Physical Sciences

TEST & EXAM PREPARATION

Retha Louw

GRADE
12
CAPS

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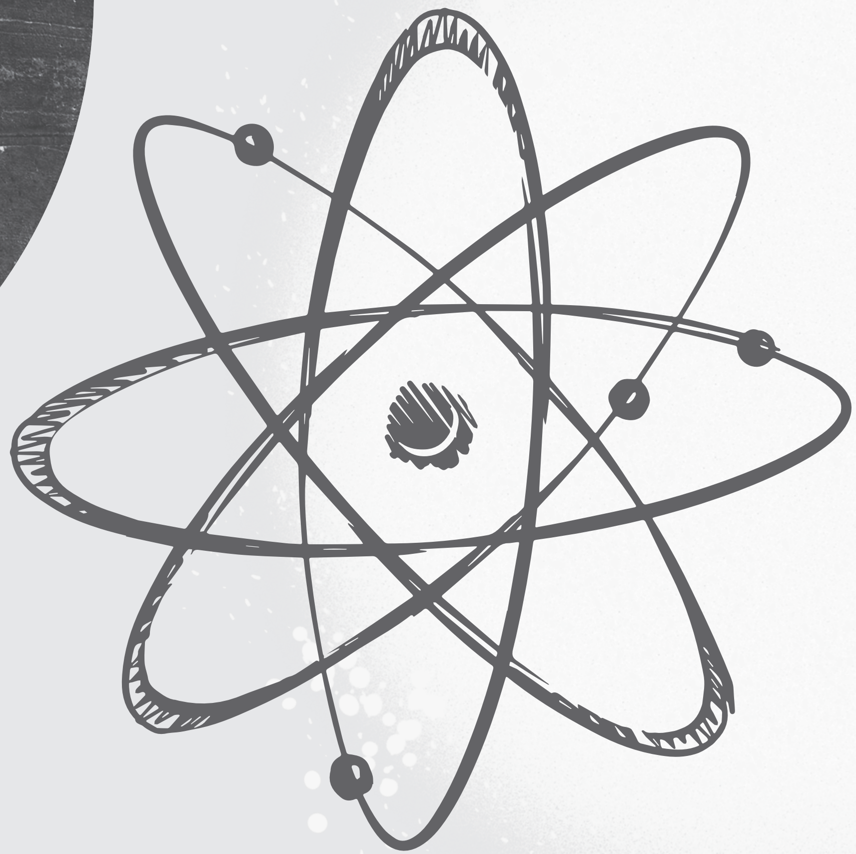

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Topic-based Questions & Answers

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1: MECHANICS

Forces; Newton's Laws

Multiple choice questions

Question 1

1.1 In which of the following cases will the resultant force on an object be zero?
An object which . . .

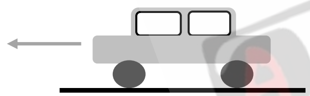
A falls freely.

B moves at constant speed on a circular path.

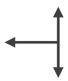
C undergoes equal displacements in equal time intervals.

D moves with constant acceleration.

1.2 A car moves horizontally at a constant velocity of 60 km·h^{-1}, in the direction shown.



Which one of the following vector diagrams indicates all the forces acting on the car?

A


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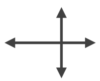
C


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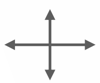
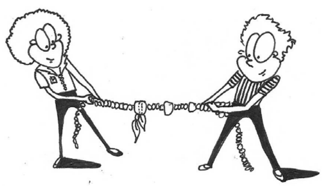
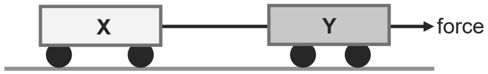
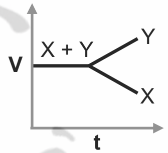




1.3 Two trolleys, X and Y, connected by a rope, move along a horizontal surface while being pulled by a constant non-zero resultant force. Friction is negligible. The rope between the trolleys suddenly snaps.



Which one of the following graphs best represents the state of motion **before** and **after** the rope snapped?

A


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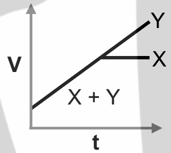

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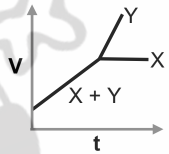

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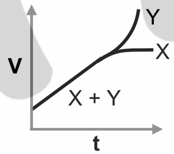
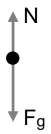


1.4 A girl enters a lift on the ground floor of a building and after travelling non-stop, gets out on the tenth floor. Which one of the following free-body diagrams is the best representation of the size and direction of the forces acting on the girl just before the lift stops on the tenth floor?

A


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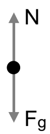

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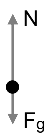

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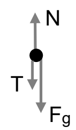


1.5 A log of wood is attached to a cart by means of a light, inelastic rope. A horse pulls the cart along a rough, horizontal road with an applied force **F**.
The total system accelerates initially with an acceleration of magnitude **a** (Figure 1). The forces acting on the cart, during the acceleration, are indicated in Figure 2.

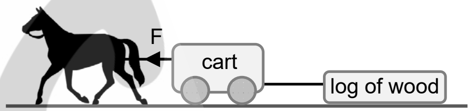


Figure 1

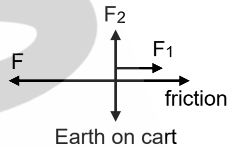


Figure 2

Which one of the following combinations would be the most appropriate labels for F_1 and F_2?

	F_1	F_2
A	Force of log on cart	Reaction force of Earth on cart
B	Force of log on cart	Force of road on cart
C	Force of rope on cart	Reaction force of Earth on cart
D	Force of rope on cart	Force of road on cart

1.6 The acceleration due to gravity at a point on the surface of the Earth is **g**. What would be the gravitational acceleration on the surface of another planet of the same mass, but which has double the diameter of the Earth?

A 4g   **B** 2g

C $\frac{1}{2}$g   **D** $\frac{1}{4}$g

Newton's Laws of Motion

Question 2

A boy (mass 12 kg) is playing on his Jungle Gym. He holds on to the pole and slips down, accelerating downwards from the platform.

2.1 Using a dot to represent the boy, draw a labelled free-body diagram to show the forces acting on the boy while slipping down the pole.

2.2 State *Newton's second law of motion*.

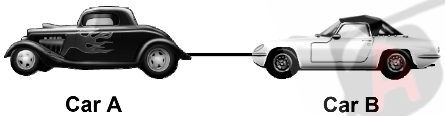
2.3 Calculate the magnitude of the frictional force between the boy and the pole if his acceleration downwards is 2,0 $m \cdot s^{-2}$.

Halfway down he lets go and falls on to the sand, hitting it with a vertical speed of 1,7 $m \cdot s^{-1}$.

2.4 If the indent he makes in the sand is 100 mm deep, calculate the average force of the sand on the boy.

Question 3

Car A is towing Car B with a light tow rope. The cars move along a straight, horizontal road.



3.1 When they begin to move, Car A exerts a forward force of 600 N on Car B by means of the tow rope. The force of friction on Car B is now 200 N. The mass of Car B is 1 200 kg.

Calculate the initial acceleration of Car B.

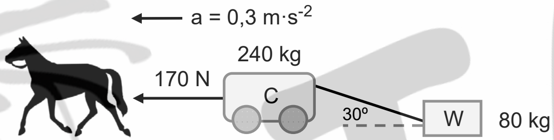
3.2 After a while the cars travel at constant velocity. The force exerted by the tow rope on Car B is now 300 N and the force of friction on Car B has increased. What is the magnitude and direction of the force of friction on Car B now?

3.3 Towing with a rope is very dangerous. A solid tow bar should be used in preference to a tow rope. This is especially true should Car A suddenly apply brakes. What would be the advantage of the solid tow bar over the tow rope in such a situation?

3.4 The mass of Car A is also 1 200 kg and both cars experience friction of 300 N. Car A and Car B are joined by a solid tow bar. Car A exerts a braking force of 9 600 N. Over what distance will the cars stop if they were moving at a velocity of 20 $m \cdot s^{-1}$?
Ignore the mass of the bar.

Question 4

A horse pulls a cart, C, mass 240 kg, with an attached log of wood, W, mass 80 kg, on a horizontal road. W is tied to the back of C by means of an inelastic rope, which forms an angle of 30º to the horizontal. The horse applies a force of 170 N on cart C and the system accelerates at 0,3 $m \cdot s^{-2}$ to the left. The force of friction on the cart is 40 N. The weight of the rope can be ignored.



4.1 Draw a free-body diagram for cart C, indicating and labelling all the forces acting on it.

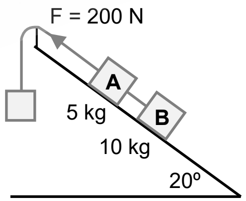
4.2 Calculate:

4.2.1 the magnitude of the force which the rope exerts on C.

4.2.2 the force of friction on W.

Question 5

A force of 200 N is needed to pull two bodies A and B, with masses as indicated in the sketch, upwards.



5.1 Draw a free-body diagram of all the forces acting on body A if the plane is frictionless.

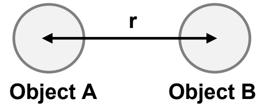
5.2 Determine the acceleration of the system of the two bodies.

5.3 Calculate the force T in the cable between the two bodies.

Newton's Law of Universal Gravitation

Question 6

Study the diagram:



A and B exert a gravitational force, X, on each other if their centre points are a distance, r, apart.

How will the force between them be affected, if . . .

6.1 the distance between the centre points is tripled?

6.2 the mass of A is doubled?

6.3 the distance between the centre points is reduced four times and only one of the masses doubled?

Question 7

The Earth has a mass of 6×10^{24} kg and an average radius of $6,4 \times 10^{6}$ m. A research satellite which has a mass of 200 kg moves in a fixed orbit around the Earth.

7.1 Calculate the orbital distance (in kilometres) above the Earth's surface, if the Earth has to apply a force of $1,9 \times 10^{3}$ N in order to keep the satellite in orbit.
($G = 6,67 \times 10^{-11}\ N \cdot m^2 \cdot kg^{-2}$)

7.2 State the law applicable to Question 7.1.

Momentum and Impulse

Multiple choice questions

Question 8

8.1 Which expression represents the change in momentum of an object?

A $\frac{F_{net}}{m}$ **B** $\frac{F_{net}}{\Delta t}$ **C** $F_{net}.m$ **D** $F_{net}.\Delta t$

8.2 A mass of 2 kg hits a wall at a velocity of 8 $m \cdot s^{-1}$. It bounces back at 6 $m \cdot s^{-1}$. The size of the impulse is. . .

A 4 N·s **B** 2 N·s **C** 28 N·s **D** 14 N·s

Test 2

Section A

Question 1

Give ONE word or term for each of the following:

1.1 The rate of change in velocity.

1.2 The change in momentum.

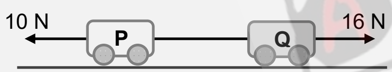
1.3 The product of the magnitude of a force on an object and the distance that the object moves in the direction of the force.

1.4 The product of the mass and the velocity of an object.

1.5 The unit of measure equal to one joule per second. [5]

Question 2

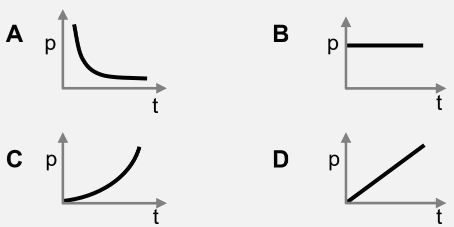
2.1 Two trolleys, P and Q, of equal mass, are connected by a light, inelastic rope. A constant force of magnitude 10 N is applied to the left on P while a constant force of magnitude 16 N is applied to the right on Q. The trolleys move on a frictionless, horizontal surface.



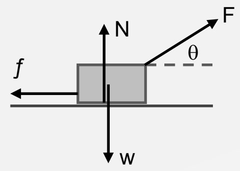
The tension in the string between the trolleys is equal to . . .

A 26 N **B** 13 N **C** 16 N **D** 6 N

2.2 Which ONE of the following momentum versus time graphs best represents the motion of an object that starts from rest and moves in a straight line under the influence of a constant net force?



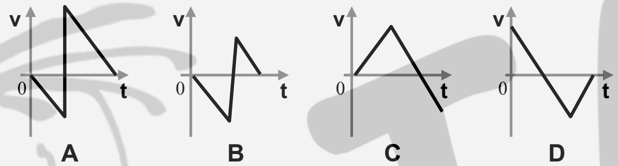
2.3 An object is pulled along a straight horizontal road to the right without being lifted. The force diagram alongside shows all the forces acting on the object.



Which ONE of the following forces does positive work on the object?

A w **B** N **C** f **D** F

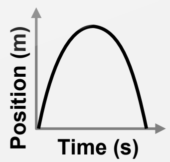
2.4 Which ONE of the following graphs is the correct one for the motion of a ball that falls to the ground and bounces back?
(Take upward direction as positive).



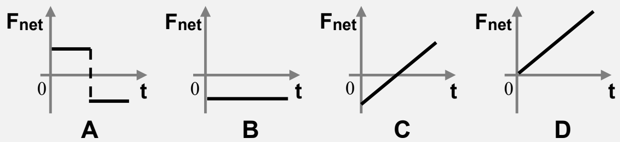
2.5 A certain planet X has half the mass of the Earth and twice the radius. If the acceleration due to the gravitational force of the Earth is g, what will be the value of the gravitational acceleration on or near the planet X?

A $\frac{g}{4}$ **B** $\frac{g}{8}$ **C** 4g **D** 8g

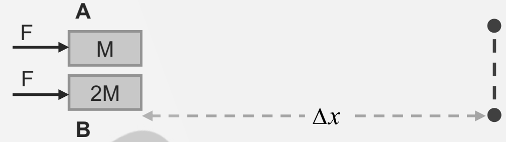
2.6 A cricket ball is thrown vertically upwards into the air and then caught again. The parabolic graph alongside is the position-time graph of the ball.



If air resistance is ignored, which one of the following correctly shows the corresponding graph of the resultant force versus time for the cricket ball?



2.7 An object A, of mass **M** is pushed along a frictionless, horizontal plane by a horizontal force **F**, through a distance Δx as shown in the diagram. Another object B, of mass **2M**, is pushed along the same plane by an equal force through an equal distance **s**.



Which object will reach the finishing line first, and how will their momentums compare when they each pass the finishing line?

	Object reaching the finishing line first	Momentum
A	B	They will have the same momentum
B	B	A will have more momentum
C	A	B will have more momentum
D	A	They will have the same momentum

2.8 Which of the following correctly describes the effect of a resultant force on an object?

A If the object is moving with a constant velocity, there is a constant resultant force on it.

B The change in momentum of the object is equal to the resultant force on it.

C The rate of change of velocity of the object with time is directly proportional to the resultant force on it.

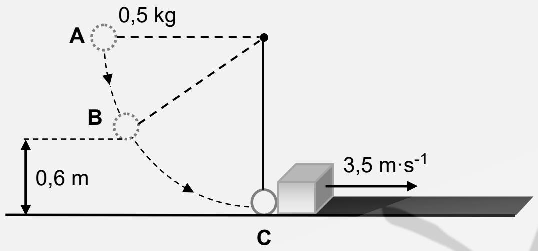
D The mass of the object changes in direct proportion to the force on it.

[8 × 2 = 16]

Section B

Question 3

A steel ball of mass 0,5 kg is suspended from a string of negligible mass. It is released from rest at point A, as shown in the sketch below. As it passes through point B, which is 0,6 m above the ground, the magnitude of its velocity is 3 m·s^{-1}. (Ignore the effects of friction.)



3.1 Write down the *principle of the conservation of mechanical energy* in words. (2)

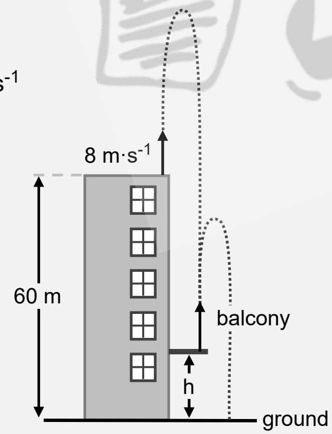
3.2 Calculate the mechanical energy of the steel ball at point B. (4)

3.3 As the steel ball swings through its lowest position at point C, it collides with a stationary crate of mass 0,1 kg. Immediately after the collision, the crate moves at a velocity of 3,5 m·s^{-1} to the right. Calculate the velocity of the steel ball immediately after the collision. (7)

[13]

Question 4

An object is projected vertically upwards at 8 m·s^{-1} from the roof of a building which is 60 m high. It strikes the balcony below after 4 s. The object then bounces off the balcony and strikes the ground as illustrated alongside. Ignore the effects of friction.



4.1 Is the object's acceleration at its maximum height **upward**, **downward** or **zero**? (1)

4.2 Calculate the:

4.2.1 magnitude of the velocity at which the object strikes the balcony. (4)

4.2.2 height, **h**, of the balcony above the ground. (5)

4.3 The object bounces off the balcony at a velocity of 27,13 m·s^{-1} and strikes the ground 6 s after leaving the balcony.

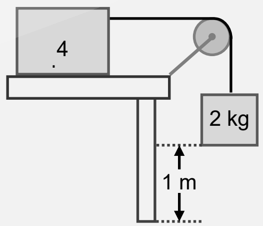
Sketch a velocity-time graph to represent the motion of the object from the moment it is projected from the **roof** of the building until it strikes the **ground**. Indicate the following velocity and time values on the graph:

- The initial velocity at which the object was projected from the roof of the building
- The velocity at which the object strikes the balcony
- The time when the object strikes the balcony
- The velocity at which the object bounces off the balcony
- The time when the object strikes the ground
- The velocity at which the object hits the ground (6)

[16]

Question 5

A block of mass 4 kg is held at rest on a rough horizontal table. The block is connected to another block of mass 2 kg by a light inelastic rope running over a light, frictionless pulley. The 2 kg block is suspended vertically as shown in the diagram below.



The 4 kg block is now released and the system of masses moves to the right. The kinetic friction coefficient between the 4 kg block and the surface of the table is 0,25. Ignore the effects of air resistance.

5.1 Draw a free-body diagram to show **all** the forces acting on the 2 kg block before motion. (2)

5.2 Write down *Newton's second law of motion* in words. (2)

Calculate the size of the:

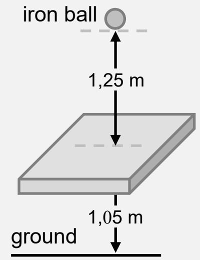
5.3 frictional force acting on the 4 kg block. (4)

5.4 speed at which the 2 kg block hits the ground. (8)

[16]

Question 6

A glass plate is mounted horizontally, 1,05 m above the ground. An iron ball with mass 0,40 kg falls from rest over a distance of 1,25 m before it hits and shatters the glass plate. The total time from the start of the fall until it hits the ground is measured at 0,80 s. The time taken to break the glass can be ignored.



6.1 Determine the speed of the ball when it strikes the glass. (3)

6.2 Show that the speed of the ball, immediately after breaking the glass, is 2,2 m·s^{-1}. (4)

6.3 Calculate the magnitude and give the direction of the change in momentum that the ball experiences during its contact with the glass plate. (3)

6.4 Give the magnitude and direction of the impulse that the glass plate experiences when the ball strikes it. (2)

6.5 Calculate the work done to break the glass plate. (4)

6.6 Explain whether or not the mechanical energy of the ball was conserved or not during the fall to the ground. (2)

[18]

Question 7

Each winter it snows on some of the mountains of the Eastern Cape. Ski resorts in the area also make artificial snow so that South Africans can enjoy as many winter sports as possible without having to go overseas.

Maria is a beginner and is learning to ski on the gentle slopes. She uses a 'T-bar' lift to get to the top of the slope.

At the 'T-bar' lift station, there is a sign such as the one depicted on the right that is designed to instruct first-time users on how to use the lift.

2: MATTER & MATERIALS: PHYSICS

Photoelectric Effect

Question 1

Give one word/phrase for the following:

1.1 The theory that states that light and other forms of electromagnetic radiation consists of photons or 'small packets of energy' and therefore has a particle nature.

1.2 The minimum energy that light or other EM radiation must have to illustrate the photoelectric effect.

1.3 The property of light that is related to the number of electrons released when the photoelectric effect is demonstrated.

1.4 The mathematical relationship between wavelength of photons and the amount of energy they possess.

1.5 The type of spectrum obtained when light from a glowing dense solid is passed through a triangular prism.

1.6 The type of spectrum obtained when white light is passed through a cold diluted gas and then observed through a diffraction grating.

1.7 The maximum wavelength of light or other EM radiation that can fall unto a metal surface and demonstrate the photoelectric effect.

Question 2

2.1 The effect of light that falls onto a metal object, depends on

A the speed of light

B the wavelength of light

C the energy the light possesses

D the size of the object

2.2 The minimum frequency of a photon that is required to emit an electron from a metal is known as:

A quantum of light **B** work function
C threshold frequency **D** photon energy

2.3 An electron that receives energy from a light photon can move to a higher energy level, only if the:

A energy difference between the levels is greater than the energy of the photon

B energy difference between the levels is smaller than the energy of the photon

C energy difference between the levels is equal to the energy of the photon

D electron has absorbed half of the photon energy

2.4 Which ONE of the following correctly represents the given types of electromagnetic radiation in order of **increasing wavelength**?

A microwaves; infrared; ultraviolet

B infrared; ultraviolet; X-rays

C radio waves; infrared; gamma rays

D ultraviolet; infrared; microwaves

2.5 Which ONE of the following phenomena provides the most conclusive evidence for the wave nature of light?

A photoelectric effect **B** refraction
C reflection **D** diffraction

2.6 When a clean metal plate is irradiated with light of sufficient energy, photoelectrons are emitted.
The intensity of the light is now increased.
This change will. . .

A increase the number of photoelectrons emitted per second.

B decrease the number of photoelectrons emitted per second.

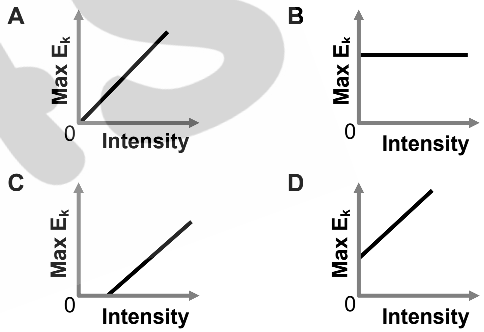
C increase the kinetic energy of the emitted photoelectrons.

D decrease the kinetic energy of the emitted photoelectrons.

2.7 A neon tube lights up when a large external voltage is applied across it.
Which ONE of the following best describes the type of spectrum observed when the gas inside the tube is viewed through a diffraction grating?

A Continuous **B** Absorption
C Line emission **D** Line absorption

2.8 Which ONE of the following graphs best shows the way in which the maximum value of the kinetic energy of the photoelectrons varies with the intensity of the light?



2.9 The energy radiated as a photon is equal to E. Determine, in terms of E, the energy of another photon of which the wavelength is half that of the first photon.

A E **B** 2E
C $\frac{E}{2}$ **D** 4E

Question 3

Consider the following information:

radio waves: $\lambda_1 = 3$ m gamma waves: $\lambda_2 = 0{,}03 \times 10^{-9}$ m

3.1 Calculate the frequency of each of the above waves.

3.2 Determine the amount of energy that photons of radio waves and gamma rays have.

3.3 What can be deduced about the frequency and energy of different types of waves?

11.2 Each photon of light has an energy of $6{,}9 \times 10^{-19}$ J. The cathode has a work function of $6{,}4 \times 10^{-19}$ J.

Calculate the:

11.2.1 wavelength of the light

11.2.2 kinetic energy of the photoelectrons

11.3 How will the reading on the ammeter change if:

11.3.1 light of the same frequency, but of higher intensity, is used

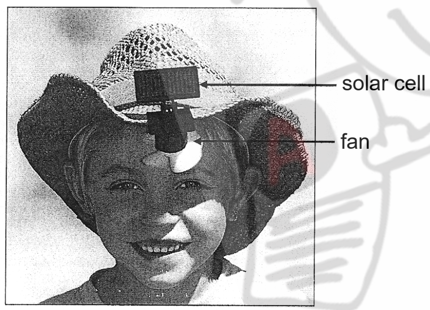
Write down **increases**, **decreases** or **remains the same**.
Fully explain the answer.

11.3.2 light of the same intensity, but of higher frequency, is used

Write down **increases**, **decreases** or **remains the same**.
Fully explain the answer.

Question 12

Nicky has a solar fan which can be clipped onto the front of her hat as shown in the picture.



The advert for the solar hat fan says the following:

> *'The solar cell can convert solar energy directly into electric power which can turn on the fan. Its fanning speed can change automatically depending on the availability of sunlight. The emission of electrons from the metal cathode of the solar cell is an application of the photoelectric effect.'*

12.1 Explain why the fan turns faster when the sunlight intensity increases.

12.2 The metal cathode of the solar cell, in the hat fan, has a work function of $3{,}408 \times 10^{-19}$ J.

12.2.1 Calculate the threshold frequency of the metal cathode.

12.2.2 Nicky shines green light from a 60 W bulb onto the solar cell. The maximum speed of the photo-electrons emitted is $2{,}39 \times 10^5$ m·s^{-1}. Calculate the energy of a photon of green light.

12.2.3 Nicky replaces the 60 W green light bulb with a 60 W ultra-violet light bulb and holds it the same distance from the solar cell of the hat fan. How will this affect the maximum speed of the emitted electrons?

Question 13

Read the article that follows.

> **Why are streetlamps yellow?**
>
> Yellow streetlights are high pressure sodium discharge lamps. The lamp is a transparent tube with electrodes embedded in either end. The tube contains an inert gas along with a bit of sodium metal.
>
> When a current is passed through the tube, the gas becomes very hot and the sodium vaporises. The vaporised sodium atoms absorb energy. As the excited electrons drop back down to a lower energy state the atoms emit photons of bright yellow light.
>
> Sometimes mercury is added to street lamps to introduce some blue and violet lines into the spectrum so that colours can be distinguished under the lamp.

[Adapted from: <http://www.antoine.frostburg.edu>]

13.1 What type of spectrum is formed by a high pressure sodium discharge lamp?

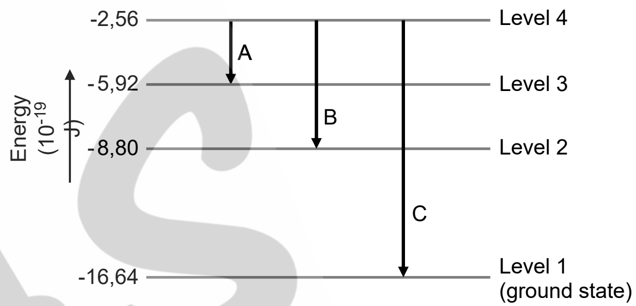
13.2 Does the spectrum produced by a sodium discharge lamp give evidence for the wave nature of light or for the particle nature of light?

13.3 Calculate the wavelength of a photon radiated from a sodium lamp if the energy transfer of the photon is $3{,}38 \times 10^{-19}$ J. Give your answer to the nearest whole number of nanometres.

Question 14

Line emission spectra are produced as a result of electron transitions between energy levels of the atom. The diagram below shows some of the outer energy levels of the mercury atom. An electron has been excited to the $-2{,}56 \times 10^{-19}$ J level (Level 4). The diagram shows three electrons dropping to a lower energy level. The ground state (Level 1) is $-16{,}64 \times 10^{-19}$ J.

Energy levels of the mercury atom



14.1 The three energy transitions produce three different spectral lines. Which transition (A, B or C) will produce the spectral line with:

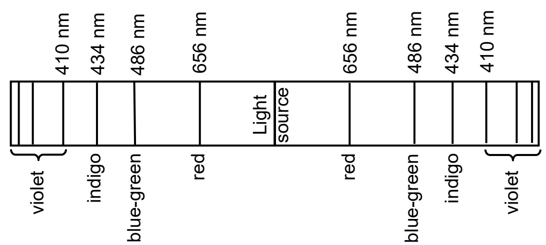
14.1.1 the longest wavelength?

14.1.2 the most energy?

14.2 Calculate the frequency of the electromagnetic radiation emitted when an electron falls from Level 4 back to its ground state (Level 1) as shown by the transition labelled C.

Question 15

The following diagram shows the spectrum of hydrogen:



15.1 What is the specific name given to this kind of spectrum?

15.2 How is this kind of spectrum obtained?

Section B

Question 3

A group of learners use the reaction between zinc and sulphuric acid to investigate one of the factors that affects reaction rate. The equation below represents the reaction that takes place.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

They add 6,5 g of zinc granules to excess **dilute** sulphuric acid and measure the mass of zinc used per unit time.

The learners then repeat the experiment using excess **concentrated** sulphuric acid.

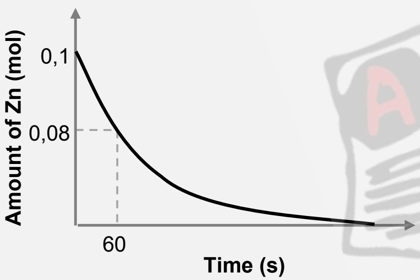
3.1 Define the term *reaction rate*. (2)

3.2 Give a reason why the acid must be in excess. (1)

3.3 Write down a hypothesis for this investigation. (2)

3.4 Give a reason why the learners must use the same mass of **zinc granules** in both experiments. (1)

The results obtained for the reaction using **dilute** sulphuric acid are represented in the graph below.



3.5 Using the graph, calculate the mass of zinc used from t = 0 s to t = 60 s. (4)

3.6 Calculate the average rate of the reaction (in gram per second) during the first 60 s. (2)

3.7 Redraw the previous graph. Use a dotted line to show the curve **on the same set of axes** that will be obtained when concentrated sulphuric acid is used. Label that curve P (no numerical values are required). (2) [14]

Question 4

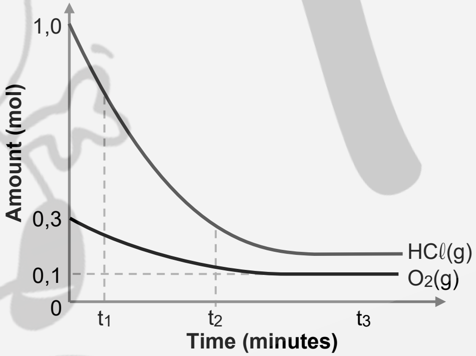
The reaction between hydrogen chloride and oxygen reaches equilibrium in a closed container according to the following balanced equation:

$$4HC\ell(g) + O_2(g) \rightleftharpoons 2H_2O(g) + 2C\ell_2(g)$$

$$\Delta H = -113\ kJ\cdot mol^{-1}$$

4.1 Is this reaction **exothermic** or **endothermic**? Give a reason for the answer. (2)

4.2 The graphs below, not drawn to scale, show how the amounts of reactants present in the container change with time at a specific temperature. The volume of the container is 5 dm^3.



4.2.1 How does the rate of the forward reaction at time t_1 compare to that at time t_2? Write down only **greater than**, **smaller than** or **equal to**. Use the graphs to give a reason for the answer. (2)

4.2.2 How does the rate of the forward and the reverse reactions compare at time t_3? Write down only **greater than**, **smaller than** or **equal to**. (1)

4.2.3 Calculate the equilibrium constant (K_c) for this reaction at this temperature. (9)

4.3 The temperature is now **increased**. How will this change affect the value of the equilibrium constant?
Write down only **increases**, **decreases** or **remains the same**. Explain the answer. (4)

4.4 How will each of the following changes affect the equilibrium concentration of $C\ell_2(g)$?
Write down only **increases**, **decreases** or **remains the same**.

4.4.1 Water vapour is added into the container. (1)

4.4.2 A catalyst is added. (1)

4.4.3 The volume of the container is increased. (1) [21]

Question 5

> Combustion in air at high temperatures produces oxides of nitrogen of which nitrogen dioxide ($NO_2(g)$), is the most common. Natural sources of nitrogen dioxide include lightning and the activity of some soil bacteria. These natural sources are small compared to emissions caused by human activity.
>
> NO_2 can irritate the lungs and cause respiratory infection. When $NO_2(g)$ dissolves in rainwater in air it forms nitric acid which contributes to acid rain.

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

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

5.3 2 mol $NO_2(g)$ and an unknown amount of $N_2O_4(g)$ are sealed in a 2 dm^3 container, that is fitted with a plunger, at a certain temperature. The following reaction takes place:

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

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

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

Haber Process

Question 4

The agrochemical industry produces artificial fertilisers that are added to agricultural soils to restore nutrients and produce larger crops. Fertilisers are available in many forms and can be purchased easily in different retail stores throughout the country.

4.1 You are provided with a 10 kg bag of fertiliser with the following information, **NPK 3:1:5 (26) SR**.

4.1.1 **Name** the primary nutrients required by all plants for healthy growth and development.

4.1.2 State the chemical formulae of three artificial fertilisers in which these respective nutrients can be found.

4.2 Fazul and Holly are enthusiastic members of their school Science Club and are busy with a school project that is investigating artificial fertilisers and how these are produced. Their research shows that the reaction between hydrogen and nitrogen to produce ammonia is an example of a chemical reaction that is able to reach dynamic chemical equilibrium within a closed system according to the following chemical equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -46\ kJ\cdot mol^{-1}$$

4.2.1 Give the name of the industrial process that uses this reaction to manufacture ammonia.

4.2.2 Which two gases are the main components of air?

4.2.3 Which property of these gases is utilised during the fractional distillation of liquid air?

4.2.4 In South Africa, where do we most likely get the hydrogen that is used in the reaction for the preparation of ammonia?

4.2.5 Nitrogen is an unreactive gas. Under which conditions would it react with hydrogen to produce ammonia?

4.3 During the reaction, the reactants and products reach a dynamic chemical equilibrium.

4.3.1 Explain what is meant by the term *dynamic equilibrium*.

Fazul analysed the reaction mixture at equilibrium (at a certain temperature and pressure) and found the following amounts of reactants and products in the reaction flask:

N_2 = 6 000 mol

H_2 = 29 000 mol

NH_3 = 18 000 mol

The volume of the reaction flask is 10^5 litres.

4.3.2 Calculate the concentrations **(in mol·dm^{-3})** of reactants and products present in the reaction flask at equilibrium. (Note: 1 litre = 1 dm^3)

4.3.3 Write down the expression for the equilibrium constant (K_c) for the reaction.

4.3.4 Calculate the value of K_c for this reaction.

Holly observes that one of the conditions affecting the equilibrium is changed and a new equilibrium is established. At the new equilibrium, the concentration of NH_3 is 0,24 mol·dm^{-3}.

4.3.5 By how much did the concentration of ammonia increase from what it was originally in Question 4.3.2?

4.3.6 If the value of K_c remains **constant** after the new equilibrium has been reached, identify TWO changes to the reaction conditions that would have increased the concentration of the ammonia.

4.4 Fazul and Holly perform the reaction at a temperature of 350ºC and a pressure of 400 atm, obtaining an NH_3 yield of approximately 70%. Fazul would like a higher yield and decides to increase the temperature to 500ºC and to add a catalyst, while keeping the pressure constant. However, the yield decreases and is now less than 50%.

4.4.1 Explain why Fazul obtains a lower yield.

4.4.2 Explain which inaccurate understanding he has regarding the action of a catalyst during a chemical reaction.

4.4.3 As the reaction proceeds, the ammonia is continuously being removed. What is the purpose of this?

4.5 After further research, both learners find that good agricultural soil contains a high component of soluble fertiliser. It is naturally present in the soil and all farmers regularly measure the mineral levels as they are essential for healthy crop growth. However when heavy rains fall, farmers regularly have to use artificial fertilisers on the land.

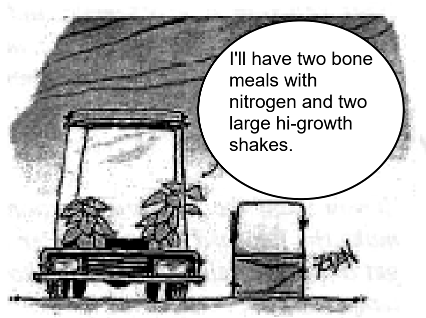
4.5.1 Using one of your examples from Question 4.1.2, explain with the aid of a chemical equation, the problem that could occur in the soil during heavy rainfall.

4.5.2 Do you think that the regular use of artificial fertilisers, not just during heavy rain, is advantageous for the environment? Give a reason for your answer.

Organic fertiliser is a natural fertiliser which produces nitrates which are slowly released into the soil over time. This process is assisted by the oxygenated water that is absorbed by the rotting material. This process is very slow yet it is becoming a popular method of fertilising crops once again.

4.5.3 Why do you think it is advantageous for a farmer to want to use organic fertilisers instead of synthetic fertilisers in his fields?

There has been much controversy over the use of organic and inorganic fertilisers in recent times. It is important to note that it makes no difference to a tomato plant if the nutrients it is absorbing come from a pile of compost (organic) or from a fertiliser factory (inorganic). A nutrient is a nutrient - it doesn't matter what the source of it might be.



Plant Fast Food

www.cartoonstock.com

ANSWERS

MECHANICS

Forces; Newton's Laws

Question 1

1.1 C

Object will move at constant velocity (travel equal displacements per time interval), if $F_{net} = 0$. B is incorrect because the object changes direction all the time.

1.2 D

The net horizontal and vertical force is zero (no acceleration in any direction).

1.3 C

When the rope breaks, Y has a greater acceleration because the same force is now acting on it only; F_{net} on X is now zero and it travels forward at constant velocity.

1.4 A

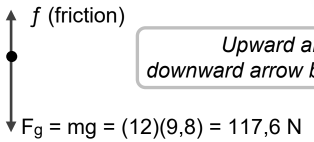
Travelling upwards, the elevator/ lift slows down; acceleration and therefore F_{net} is downwards ($F_g > N$).

1.5 D

1.6 D

Question 2

2.1



Upward arrow shorter than downward arrow because a is downwards.

2.2 Newton II: When a resultant/net force is acting on an object, the object accelerates in the direction of the force. The acceleration (a) is directly proportional to the force (F_{net}) and inversely proportional to its mass.

2.3

$$F_{net} = ma$$
$$\therefore F_g + f = ma$$
$$\therefore (12)(9,8) + f = (12)(2)$$
$$\therefore f = 24 - 117,6$$
$$= -93,6 \text{ N} = 93,6 \text{ N upwards}$$

Take ↓ +

2.4

$$W_{net} = \Delta E_k$$
$$\therefore F_{net}\,\Delta y \cos\theta = \frac{1}{2}m(v_f^2 - v_i^2)$$
$$\therefore F_{net}\,(0,1)\cos 180^\circ = \left(\frac{1}{2}\right)(12)\,[0 - (1,7)^2]$$
$$\therefore F_{net} = 173,4 \text{ N upwards}$$

Take ↓ +

$$F_{net} = F_g + F_{sand}$$
$$\therefore -173,4 = 117,6 + F_{sand}$$
$$\therefore F_{sand} = -291 \text{ N}$$
$$= 291 \text{ N upwards}$$

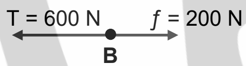
$\Delta y = 100$ mm $= 0,1$ m
$v_f = 0$ m·s^{-1}
$v_i = 1,7$ m·s^{-1} ↓

Question 3

3.1

$$f_{net} = ma$$
$$\therefore T + f = ma$$
$$\therefore 600 + (-200) = 1\,200a$$
$$\therefore 400 = 1\,200a$$
$$\therefore a = 0,33 \text{ m·s}^{-2} \text{ left}$$

$m_B = 1\,200$ kg

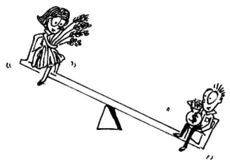


Take ← +

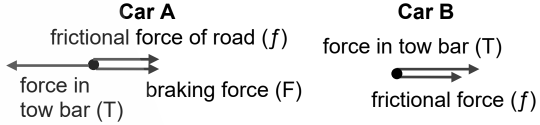
3.2

$$F_{net} = ma$$
$$\therefore T + f = ma$$
$$\therefore 300 + f = 0$$
$$\therefore f = -300$$
$$= 300 \text{ N right}$$

3.3 Using a solid tow bar instead of a rope, B maintains a constant distance behind A. If A suddenly brakes, car B will slow down together with car A and keep at the same distance behind A. If A suddenly stops with a rope between them, the rope will slacken and the tension in the rope falls away. Therefore, B will continue its motion and may collide with A (Newton I).



3.4



For car A:

Take ← +

$$F_{net} = ma$$
$$\therefore F + T + f_A = ma$$
$$\therefore (-9\,600) + T + (-300) = 1\,200a \quad \ldots ❶$$

For car B:

$m_A = m_B = 1\,200$ kg
$F = 9\,600$ N
$f_A = f_B = 300$ N

$$F_{net} = ma$$
$$\therefore T + f_B = ma$$
$$\therefore (-T) + (-300) = 1\,200a \quad \ldots ❷$$

❶ + ❷: $(-9\,600) + (-600) = 2\,400a$

$$\therefore a = -4,25 \text{ m·s}^{-2}$$
$$= 4,25 \text{ m·s}^{-2} \text{ right}$$

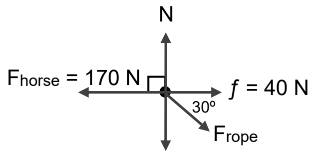
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\therefore 0 = 20^2 + 2(-4,25)\,\Delta x$$
$$\therefore 8,5\,\Delta x = 400$$
$$\therefore \Delta x = 47,06 \text{ m}$$

$v_i = 20$ m·s^{-1}
$v_f = 0$ m·s^{-1}

The shortest stopping distance is 47,06 m

Question 4

4.1



$F_g = mg$
$= (240)(9,8)$
$= 2\,352$ N

ƒ = frictional force
N = normal force from road
F = applied force
F_g = weight

When labelling, describe each force fully in a key. Do not just give letters.

Question 4

4.1.1 Bystander runs to the accident scene:

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

$$304{,}55 = \left(\frac{330 + 5}{330 - 0}\right) f_S$$

$$\therefore f_B = 300 \text{ Hz}$$

$+v_L = +5 \text{ m·s}^{-1}$
$v_S = 0$
$f_L = 304{,}55$ Hz
$v = 330 \text{ m·s}^{-1}$

4.1.2 Bystander runs away from the accident scene:

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

$$= \left(\frac{330 - 5}{330 + 0}\right)(300)$$

$$= 295{,}45 \text{ Hz}$$

$-v_L = -5 \text{ m·s}^{-1}$
$v_S = 0$
$f_S = 300$ Hz
$v = 330 \text{ m·s}^{-1}$

4.2 As the bystander moves closer to the source of the sound waves, he hears sound waves with a higher frequency - and therefore also a higher pitch - and when he moves away from the source, he hears sound waves with a lower frequency (pitch) than when he is stationary.

Question 5

5.1 The Doppler effect is the change in frequency (and therefore the change in pitch of the sound) that is perceived when the sound source and listener move in relation to each other and to the medium in which the sound is transmitted. (When they are moving towards each other, the frequency/pitch is higher, and when they move away from each other the frequency/pitch is lower, than what is heard when both are standing still.)

5.2 Humans can hear sound, but not ultrasound - it is outside of our hearing range. Audible sound frequencies range from 20 Hz to 20 000 Hz. Ultrasound has frequencies above 20 000 Hz.

5.3 The development of a foetus can be monitored in a safe manner in the mother's uterus with the help of ultrasound and the Doppler effect:

- A device that consists of a transmitter and a receiver is placed directly on the mother's skin.
- An ultrasonic sound wave is transmitted, moves through the skin, tissue, bone and fluids of the foetus at different velocities, and the reflected sounds are received again.
- The direction and depth of the 'sent-back' (received) sounds can be determined. These sounds are interpreted every second and converted to an electronic image on a screen.

5.4 *Hint: First calculate the frequency of the sound when it reaches the burglar.*

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

$$= \left(\frac{340 + 0{,}05}{340 - 0}\right)(30\ 000)$$

$$= 30\ 004{,}41 \text{ Hz}$$

(this is the frequency of sound when it that reaches the burglar)

$f_L = ?$
$v_L = 0{,}05 \text{ m·s}^{-1}$
$f_S = 30\ 000$ Hz
$v_S = 0$
$v = 340 \text{ m·s}^{-1}$

Hint: Now calculate the frequency of the sound when reflected back to the detector.

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

$$= \left(\frac{340 + 0}{340 - 0{,}05}\right)(30\ 004{,}41)$$

$$= 30\ 008{,}82 \text{ Hz}$$

$v_S = 0{,}05 \text{ m·s}^{-1}$
$f_S = 30\ 004{,}41$ Hz
$v_L = 0 \text{ m·s}^{-1}$
$v = 340 \text{ m·s}^{-1}$

5.5

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

$$= \left(\frac{340 + 20}{340 - 0}\right) f_S = 1{,}06\ f_S$$

$v_L = 72 \text{ km·h}^{-1}$
$= \frac{72\ 000}{3\ 600}$
$= 20 \text{ m·s}^{-1}$

The frequency of the sound heard by the policeman is 1,06 times greater than the frequency transmitted by the alarm.

Question 6

6.1 If the source is moving away then the formula to use is:

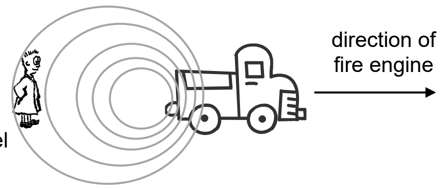
$$f_L = \frac{v \pm v_L}{v \pm v_S} f_S$$

$$= \left(\frac{330 - 0}{330 + 20}\right)(250)$$

$$= 235{,}71 \text{ Hz}$$

$f_S = 250$ Hz
$v_S = 20 \text{ m·s}^{-1}$
$v_L = 0 \text{ m·s}^{-1}$
$v = 330 \text{ m·s}^{-1}$

6.2



6.3 The speed of light is very much faster than that of sound. This means that adding 20 m·s^{-1} to 3×10^8 (speed of light), will not have any noticeable effect on the fraction $\left(\frac{v}{v + v_S}\right)$. There is a noticeable change in the frequency of the sound, but not of the red light.

Question 7

7.1

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

$$\therefore 1\ 000 = \left(\frac{340 + v_L}{340}\right)(960)$$

$$\therefore \frac{340 + v_L}{340} = 1{,}04$$

$$\therefore 340 + v_L = 354{,}17$$

$$\therefore v_L = 14{,}17 \text{ m·s}^{-1}$$

$f_S = 960$ Hz
$v_S = 0 \text{ m·s}^{-1}$
$f_L = 1\ 000$ Hz
$v_L = ?$
$v_{(sound)} = 340 \text{ m·s}^{-1}$

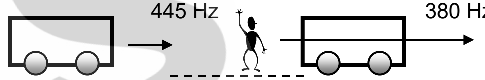
7.2 higher than

Form the formula $f_L = \frac{v \pm v_L}{v \pm v_S} f_S$ it is clear that if v_L increases, f_L will increase.

Question 8

8.1 ❶: friend ❷: lady

8.2.1



$$f_L = \frac{v \pm v_L}{v \pm v_S} f_S \quad \text{(towards lady)}$$

$$\therefore 445 = \left(\frac{343 + 0}{343 - v_S}\right) f_S \quad \ldots \mathbf{1}$$

$f_L = 445$ Hz
$v_L = 0 \text{ m·s}^{-1}$
$f_S = ?$
$v_S = ?$
$v = 343 \text{ m·s}^{-1}$

$$f_L = \frac{v \pm v_L}{v \pm v_S} f_S \quad \text{(away from friend)}$$

$$\therefore 380 = \left(\frac{343 - 0}{343 + v_S}\right) f_S \quad \ldots \mathbf{2}$$

$f_L = 380$ Hz

From **1**: $(445)(343 - v_S) = 343 f_S$
From **2**: $(380)(343 + v_S) = 343 f_S$
} solve simultaneously

$$\therefore (445)(343 - v_S) = (380)(343 + v_S)$$

$$\therefore 152\ 635 - 445 v_S = 130\ 340 + 380 v_S$$

$$\therefore 22\ 295 = 825 v_S$$

$$\therefore v_S = 27{,}02 \text{ m·s}^{-1}$$

8.2.2 Take equation **1** above:

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

$$\therefore 445 = \left(\frac{343 + 0}{343 - 27{,}02}\right) f_S$$

$$\therefore 343 f_S = 140\ 620$$

$$\therefore f_S = 409{,}94 \text{ Hz}$$

$v_S = 27{,}02 \text{ m·s}^{-1}$
$f_L = 445$ Hz
$v_L = 0 \text{ m·s}^{-1}$
$v = 343 \text{ m·s}^{-1}$

EXAM PAPERS

PAPER A1

National Nov 2013 - Adapted for CAPS

Question 1

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (**A - D**) next to the question numbers (1.1 - 1.10).

1.1 Which ONE of the following physical quantities is equal to the product of force and constant velocity?

A work   **B** power

C energy   **D** acceleration (2)

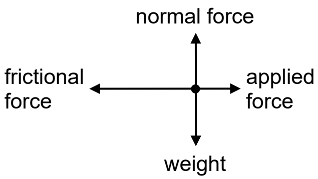
1.2 A 30 kg iron sphere and a 10 kg aluminium sphere with the same diameter fall freely from the roof of a tall building. Ignore the effects of friction.

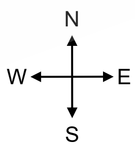
When the spheres are 5 m above the ground, they have the same . . .

A momentum   **B** acceleration

C kinetic energy   **D** potential energy (2)

1.3 The free-body diagram below shows the relative magnitudes and directions of all the forces acting on an object moving horizontally in an easterly direction.





The kinetic energy of the object . . .

A is zero   **B** increases

C decreases   **D** remains constant (2)

1.4 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)

1.5 An astronomer, viewing light from distant galaxies, observes a shift of spectral lines toward the red end of the visible spectrum. This shift provides evidence that . . .

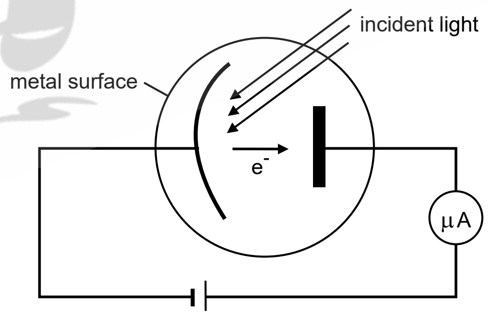
A the universe is expanding.

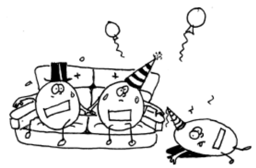
B the galaxies are moving closer towards Earth.

C Earth is moving towards the distant galaxies.

D the temperature of Earth's atmosphere is increasing. (2)

1.6 When light of a certain frequency is incident on the cathode of a photocell, the ammeter in the circuit registers a reading.





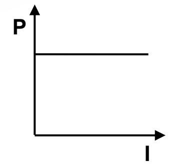
The frequency of the incident light is now increased while keeping the intensity constant. Which ONE of the following correctly describes the reading on the ammeter and the reason for this reading?

	Ammeter reading	Reason
A	increases	More photoelectrons are emitted per second.
B	increases	The speed of the photoelectrons increases.
C	remains the same	The number of photo-electrons remains the same.
D	remains the same	The speed of the photo-electrons remains the same.

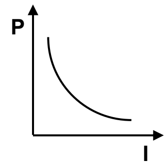
(2)

1.7 Which ONE of the following graphs best represents the relationship between the electrical power and the current in a given ohmic conductor?

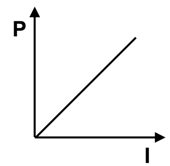
A



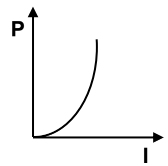
B



C



D



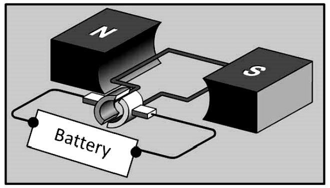
(2)

1.8 In a vacuum, all electromagnetic waves have the same . . .

A energy   **B** speed

C frequency   **D** wavelength (2)

1.4 What type of electrical machine is represented in the diagram below?

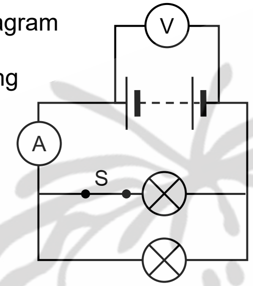


[Adapted from PLATO MSS 11 - 16]

A DC motor **B** AC motor
C DC generator **D** AC generator (2)

1.5 In the accompanying circuit diagram the resistances of the battery, ammeter, switch and connecting wires are negligible.
The voltmeter has a very high resistance.

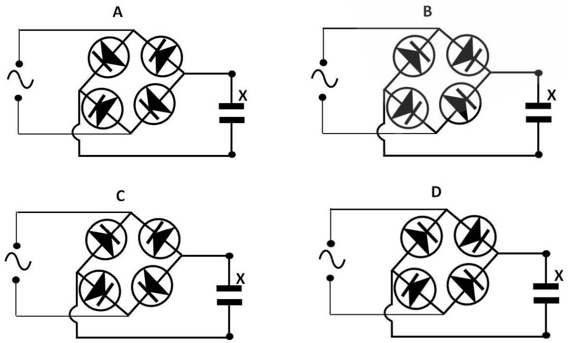
How are the readings on the ammeter and voltmeter affected if switch S is opened?



	Ammeter	Voltmeter
A	decreases	increases
B	decreases	no change
C	increases	no change
D	increases	decreases

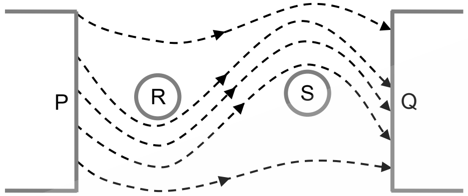
(2)

1.6 *(IEB only)* Which ONE of the following arrangements of diodes will change the AC input current to DC in such a way that the top plate (X) of the capacitor is always negative?



(2)

1.7 The diagram represents a cross-section through a rectangular current carrying coil of lengths R and S, of a motor, between magnetic poles, P and Q. The magnetic field lines are shown.

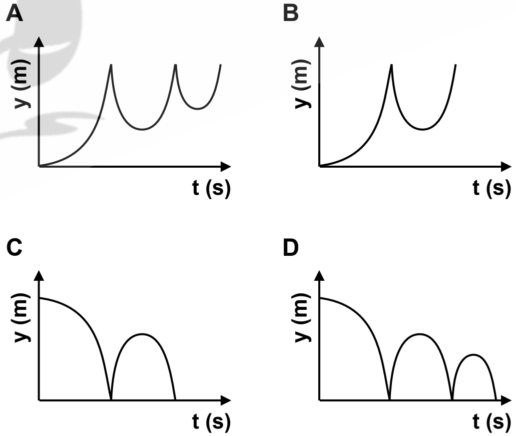


Which ONE of the following correctly gives the polarity of the pole P and the direction of the current inside R of the coil?

	Polarity of P	Current in R
A	south	into page
B	south	out of page
C	north	into page
D	north	out of page

(2)

1.8 Which ONE of the following position-time graphs represents a ball that is dropped and bounces **twice** before coming to rest? The frame of reference is the starting point.

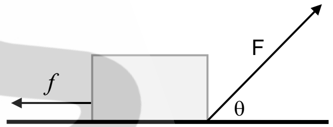


(2)

1.9 Two identical objects are dropped from rest from different heights in a vacuum. After they have both fallen for the same time which ONE of the following physical quantities will be different for the two objects?

A velocity
B kinetic energy
C gravitational potential energy
D acceleration (2)

1.10 A box is pulled in a straight line, a distance Δx, across a horizontal rough surface by means of a rope inclined at an angle θ to the horizontal.
The constant applied force is **F** and the constant frictional force is f.



The work done by the rope on the box in moving it a distance Δx is:

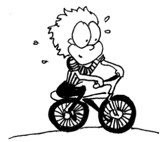
A $F.\Delta x$ **B** $(F \cos \theta - f).\Delta x$
C $(F \cos \theta + f).\Delta x$ **D** $F \cos \theta.\Delta x$ (2)
[20]

Question 2

2.1 A cyclist (Paul) has a velocity of 20 $m{\cdot}s^{-1}$ east and a constant acceleration of 4 $m{\cdot}s^{-2}$ west. Another cyclist (Peter) has a velocity of 20 $m{\cdot}s^{-1}$ east and a constant acceleration of 4 $m{\cdot}s^{-2}$ east.

2.1.1 After 1 s calculate the magnitude of the velocity of
(a) Paul (b) Peter (5)

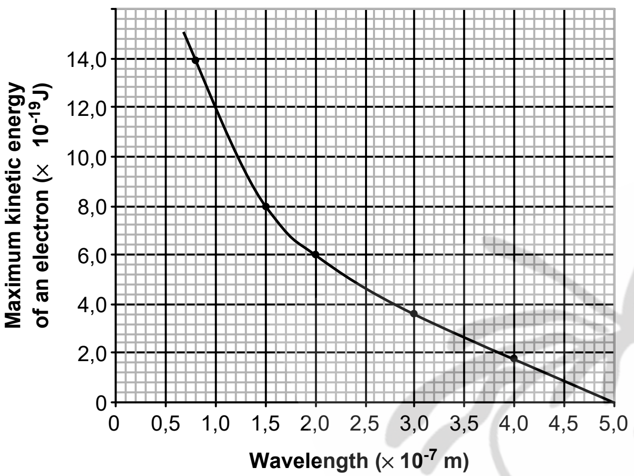
2.1.2 Explain why Peter and Paul have such different velocities after 1 s even though they both experienced an acceleration of 4 $m{\cdot}s^{-2}$. (2)



Question 9

The graph below shows how the maximum kinetic energy of an electron emitted from the metal cathode of a photoelectric cell varies with the wavelength of the incident radiation.

Graph of maximum kinetic energy of an electron versus wavelength



9.1 Use the graph to determine the maximum kinetic energy of the electron emitted when the wavelength of the incident radiation is $1,0 \times 10^{-7}$ m. (1)

9.2 Describe the relationship shown in the graph. (2)

9.3 Use your knowledge of the photoelectric effect to **explain** the relationship shown in the graph. Support your answer with reference to relevant formulae. (3)

9.4 Use the graph to calculate the threshold frequency of the light needed to emit electrons from the metal cathode of the photovoltaic cell. (4)

9.5 Calculate the work function of the metal used for the cathode of the photovoltaic cell. (3)

[13]

TOTAL: 200

PAPER E2

IEB November 2014

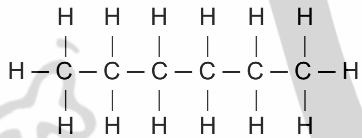
Question 1

Answer the following questions. Write only the letter (**A** - **D**) of the most correct response next to the question number (1.1 - 1.10).

1.1 Sodium chloride ($NaC\ell$) is a solid which is soluble in water. Which ONE of the following describes the intermolecular forces that exist between sodium chloride and water in solution?

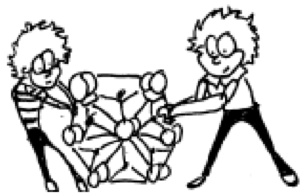
- **A** ion-dipole
- **B** dipole-dipole
- **C** ion-induced dipole
- **D** induced dipole-dipole (2)

1.2 Consider the structure of hexane.



A molecule of hexane is considered to be non-polar. Which ONE of the following statements best describes the reason why hexane is non-polar?

- **A** Hexane contains only single bonds between atoms.
- **B** The electronegativity difference between C and H atoms is so small as to be considered non-polar.
- **C** Hexane is a linear molecule hence is symmetrical.
- **D** The charge distribution of electrons within the hexane molecule is symmetrical. (2)



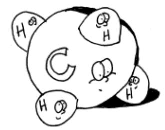
1.3 Hydrogen bonding is a type of intermolecular force that can exist between the molecules of certain compounds. Which ONE of the statements below best describes the conditions under which hydrogen bonding is most likely to occur?

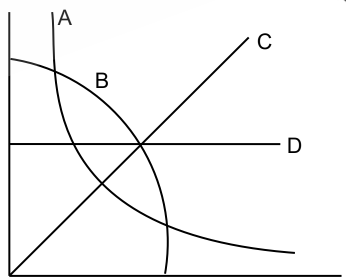
It occurs between . . .

- **A** small molecules which contain hydrogen atoms
- **B** molecules in which hydrogen is bonded to small atoms with high electronegativity
- **C** large molecules which contain both hydrogen and oxygen atoms
- **D** molecules in which hydrogen is bonded to small atoms with low electronegativity (2)

To answer Questions 1.4 and 1.5, refer to the description below and the graphs A to D that are provided.

In an experiment to determine the effect of concentration on reaction rate, a constant volume of $HC\ell(aq)$ of concentration 2 $mol \cdot dm^{-3}$ is added to a constant volume of $Na_2S_2O_3(aq)$ of varying concentrations.





1.4 Which ONE of the graphs A, B, C or D represents the plot of concentration of sodium thiosulphate (vertical axis) against time taken (horizontal axis) for the reaction? (2)

1.5 Which ONE of the graphs A, B, C or D represents the plot of reciprocal of time $\left(\frac{1}{t}\right)$ (vertical axis) against concentration of sodium thiosulphate (horizontal axis) for this reaction? (2)