistor. (3)

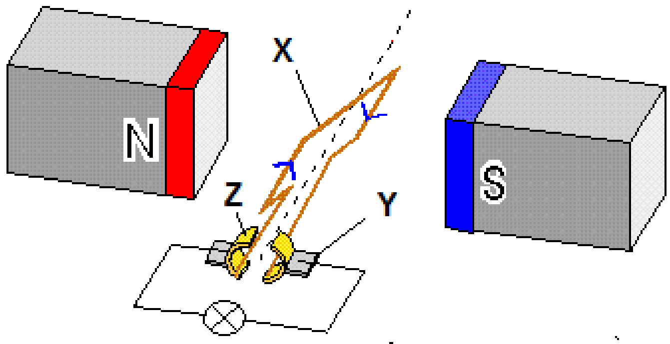
4.4 Suppose we would like the average power dissipated to be 8 W. Should the resistance be increased or decreased assuming the same AC generator is used? (1)

____ **[12]**

phys

QUESTION 5

The diagram below shows a simplified version of a generator. A light bulb of 25 Ω is connected to it with wires of negligible resistance.



5.1 What type of generator (AC or DC) is represented in the diagram? (1)

____

5.2 State the energy conversion in generators. (1)

____

5.3 Write down the name of component **X**. (1)

____

5.4 Explain the function of:

5.4.1 Component **Y** (1)

____

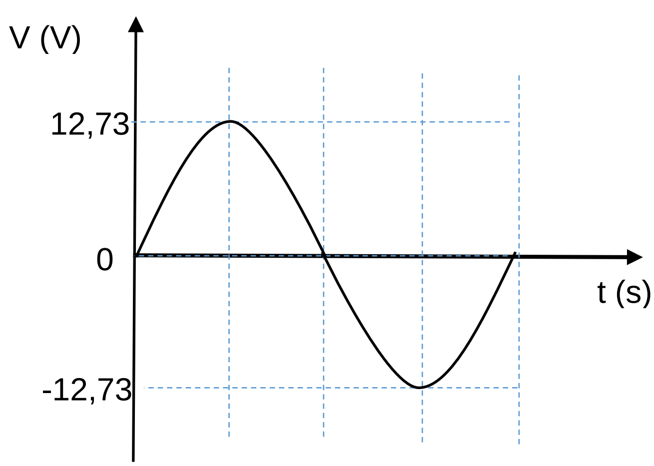
____

5.4.2 Component **Z** (1)

____

____

Component **Z** in the above generator is replaced by slip rings. The graph below shows how the potential difference across the light bulb, resistance 25 Ω, changes with time for one complete cycle when this generator is functioning.



phys

5.5 Calculate the:

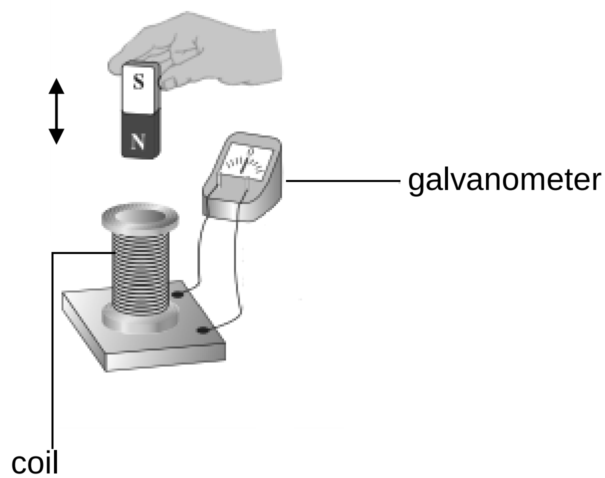
5.5.1 rms voltage across the light bulb. (3)

5.5.2 Average power dissipated in the bulb (3)

[11]

QUESTION 6 (DBE/November 2015)

6.1 A teacher demonstrates how current can be obtained using a bar magnet, a coil and a galvanometer. The teacher moves the bar magnet up and down, as shown by the arrow in the diagram below.



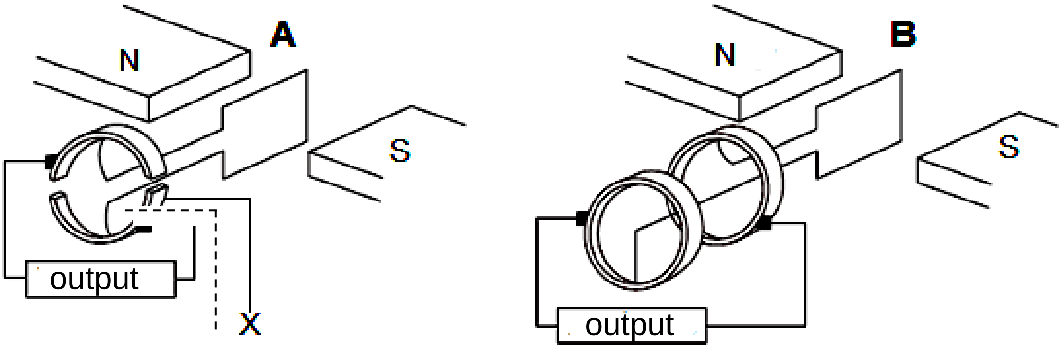
6.1.1 Briefly describe how the magnet must be moved in order to obtain a LARGE deflection on the galvanometer.

___

___

___ (2)

The two devices, **A** and **B**, below operate on the principle described in QUESTION 6.1.1 above.



6.1.2 Write down the name of the principle. (1)

____

6.1.3 Write down the name of part **X** in device **A**. (1)

____

6.2 A 220 V, AC voltage is supplied from a wall socket to an electric kettle of resistance 40,33 Ω. Wall sockets provide rms voltages and currents.

Calculate the:

6.2.1 Electrical energy consumed by the kettle per second

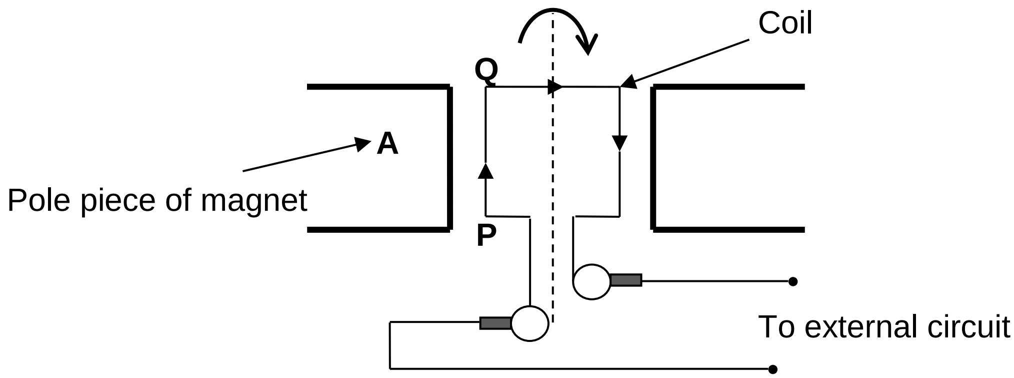
(4)

6.2.2 Maximum (peak) current through the kettle (3)

[11]

QUESTION 7 (DBE/Feb.–Mar. 2016)

7.1 A simplified sketch of an AC generator is shown below.



The coil of the generator rotates clockwise between the pole pieces of two magnets. At a particular instant, the current in the segment **PQ** has the direction shown above.

7.1.1 Identify the magnetic pole **A**.
Only write NORTH POLE or SOUTH POLE. (1)

____

7.1.2 The coil is rotated through 180º.

Will the direction of the current in segment **PQ** be from **P** to **Q** or **Q** to **P**?

____ (1)

7.2 An electrical device is connected to a generator which produces an rms potential difference of 220 V. The maximum current passing through the device is 8 A.

Calculate the:

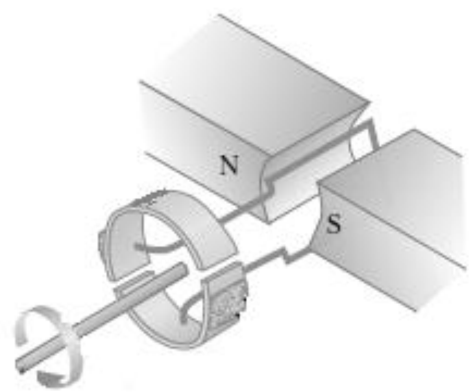
7.2.1 Resistance of the device (5)

7.2.2 Energy the device consumes in two hours (5)

[12]

QUESTION 8 (DBE/November 2016)

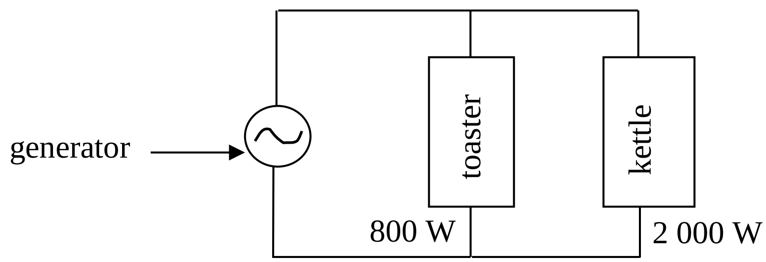
8.1 A generator is shown below. Assume that the coil is in a vertical position.



8.1.1 Is the generator above AC or DC? Give a reason for the answer. (2)

8.1.2 Sketch an induced emf versus time graph for ONE complete rotation of the coil. (The coil starts turning from the vertical position.) (2)

8.2 An AC generator is operating at a maximum emf of 340 V. It is connected across a toaster and a kettle, as shown in the diagram below.



The toaster is rated at 800 W, while the kettle is rated at 2 000 W. Both are working under optimal conditions.

Calculate the:

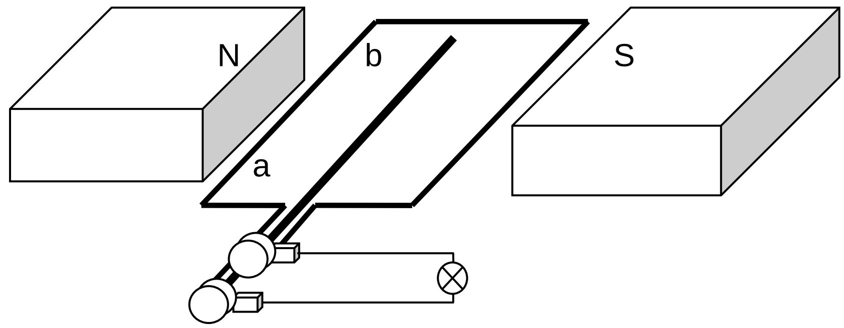
8.2.1 rms current passing through the toaster (3)

8.2.2 Total rms current delivered by the generator (4)

[11]

QUESTION 9 (FS/September 2016.)

9.1 A simplified diagram of an AC generator is shown below. The direction of the current in the coil is from **b** to **a**.



9.1.1 In which direction is the coil being rotated?
Write only CLOCKWISE or ANTICLOCKWISE. (1)

____

9.1.2 A maximum voltage is generated if the coil moves through the position indicated in the diagram above. Give an explanation for this observation. (2)

____

____

9.1.3 Starting from the position shown in the diagram above, sketch a graph of output voltage versus time for one complete cycle of the coil. (2)

9.1.4 State ONE way in which the generator shown above can be used to produce a higher output voltage.

____ (1)

9.1.5 Give ONE advantage for the use of alternating current.

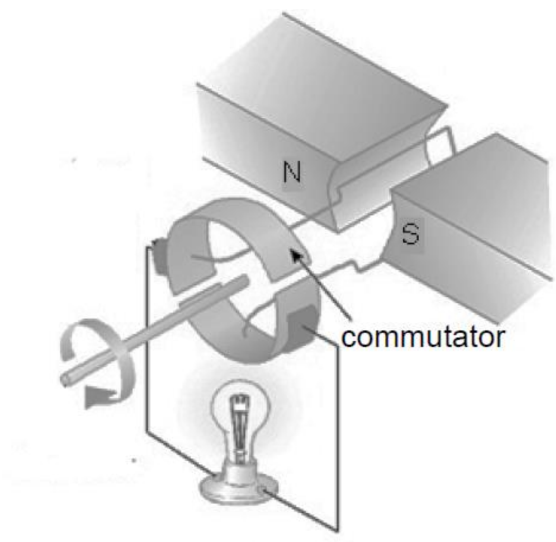
____ (1)

9.2 An electric fan with a power rating of 80 W is connected to an AC source which produces a maximum current of 7 A. Calculate the resistance of the fan. (5)

[12]

QUESTION 10 (DBE/November 2014)

10.1 A generator is shown below. Assume that the coil is in a vertical position.



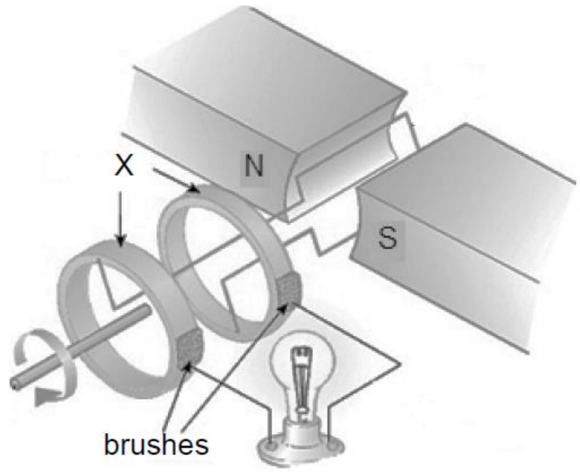
10.1. Name the principle on which the machine operates. (1)

____

10.2 Name THREE ways in which to make this bulb burn brighter. (3)

____
____
____

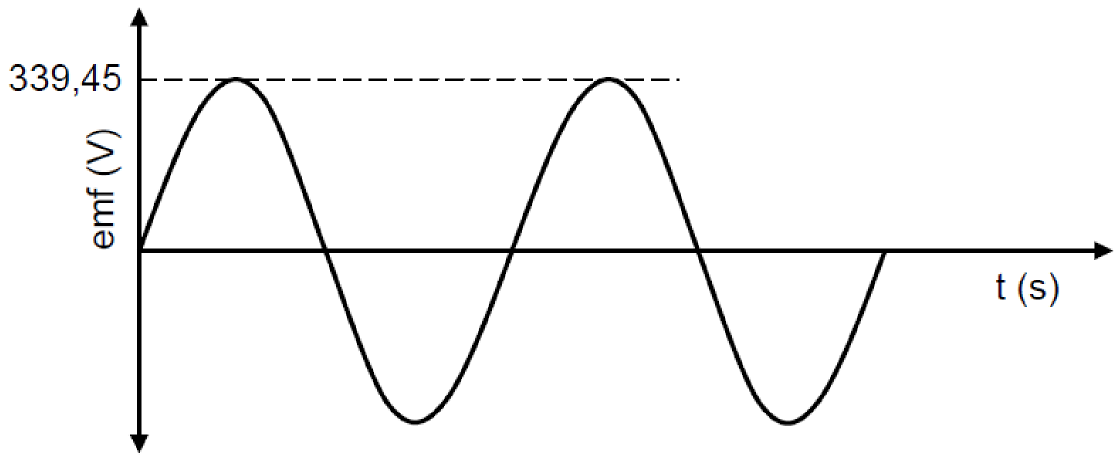
10.3 Some changes have been made to the machine and a new device is obtained as shown below.



10.3.1 Name part **X** in the new device. (1)

____

10.4 The graph of output emf versus time obtained using the device in QUESTION 9.3 is shown below.



:

10.4.1 Define the term *root mean square value* of an AC voltage. (2)

____

____

10.4.2 Calculate the rms voltage. (3)

[10

phys

TOPIC 4: MATTER AND MATERIALS
4.1. OPTICAL PHENOMENA AND PROPERTIES OF MATERIALS

<table>
<tr><th rowspan="2">ENERGY RADIATION</th><th colspan="2">PHOTOELECTRIC EFFECT</th><th colspan="2">SPECTRA</th></tr>
<tr><th>Theory</th><th>Photoelectric equation</th><th>Absorption</th><th>Emission</th></tr>
<tr>
<td>The energy radiated by hot objects is liberated in the form of separate packets of energy called quanta.
A quantum of energy is called photon
The energy of a photon is
$E = hf$

The energy of the radiation is $E = Nhf$ where N is the number of photons emitted.

Power of the radiating sources
$P = \frac{\Delta N}{\Delta t} hf$</td>
<td>Photoelectric effect is the process whereby electrons are ejected from a metal surface when light of suitable frequency is incident on that surface.
Threshold frequency, f_o, is the minimum frequency of light needed to emit electrons from a certain metal surface.
Work function, W_o, is the minimum energy that an electron in the metal needs to be emitted from the metal surface.
Effect of intensity on the photoelectric effect. The number of electrons emitted per unit time is proportional to the intensity of incident light.
Effect of frequency on the photoelectric effect. The maximum kinetic energy of the photoelectrons is linearly proportional to the frequency of the incident radiation.
Significance of the photoelectric effect. The photo-electric effect establishes the quantum theory and it illustrates the particle nature of light.</td>
<td>$E = W_o + E_{k(max)}$

Where $E = hf$

OR $E = \frac{hc}{\lambda}$

Maximum kinetic energy ($E_{K(\max)}$)

$E_{K(\max)} = \frac{m_e v_{\max}^2}{2}$

Work function

$W_0 = h\ f_0$

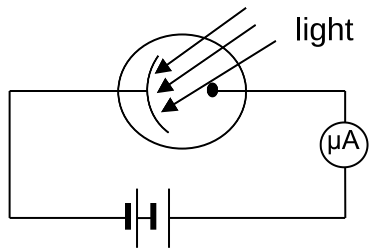
OR

$W_0 = \frac{hc}{\lambda_0}$</td>
<td>An atomic absorption spectrum is formed when certain frequencies of electromagnetic radiation that passes through a medium, e.g. a cold gas, is absorbed.</td>
<td>An atomic emission spectrum is formed when certain frequencies of electromagnetic radiation are emitted due to an atom's electrons making a transition from a high-energy state to a lower energy state.</td>
</tr>
</table>

EXAMPLE

QUESTION 1

The relationship between the maximum kinetic energy of ejected electrons (photo-electrons) and the frequency of radiation is being investigated.



Light of different frequencies is incident on the aluminium cathode of a photo-cell and the maximum kinetic energy of the ejected electrons are determined and recorded in the table below.

The table below shows the results obtained during the investigation.

Experiment	Frequency (f) (x 10^{15} Hz)	Maximum kinetic energy ($E_{k(max)}$) (x 10^{-19} J)
1	1.03	0
2	2.06	6.8
3	3.09	13.6
4	4.12	20.4
5	5.15	27.2

1.1 Define the term *threshold (cut off) frequency* in words. (2)

1.2 Draw a graph of maximum kinetic energy of the photoelectrons versus frequency of the incident radiation on the graph paper provided. (3)

The threshold frequency of aluminium is 4,3 x10^{14} Hz. Light of wavelength 330 nm is incident on the surface of the metal.

1.3 Calculate the maximum kinetic energy of the photo-electrons ejected. (4)

Light of the same frequency but higher intensity is now incident on the surface of the aluminium metal.

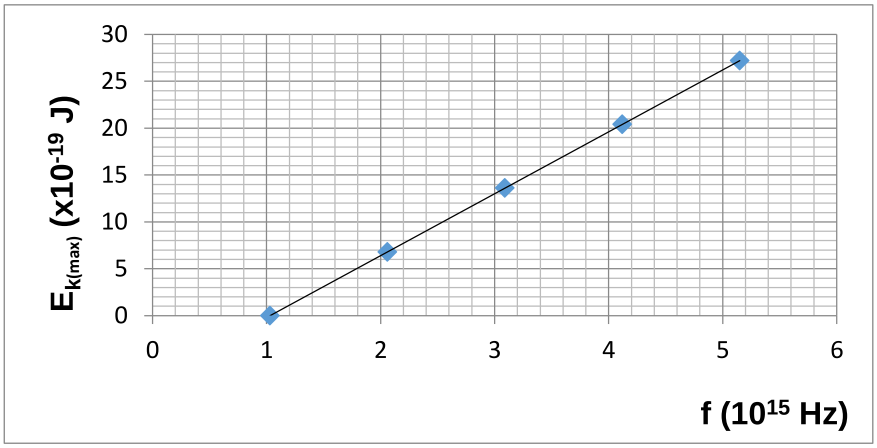
1.4 How will the value of the maximum kinetic energy be affected? Only write down INCREASES, DECREASES or REMAINS THE SAME.
Give a reason for the answer. (2)

[11]

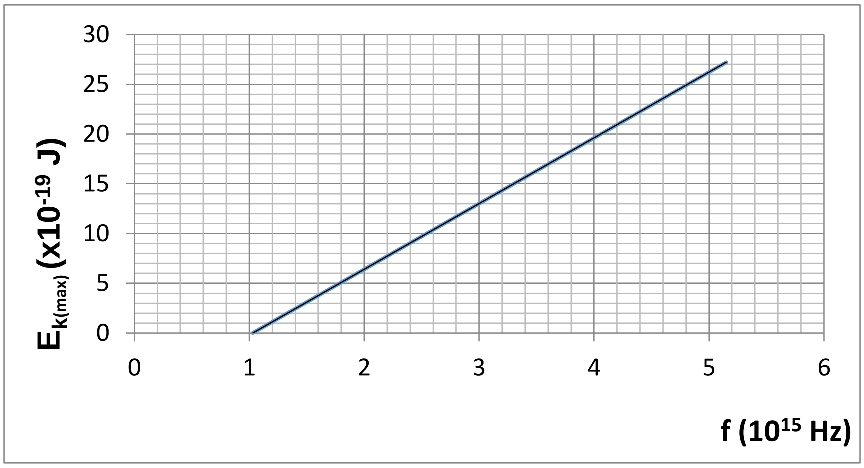
SOLUTION

1.1 Minimum frequency of the incident radiation✓ required to eject an electron from the metal surface.✓ (2)

1.2



OR



(3)

Criteria for marking the graph	Marks
Correct shape	1
Graph stars at 1,03 x 10^{15} Hz	1
Coordinates plotted correctly	1

1.3 **OPTION 1**

$E = W + E_{K(MAX)}$
$E_{K(MAX)} = E - W$
$E_{K(MAX)} = HF - HF_O$
$E_{K(MAX)} = HC/\Lambda - HF_O$
$E_{K(MAX)} = H(C/\Lambda - F_O)$

✓Any one

$E_{K(MAX)} = 6{,}63 \text{ X}10^{-34} \left(\frac{3\times10^{8}}{330\times10^{-9}}\right.$ ✓ $\left.- 4{,}3 \text{ X } 10^{14}\right.$ ✓$)$

$E_{K(MAX)} = 3{,}18 \text{ X}10^{-19}$ J ✓

OPTION2

$E_{K(max)}$ =E- W ✓

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6{,}63 \times 10^{-34} \times 3 \times 10^{8}}{3{,}30 \times 10^{-7}}$$

E= 6,03 X 10^{-19} J✓

W= hf_O

W= 6,63 X10^{-34} X 4,3 X 10^{14}

W= 28,51 X 10^{-20} J= 2,85 X 10^{-19} J✓

$E_{K(max)}$= 6,03 X 10^{-19} - 2,85 X 10^{-19}

$E_{K(max)}$=3,18 X 10^{-19} J✓ (4)

1.4 Remains the same ✓

Maximum kinetic energy of the photoelectrons ejected does not depend on the intensity of the incident radiation.✓

OR

Maximum kinetic energy of the photoelectrons ejected depends only on the frequency of the incident radiation and it remains the same (constant), ✓ (2)

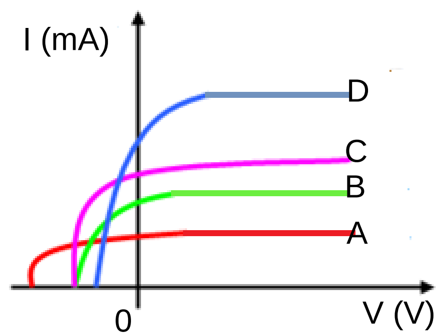
[11]

EXERCISES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 In an investigation to determine the effect of the intensity of a radiation on the photo-electric current, radiations of the same frequency with different intensities is incident on a photo-cell. The following graphs of current (I) versus potential difference (V) were obtained.



Which ONE of the curves corresponds to a radiation of the greatest intensity?

____ (2)

1.2 A grade 12 learner observes a sodium vapour light bulb through a spectroscope. The spectrum observed consists of …

A two dark lines on the yellow part of the spectrum of white light.

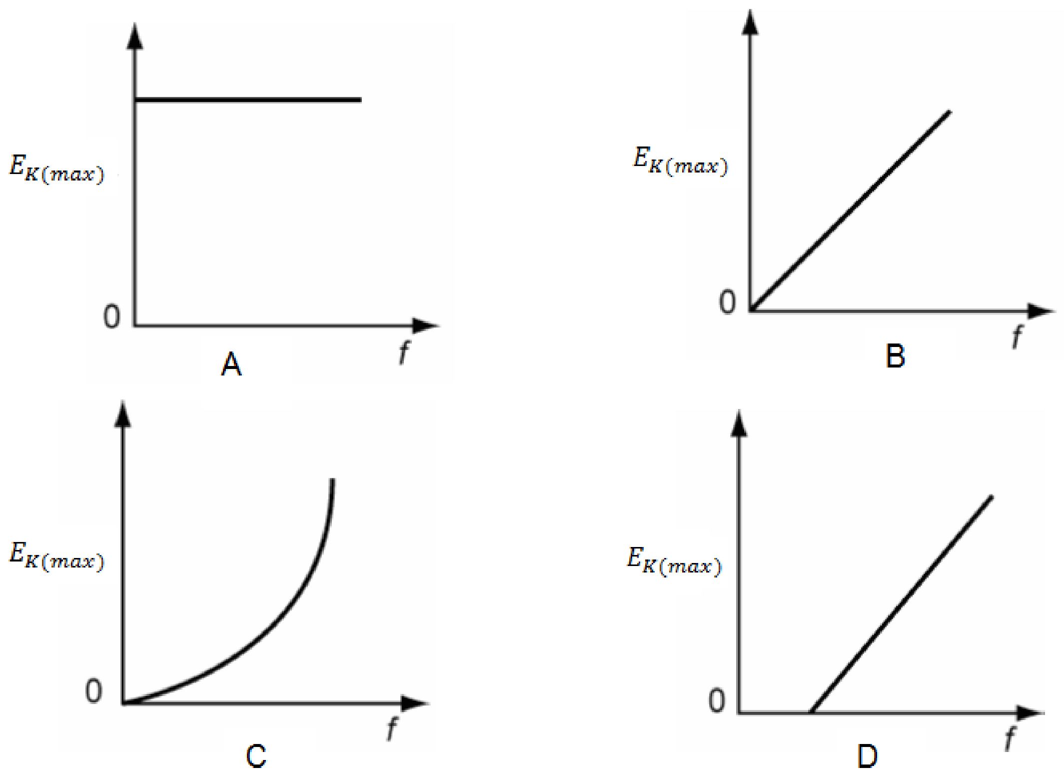
B a full range of colours.

C two yellow lines on a dark background.

D many dark lines on the spectrum of white light. (2)

____

1.3 Which ONE of the following graphs best illustrates the relationship between maximum kinetic energy (E_{kmax}) of the emitted electrons from a metal surface and frequency (*f*) of the incident light?



(2)

1.4 When light of a certain wavelength is incident on a metal surface, no electrons are ejected. Which ONE of the following changes may result in electrons being ejected from the metal surface?

A Increase the intensity of the light.

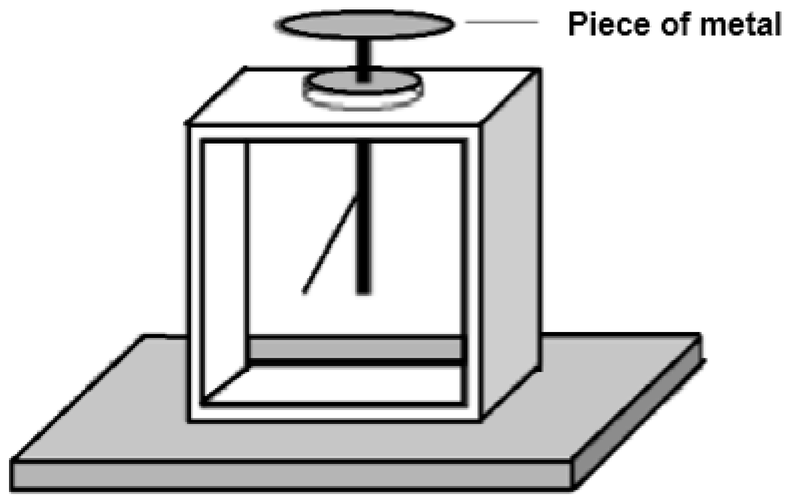
B Use light with a much shorter wavelength.

C Use metal with a larger work function.

D Increase the surface area of the metal.

(2)

1.5 Grade 12 learners investigate the effect of light on the emission of electrons from a metal surface. They use ultraviolet and red light respectively, together with an electroscope and a piece of metal that has been cleaned. First they used red light to see the effect on the deflection of the electroscope. After that they used ultraviolet light.



The phenomenon investigated is called …

A Doppler effect.

B Compton effect.

C photoelectric effect.

D thermal radiation. (2)

1.6 The wavelength of a monochromatic light source **P** is twice that of a monochromatic light source **Q**. The energy of a photon from source **P** will be … of a photon from source **Q**.

A a quarter of the energy

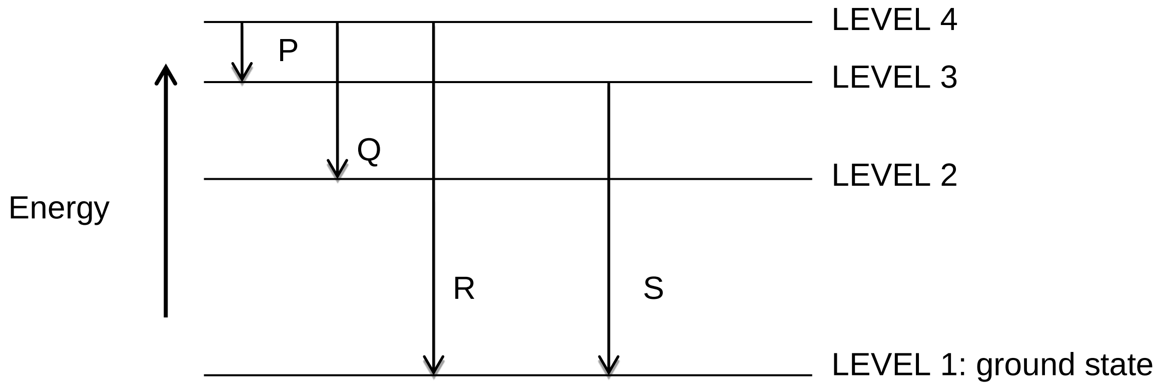
B half the energy

C equal to the energy

D twice the energy

(2)

1.7 The possible atomic transitions in an excited atom of an element are shown below.



Which transition will produce the spectral line with the longest wavelength?

A P

B Q

C R

D S (2)

1.8 Which ONE of the following phenomena gives a conclusive evidence for the particle nature of light?

A Diffraction

B Interference

C Doppler effect

D Photo-electric effect

(2)

1.9 A metal plate is illuminated with light of a certain frequency. Which of the following determine whether or not electrons are ejected?

A The material of which the plate is made

B The area of the plate.

C The intensity of the light

D How long the plate is exposed to the light. (2)

____

1.10 A bundle of BLUE light is incident on the cathode of a photo-electric cell. The milli-ammeter registers a current in the circuit. The BLUE light is removed and ULTRA-VIOLET light with a lower intensity is incident on the same photo-electric cell. How does the amount of electrons emitted per second and the maximum speed of the photoelectrons compare when ULTRA-VIOLET light is used?

	Amount of electrons emitted per second	**Maximum speed of photoelectrons**
A	Decreases	Decreases
B	Increases	Decreases
C	Decreases	Increases
D	Stays the same	Increases

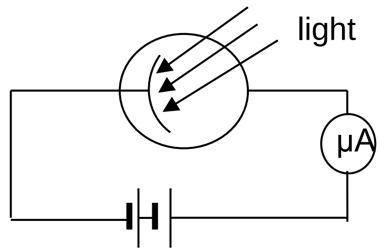
(2)

____

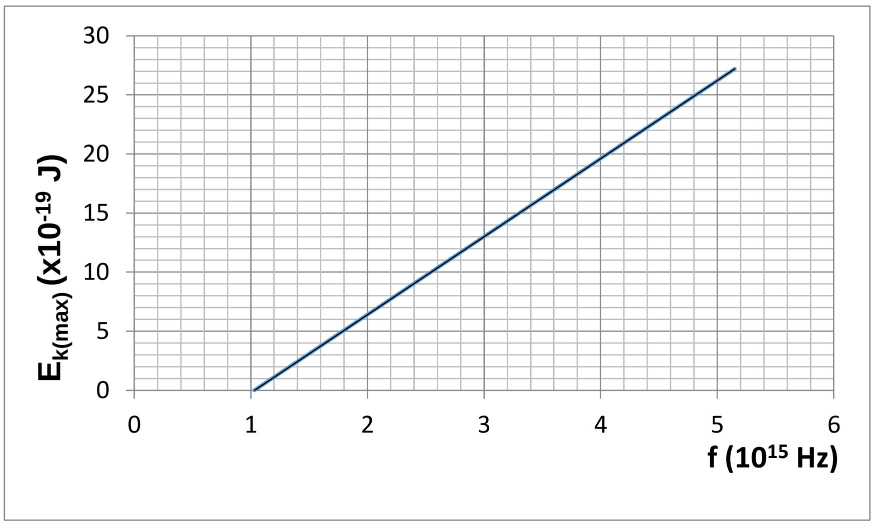
[20]

QUESTION 2

The relationship between the maximum kinetic energy of ejected photo-electrons and the frequency of radiation is being investigated.



Light of different frequencies are incident on the aluminium cathode of a photo-cell and the kinetic energy of the ejected photo-electrons are determined. The graph below is drawn according to the data collected from the investigation.



2.1 Write down an investigative question for this investigation. (2)

2.2 Write down the:

2.2.1 independent variable (1)

2.2.2 controlled variable (1)

2.3 Write down a possible conclusion for this investigation. (2)

Aluminium is now replaced by another metal **X** with work function 8 x10 $^{-19}$ J. The incident light has a wavelength of 200 nm.

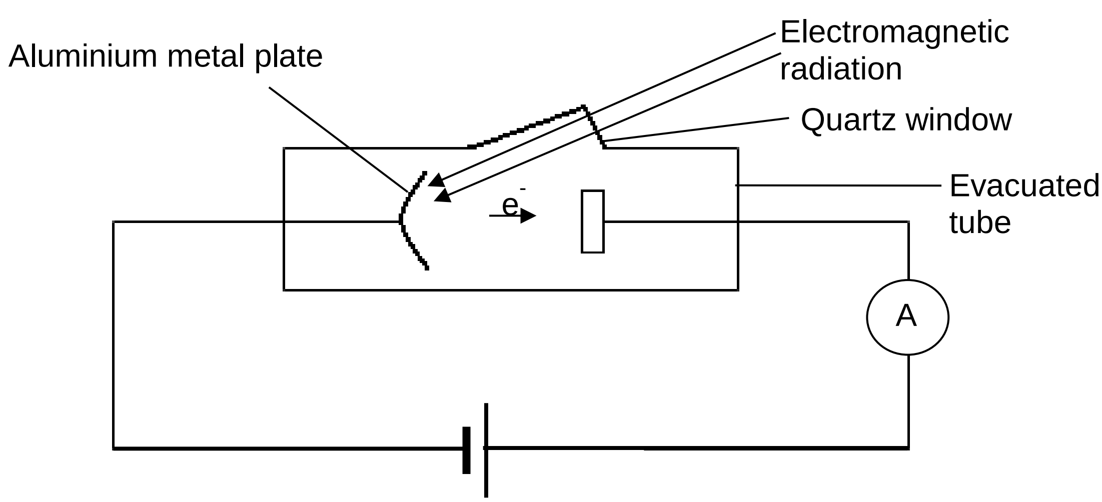
2.4 Calculate the maximum kinetic energy of the electrons ejected from the surface of the metal. (5)

2.5 The intensity of the incident light is now increased. How will this affect the maximum kinetic energy calculated in QUESTION 2.4?
Give a reason for the answer. (2)

2.6 The wavelength of the incident light is now increased keeping the intensity constant. How will this affect the maximum kinetic energy calculated in QUESTION 2.4? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)
[14]

QUESTION 3

The diagram below shows an aluminium metal plate that emits electrons when radiation of wavelength 200 nm is incident on it. The aluminium metal plate is connected to a source of potential difference and an ammeter that reads the saturated current as shown in the circuit below.



3.1 Name the phenomenon described above. (1)

3.2 State the significance of this phenomenon. (2)

The work function of aluminium is $6{,}7 \times 10^{-19}$ J.

3.3 Define the term *work function* of a metal in words. (2)

3.4 Calculate the maximum kinetic energy of the ejected photoelectrons. (4)

3.5 How will the reading on the ammeter change if the intensity of the electromagnetic radiation is increased? Write down INCREASES, DECREASES or REMAINS THE SAME. Explain your answer. (3)

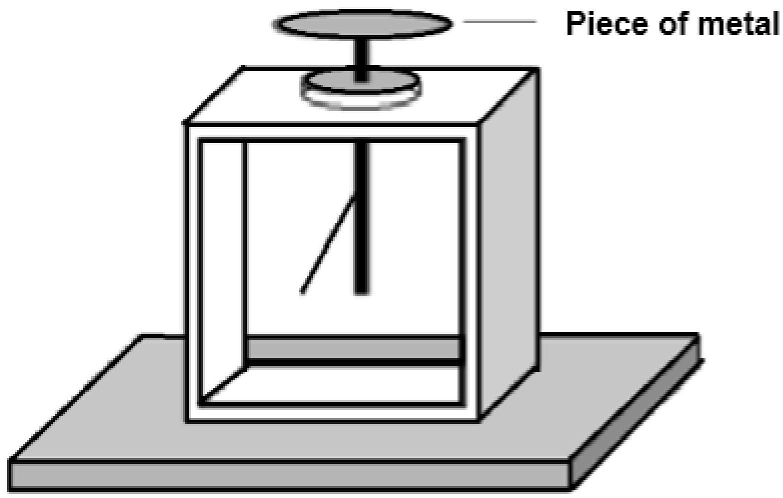
3.6 Incident radiation with a greater frequency is now used. How will the reading on the ammeter change? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

[13]

phys

QUESTION 4

Grade 12 learners investigate the effect of frequency of light on the emission of electrons from a metal. They use ultraviolet and red light respectively, together with an electroscope and a piece of metal that has been cleaned. First they used red light to see the effect on the deflection of the electroscope. After that they used ultraviolet light.



4.1 Name the phenomenon that the learners are investigating. (1)

____

4.2 Write down an investigative question for this investigation. (2)

____

____

4.3 For this investigation write down:

4.3.1 the independent variable. (1)

____

4.3.2 the dependent variable. (1)

____

4.3.3 a control variable. (1)

____

phys

4.4 Light with a wavelength of 7.8×10^{-7} m shines on the metal. The metal has a work function of $1{,}8 \times 10^{-19}$ J.

4.4.1 Define *work function* in words. (2)

____

____

4.4.2 Calculate the maximum kinetic energy of the ejected electrons. (5)

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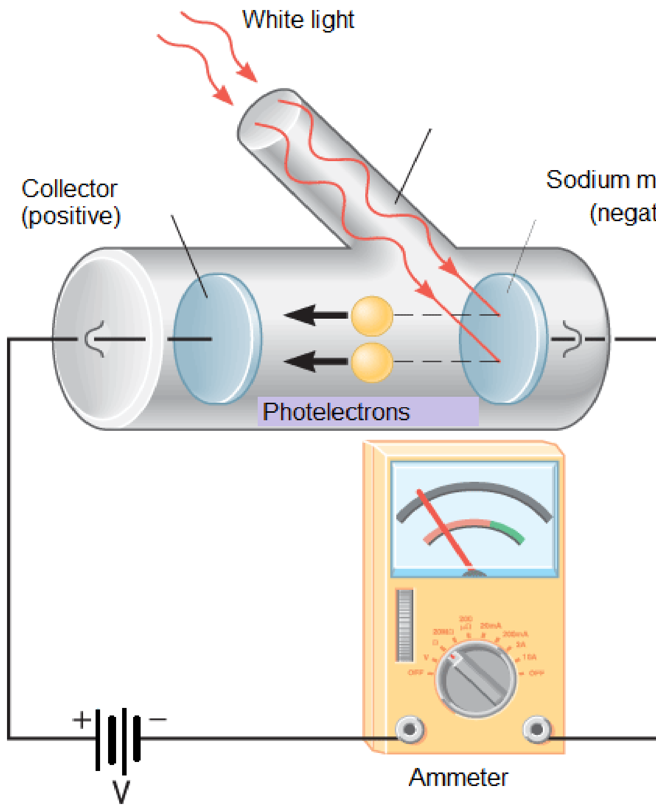
phys

QUESTION 5

In the diagram below a beam of white light containing frequencies between 4 x 10 ^{14}Hz and 8 x 10^{14} Hz is incident on a sodium metal plate which has a work function of 3,65 x 10^{-19} J. Electrons are ejected, which are them attracted to a positively charged "collector" plate. The result is an electric current that can be measured with an ammeter.



5.1 Define the term *work function in* words. (2)

___

___

5.2 What is the range of frequencies in this beam of light for which electrons are ejected from the sodium surface? (4)

5.3 Calculate the maximum kinetic energy of the photoelectrons that are ejected from this surface. (4)

5.4 The intensity of white light incident on the sodium metal is now increased.

How will the reading of the ammeter be affected? Only write down INCREASES, DECREASES or REMAINS THE SAME.
Explain the answer. (3)

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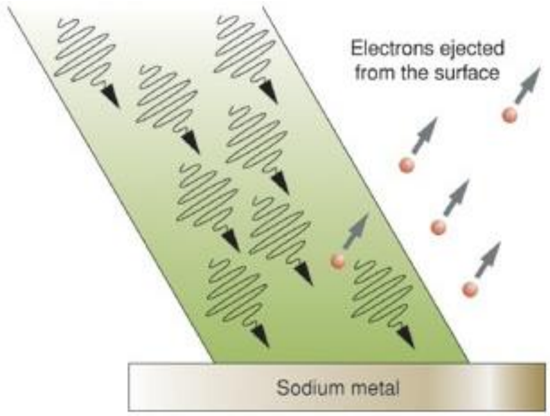
[13]

phys

QUESTION 6

A beam of violet light is falling on a sodium metal plate of work function $3,65 \times 10^{-19}$ J. It is found that electrons are ejected from the metal surface.



6.1 Identify the optical phenomenon explained above. (1)

____

6.2 What nature of light is deduced from this optical phenomenon? (1)

____

6.3 Explain the term work function. (2)

____

____

6.4 If the ejected electrons have a maximum velocity of $5,14 \times 10^5$ m.s^{-1}, calculate the wavelength of the violet light used. (5)

6.5 The intensity of the violet light is increased while using the same sodium metal plate.

6.5.1 What effect does this have on the number of electrons ejected? Write only INCREASES, DECREASES and REMAINS THE SAME. (1)

____

6.5.2 Explain your answer to QUESTION 6.5.1. (2)

____

____

____

Ultra violet is an electromagnetic wave having shorter wavelength than violet rays. Sun is a major source of this radiation. <u>There are views that exposure to sun is advantageous and also dangerous.</u>

6.6 Motivate the statement that is underlined. (2)

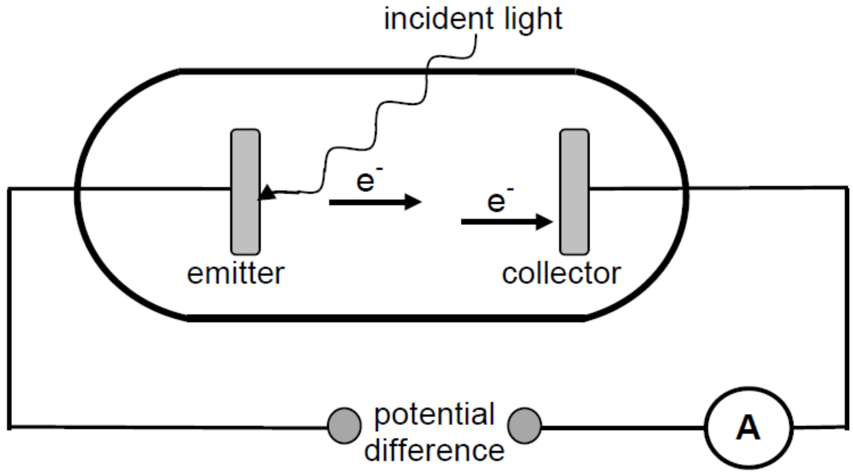
____

____

[14]

QUESTION 7

The apparatus below is used to demonstrate the photoelectric effect.



7.1 Define the term *photoelectric effect* in words. (2)

___

___

The incident monochromatic light transfers 8,0 x 10^{-9} J of energy in one second to a certain area of the emitter. The wavelength of a photon in the incident light is 260 nm. If one photon releases one electron, calculate the:

7.1.2 Number of electrons released from the surface of that area of the emitter in one second (5)

7.1.3 Current produced, in amperes (4)

7.2 The sketches below show examples of a line EMISSION and A*BSORPTION spectra*.

Hydrogen emission spectrum

Hydrogen absorption spectrum

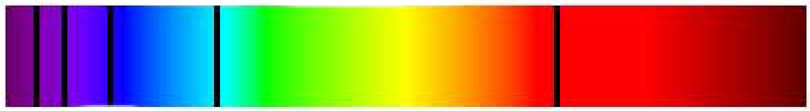


Figure 5

7.2.1 Explain the difference between *atomic absorption spectra* and *atomic emission spectra*. (4)

____

____

____

[13]

QUESTION 8 (DBE/November 2015)

In an experiment to demonstrate the photoelectric effect, light of different wavelengths was shone onto a metal surface of a photoelectric cell. The maximum kinetic energy of the emitted electrons was determined for the various wavelengths and recorded in the table below.

INVERSE OF WAVELENGTH $\frac{1}{\lambda}$ **(× 10^{6} m^{-1})**	**MAXIMUM KINETIC ENERGY** $E_{k(max)}$ **(× 10^{-19} J)**
5,00	6,60
3,30	3,30
2,50	1,70
2,00	0,70

8.1 What is meant by the term *photoelectric effect?* (2)

____

____

8.2 Draw a graph of $E_{k(max)}$ (y-axis) versus $\frac{1}{\lambda}$ (x-axis). (3)

8.3 USE THE GRAPH to determine:

8.3.1 The threshold frequency of the metal in the photoelectric cell (4)

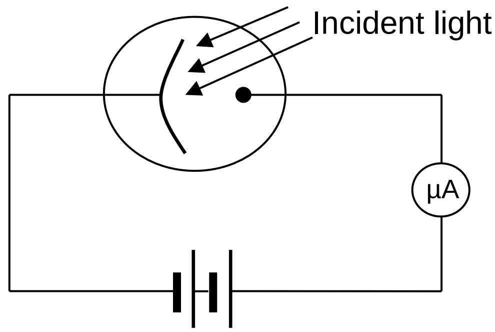
8.3.2 Planck's constant (4)

[13]

QUESTION 9 (DBE/Feb.–Mar. 2016)

An investigation was conducted to determine the effects of changes in frequency AND intensity on the current generated in a photoelectric cell when light is incident on it.

The apparatus used in the investigation is shown in the simplified diagram below.



The results of the experiment are shown in the table below.

EXPERIMENT	FREQUENCY (Hz)	INTENSITY (Cd)	CURRENT (μA)
A	$4,00 \times 10^{14}$	10	0
B	$4,50 \times 10^{14}$	10	0
C	$5,00 \times 10^{14}$	10	0
D	$5,01 \times 10^{14}$	10	20
E	$5,01 \times 10^{14}$	20	40
F	$6,50 \times 10^{14}$	10	30

9.1 Define the term *work function*. (2)

____

____

9.2 Identify an independent variable. (1)

____

The threshold frequency for the metal used in the photocell is $5,001 \times 10^{14}$ Hz.

9.3 Define the term *threshold frequency.* (2)

____

____

9.4 Calculate the maximum speed of an emitted electron in experiment **F**. (5)

In experiments **D** and **E**, the current doubled when the intensity was doubled at the same frequency.

9.5 What conclusion can be made from this observation? (2)

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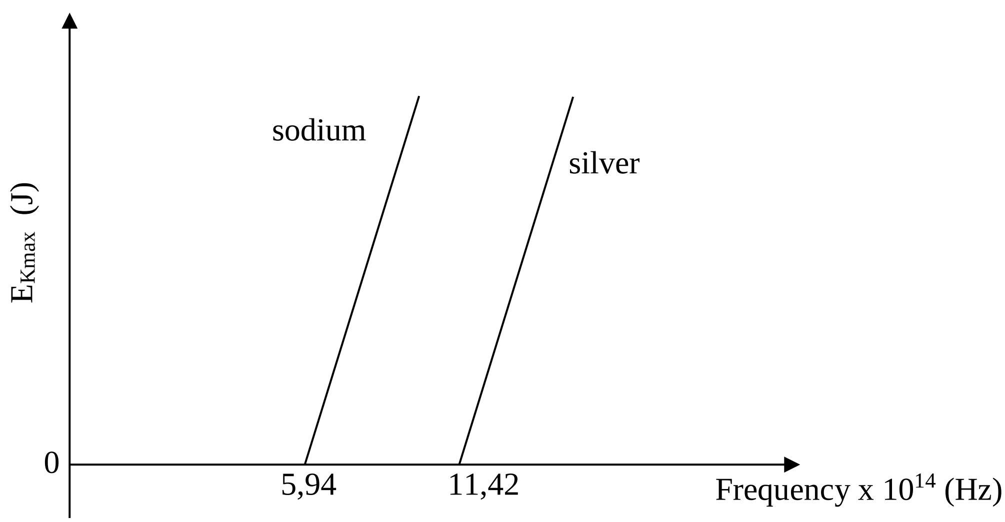
QUESTION 10 (DBE/November 2016)

10.1 A learner is investigating the photoelectric effect for two different metals, silver and sodium, using light of different frequencies. The maximum kinetic energy of the emitted photoelectrons is plotted against the frequency of the light for each of the metals, as shown in the graphs below.



10.1.1 Define the term *threshold frequency*. (2)

10.1.2 Which metal, sodium or silver, has the larger work function? Explain the answer. (3)

____

____

____

10.1.3 Name the physical constant represented by the slopes of the graphs. (1)

____

10.1.4 If light of the same frequency is shone on each of the metals, in which metal will the ejected photoelectrons have a larger maximum kinetic energy? (1)

____

10.2 In a different photoelectric experiment blue light obtained from a light bulb is shone onto a metal plate and electrons are released.
The wavelength of the blue light is 470×10^{-9} m and the bulb is rated at 60 mW. The bulb is only 5% efficient.

10.2.1 Calculate the number of photons that will be incident on the metal plate per second, assuming all the light from the bulb is incident on the metal plate. (5)

10.2.2 **Without any further calculation**, write down the number of electrons emitted per second from the metal. (1)

____

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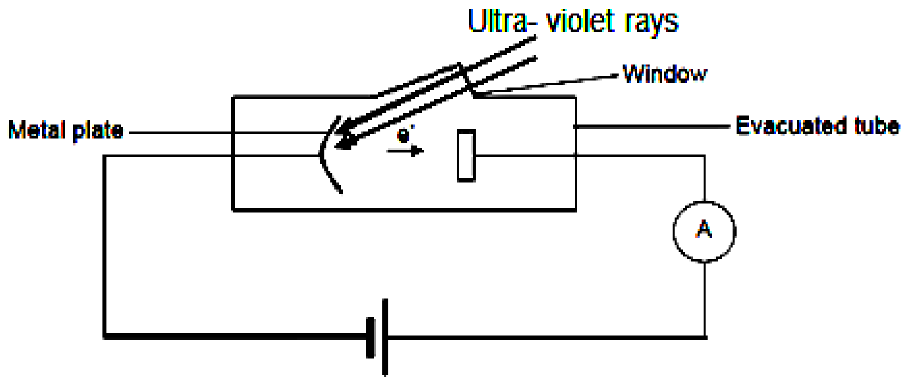
QUESTION 11

A group of grade 12 learners were investigating the dependence of work function of different metals on the kinetic energy of the ejected electrons. They used an apparatus as shown in the sketch below.



Ultra- violet rays of wavelength 2×10^{-8} m is passed through a window and allowed to fall on different metal plates and the corresponding maximum kinetic energy is measured. The learners summarised their observations in the following table.

Name of the metal plate used	Maximum kinetic energy ($\times 10^{-18}$ J)
Cesium	9.61
Lead	9.28
Potassium	9.58
Silver	9.19
Zinc	9.56

11.1 Define the term *work function*. (2)

11.2 Write an investigative question for the learners' investigation. (2)

11.3 Identify the following in the learners' investigation

11.3.1 Dependent variable (1)

11.3.2 Independent variable (1)

11.3.3 Controlled variable (1)

phys

11.4 Without using calculations identify the metal having the highest work function in the learners' investigation. (2)

____

11.5 Explain your answer to QUESTION 11.4 using Einstein's equation for the photoelectric effect. (3)

____
____
____
____

11.6 Use the observation table of the learners to find the work function of lead. (5)

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phys