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CRAWFORD SCHOOLS PRELIMINARY EXAMINATION

AUGUST/SEPTEMBER 2021

PHYSICAL SCIENCES: PAPER 1

Time: 3 hours

200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 17 pages including an Answer Sheet of 2 pages, and a Data Sheet of 2 pages. Please make sure that your question paper is complete.
2. Read the questions carefully.
3. Answer ALL the questions.
4. Start each question on a new page.
5. Number your answers as the questions are numbered.
6. Use the data and formulae whenever necessary.
7. Show your working in all calculations.
8. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
9. Answers must be expressed in decimal format, not left as proper fractions.
10. Where appropriate express answers to TWO decimal places.
11. It is in your own interest to write legibly and to present your work neatly.

QUESTION 1 - MULTIPLE CHOICE QUESTIONS

Answer these questions on the multiple-choice grid that is given on the Answer Sheet. Make a cross (X) in the box corresponding to the letter that you consider to be correct.

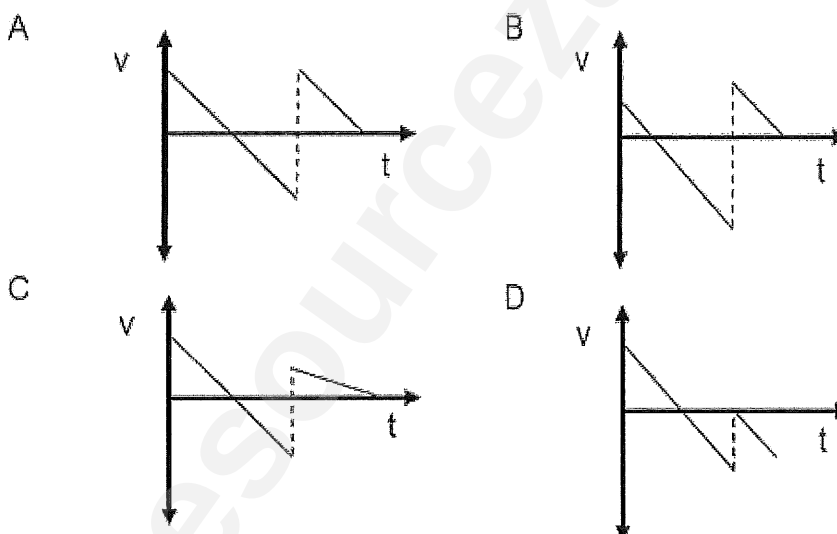
1.1 Which of the following groups consists only of vector quantities?

- A Velocity, Displacement, Energy
- B Momentum, Acceleration, Work
- C Weight, Momentum, Displacement
- D Power, Force, Acceleration

(2)

1.2 A ball is projected vertically upwards from the ground. It returns to the ground, makes an elastic collision with the ground, and then bounces to a maximum height. Ignore air resistance.

Which ONE of the following velocity-time graphs CORRECTLY depicts the motion of the ball?



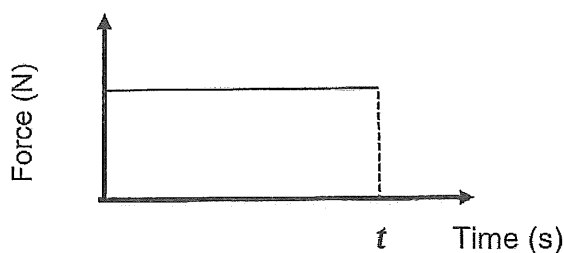
(2)

1.3 An object, moving at a constant velocity, has kinetic energy, E , and momentum, p . The velocity of the object is now doubled. Which one of the following options gives the correct magnitude of the kinetic energy and momentum of the object after the velocity has doubled?

	Kinetic Energy	Momentum
A	$2E$	$2p$
B	$4E$	$2p$
C	$4E$	$4p$
D	$2E$	$4p$

(2)

- 1.4 The graph below shows a force, F , that acts on a tennis ball for time, t .
What is represented by the area of the graph during time t ?



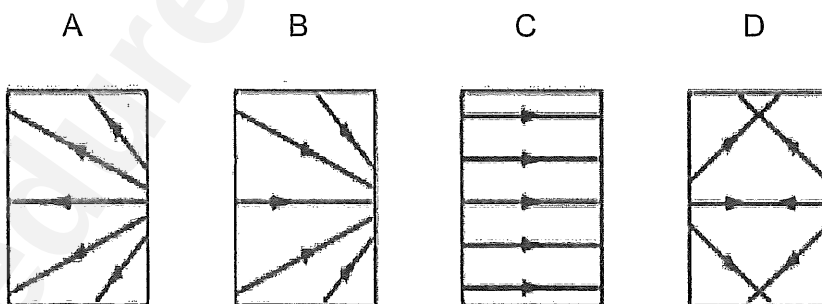
- A Change in momentum
 - B Power
 - C Work done
 - D Change in kinetic energy
- (2)

- 1.5 As a spaceship moves further away from Earth:

- A the universal gravitational constant, G , decreases in value and the gravitational field, g , increases in value.
- B the universal gravitational constant, G , increases in value and the gravitational field, g , decreases in value.
- C the universal gravitational constant, G , remains constant in value, and the gravitational field, g , also remains constant in value.
- D the universal gravitational constant, G , remains constant in value, and the gravitational field, g , decreases in value.

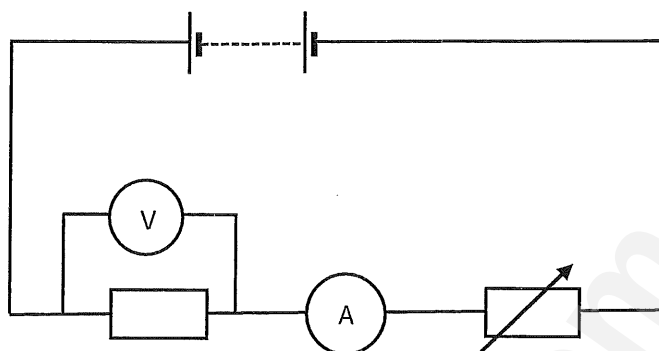
(2)

- 1.6 Which **one** of the diagrams below is **not** a possible electric field configuration for a region of space which does **not** contain any charges?



(2)

- 1.7 The diagram below shows a battery, a resistor, an ammeter, and a rheostat connected in series. A voltmeter is connected across the resistor.



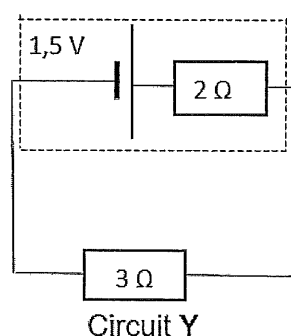
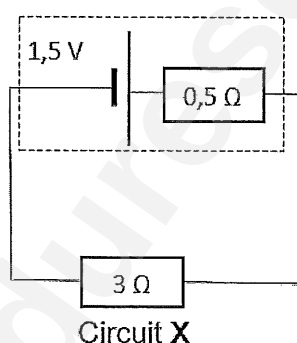
The value of the rheostat is reduced.

Which option correctly describes the changes in the readings on the ammeter and the voltmeter?

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

(2)

- 1.8 The diagram below shows two circuits. In the circuits, only the internal resistance of the cell differs. In Circuit X the internal resistance is $0,5 \Omega$ and in Circuit Y the internal resistance is 2Ω .

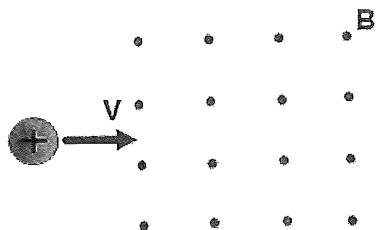


Which option in the table is correct?

	Potential difference across 3Ω resistor	Power dissipated in 3Ω resistor
A	Greater in X than in Y	Less in X than in Y
B	Greater in X than in Y	Greater in X than in Y
C	Less in X than in Y	Less in X than in Y
D	Less in X than in Y	Greater in X than in Y

(2)

- 1.9 A positive charge moving with a constant velocity, $\mathbf{v}$, enters a region of a uniform magnetic field coming out the page. The direction of the magnetic force on the charge is...



- A Left
- B Right
- C Down
- D Up

(2)

- 1.10 When monochromatic light is shone onto a clean cadmium surface, electrons with kinetic energy up to maximum of $2P$ are released. The work function of cadmium is P . The frequency of the photons is...

- A $\frac{3P}{h}$
- B $\frac{P}{h}$
- C Ph
- D $3Ph$

(2)

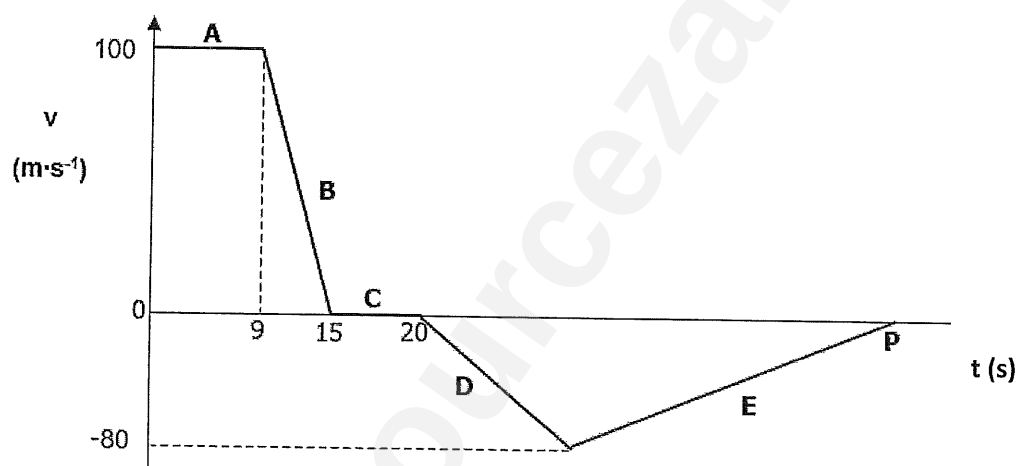
[20]

QUESTION 2

Levi would love an opportunity to test drive the fastest supercar in production – the Bugatti Chiron.



The car has a reported top speed of close to $500 \text{ km}\cdot\text{h}^{-1}$. The velocity-time graph below represents the motion of the car, initially travelling **east**, on a straight road.

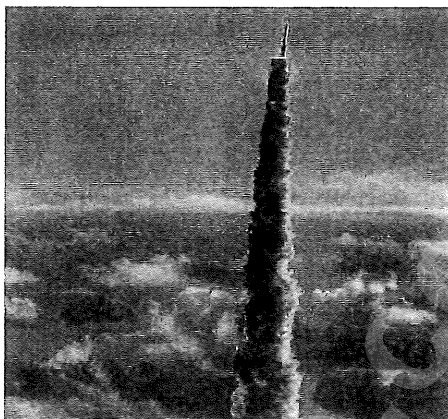


- 2.1 Use the graph to calculate the acceleration of the car during section **B**. (3)
- 2.2 Use the graph to calculate the distance travelled by the car during the first 15 s. (3)
- 2.3 Describe the motion of the car during section **E** of the graph. (2)
- 2.4 At time **P** the car is back at its starting point (i.e. it is back where it was at time $t = 0 \text{ s}$). Use information from the graph to calculate time **P**. (4)
- 2.5 Draw an acceleration-time sketch graph for the car, clearly labelling sections **A**, **B**, **C**, **D** and **E**. It is not necessary to show any values.

QUESTION 3

A rocket, initially at rest, is launched vertically upwards with a constant acceleration of $12 \text{ m}\cdot\text{s}^{-2}$.

At an altitude of 1 km, the rocket engine cuts off. Air friction is negligible in this problem.



<http://www.internalvoices.org/groupwallpapers/rocket-launch-wallpaper/>

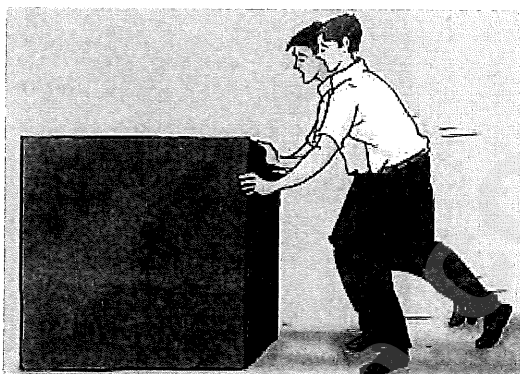
Take upwards as positive.

- 3.1 Define *velocity*. (2)
- 3.2 Calculate the velocity of the rocket at an altitude of 1 km, when the engine cuts off. (3)
- 3.3 Calculate the time it takes the rocket to reach an altitude of 1 km. (3)
- 3.4 Calculate the maximum height reached by the rocket above Earth. (5)
- 3.5 Calculate the total time that the rocket was in the air i.e. from the moment of launch to its return to Earth. (5)
- 3.6 Calculate the rocket's velocity the moment it reaches Earth. (4)
- 3.7 Sketch a graph of the velocity versus time for the entire motion of the rocket, from initial launch to return to Earth. (Include calculated times and velocities from 3.2, 3.3, 3.5 and 3.6) (4)

[26]

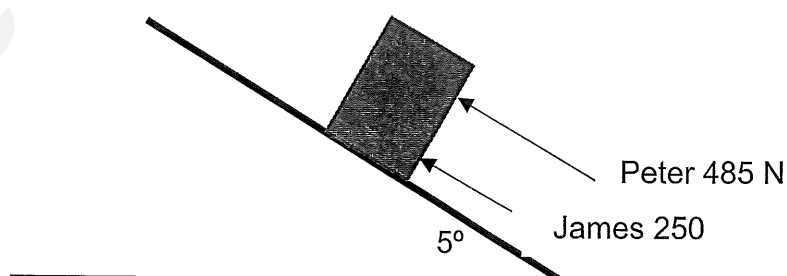
QUESTION 4

- 4.1 Two boys, Peter and James are pushing a box with a mass of 200 kg horizontally, on a rough surface. Peter and James apply horizontal forces of 485 N and 250 N respectively to the left. The box experiences a frictional force of 588 N. Ignore the effects of air resistance.



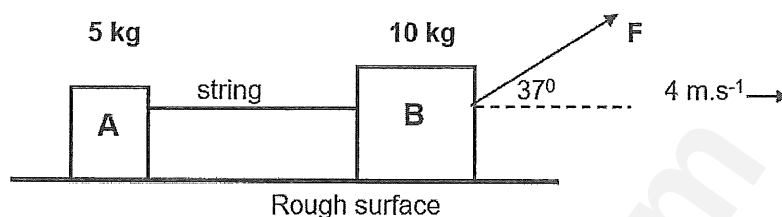
<https://ncert.nic.in/textbook/pdf/hesc111.pdf>

- 4.1.1 Define *frictional force due to a surface*. (2)
- 4.1.2 Draw a fully labelled free body diagram to show the **horizontal forces** acting on the box. (3)
- 4.1.3 Calculate the magnitude of the acceleration of the box. (3)
- 4.1.4 Peter and James now push the same box up a slope with an incline of 5° to the horizontal. The forces exerted by the two boys are the same in magnitude as shown in the diagram below. The coefficient of kinetic friction between the box and the surface is 0,3.



- Using suitable **calculations** to support your answer, **describe** what would happen to the box. (5)

- 4.2 Two boxes, **A** and **B**, resting on a rough horizontal surface, are connected by a light inextensible string. The boxes have masses 5 kg and 10 kg respectively. A constant force, **F**, acting at an angle of 37° to the horizontal, is applied to the 10 kg box, as shown below.



The two boxes now move to the right at a **constant speed** of 4 m.s^{-1}

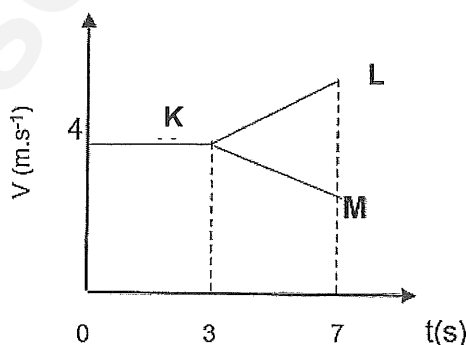
- 4.2.1 State *Newton's First Law*. (2)

Box **A** experiences a constant frictional force of 3 N and box **B** a constant frictional force of 6 N.

- 4.2.2 Calculate the magnitude of force **F**. (5)

- 4.2.3 How will the magnitude of the normal force acting on block **B** change if the angle between force **F** and the horizontal increases to 50° ? Use a suitable equation to explain your answer. (4)

The string connecting blocks **A** and **B** suddenly breaks while force **F** is still being applied. The velocity-time graph for the motion of blocks **A** and **B**, before and after the string breaks, are shown below.



- 4.2.4 Write down the time at which the string breaks. (1)

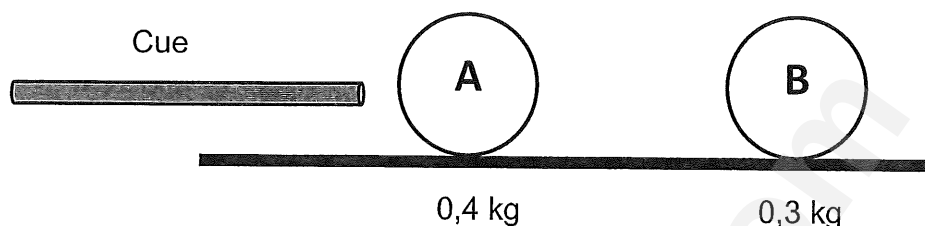
- 4.2.5 Which portion (**K**, **L** or **M**) of the graph represents the motion of box **A**, after the string breaks? Use the information in the graph and the forces acting on block **A** to fully explain the answer. (3)

- 4.2.6 Calculate the acceleration of box **A** after the string breaks. (2)

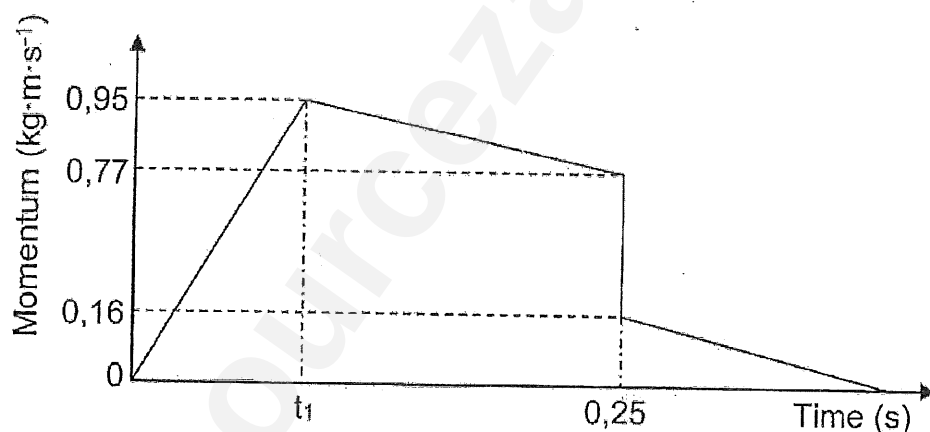
QUESTION 5

(adapted from Provincial Prelim P1 2020)

In a game of snooker, the cue strikes ball **A** of mass 0,4 kg, as shown in the diagram below. Ball **A** rolls across the table and collides with ball **B** of mass 0,3 kg.



The momentum versus time sketch graph below is drawn for ball **A** from the moment it is struck by the cue ($t = 0$ s), as it leaves the cue ($t = t_1$ s) and as it collides with ball **B** at 0,25 s.



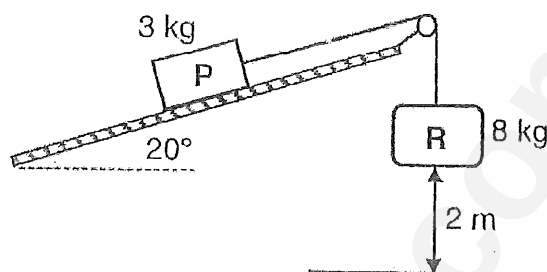
- 5.1 Define *impulse*. (2)
- 5.2 Use the information on the graph to:
- 5.2.1 calculate the value of the time t_1 , if the force exerted by the cue on ball **A** is 65 N. (4)
- 5.2.2 explain why it is correct to assume that ball **A** experiences friction due to the table. (2)
- 5.2.3 calculate the velocity of ball **B** immediately after the collision. (4)

[12]

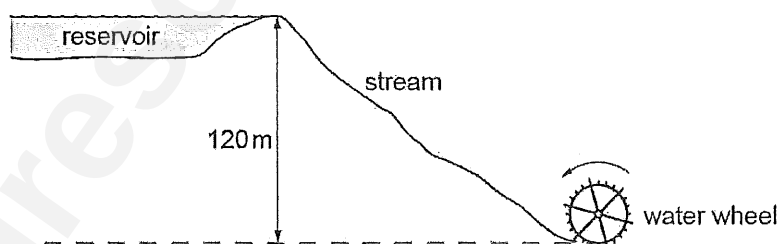
QUESTION 6

adapted from Provincial Prelim P1 2020 and Glenwood House Prelim P1 2020)

- 6.1 A 3 kg block **P** is connected to an 8 kg block **R**, by a light inextensible string that is moving over a frictionless pulley. The kinetic frictional force on block **P** is 15 N. When the system is released from rest, block **R** moves downwards.



- 6.1.1 Name a conservative force that acts on the system. (1)
- 6.1.2 State the *Work-Energy Theorem* in words. (2)
- 6.1.3 Using energy principles, calculate the speed of block **R** after it moved 2 m vertically downwards. (6)
- 6.2 Water flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in the diagram below:



1 kg of water falls from rest through a vertical height of 120 m. (Ignore the effects of air resistance).

- 6.2.1 Show that the speed of the water as it reaches the wheel is $48,5 \text{ m}\cdot\text{s}^{-1}$. (3)
- 6.2.2 The rotating water wheel produces 110 kW of output electrical power. The production of electrical energy from the kinetic energy of the water is 80 % efficient. Calculate the mass of water flowing through the wheel per second. (5)

[17]

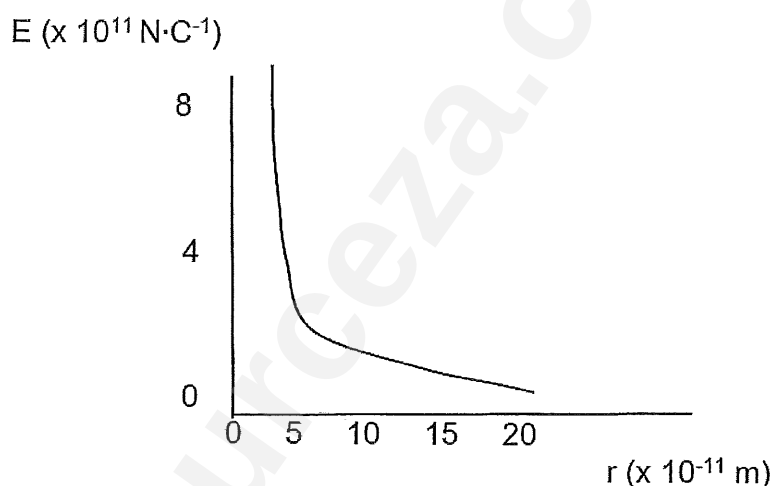
QUESTION 7

- 7.1 A 500 kg research satellite is orbiting the Earth at a certain average height above the Earth's surface. The Earth exerts a force of $1,5 \times 10^3$ N on the satellite to keep it in orbit. Calculate how many kilometres above the Earth's surface the satellite is moving.

The radius of the Earth is $6,38 \times 10^3$ km and the mass of the Earth is $5,98 \times 10^{24}$ kg.

(5)

- 7.2 The graph shows the variation of electric field, E , with distance r , from the centre of a hydrogen nucleus, which contains a single proton.



- 7.2.1 Define the *magnitude of the electric field at a point*. (2)

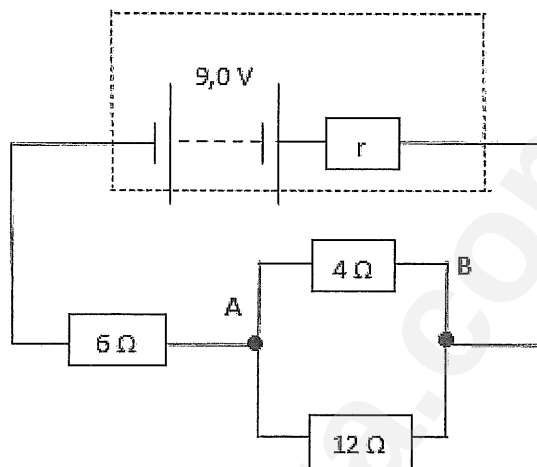
- 7.2.2 Determine the value of the electric field at a distance of $5,0 \times 10^{-11}$ m from the centre of a hydrogen nucleus, which contains a single proton. (3)

- 7.2.3 Use your value of the electric field to calculate the magnitude of the force between the nucleus and an electron separated by a distance of $5,0 \times 10^{-11}$ m. (3)

[13]

QUESTION 8

A battery with an emf of 9 V and internal resistance, r , is connected in the circuit shown in the diagram below. The current in the battery is 0,8 A.



- 8.1 Define *emf*. (2)
- 8.2 Calculate the effective resistance of the parallel network. (2)
- 8.3 Calculate the potential difference between points **A** and **B** in the circuit. (3)
- 8.4 Calculate the amount of charge flowing in the 12 Ω resistor in 20 seconds. (5)
- 8.5 Calculate the internal resistance of the battery. (4)
- 8.6 Calculate the TOTAL energy supplied by the battery in 5 minutes. (4)
- 8.7 Calculate the percentage of energy dissipated by the internal resistance in 5 minutes. (5)

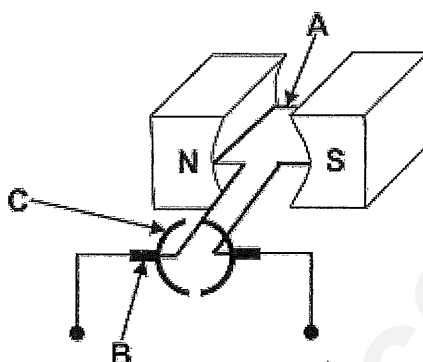
The 6 Ω resistor is NOW connected in parallel with the 4 Ω and 12 Ω resistors.

- 8.8 Will the energy dissipated by the internal resistance in 5 minutes INCREASE, DECREASE or REMAIN THE SAME? Explain your answer, include an appropriate formula. (4)

[29]

QUESTION 9

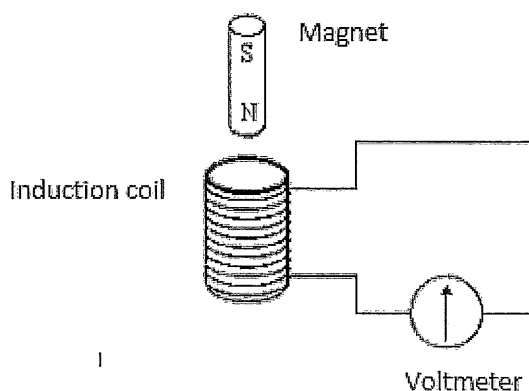
9.1 A simplified diagram of an electric motor is shown below.



- 9.1.1 Name the components labelled **B** and **C**. Write down only the name of the component next to the letters **B** and **C**. (2)
- 9.1.2 Write down the function of the component labelled **C**. (2)
- 9.1.3 Explain why component **A** experiences a magnetic force when a current is passed through it. (2)

9.2 A group of Grade 12 students dropped a magnet from various heights above the top of the coil to investigate the relationship between the velocity of the magnet and the maximum induced emf in the coil.

They set up the following apparatus. An induction coil with a fixed number of turns was connected to a zero centered voltmeter and the same magnet with the north pole facing downwards was dropped from various heights above the induction coil. (Ignore the effects of air resistance).



They recorded their results in a table.

Height (m)	Velocity (m·s ⁻¹)	Voltmeter reading (V)
1	4,43	6,65
2	6,26	9,45
3	7,67	11,51
4	8,85	13,28
5		14,85
10	14,00	21,00

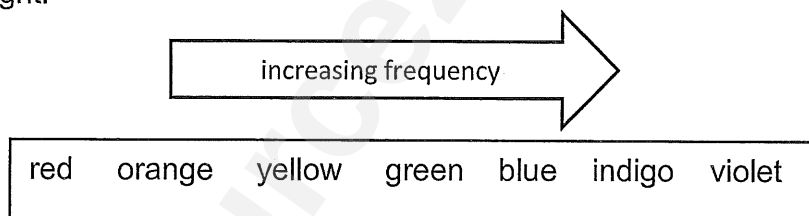
- 9.2.1 State *Faraday's law of electromagnetic induction*. (2)
- 9.2.2 State the independent variable. (1)
- 9.2.3 Complete the table on the **answer sheet** by filling in the missing value for the velocity. (2)
- 9.2.4 Plot a graph of induced emf (voltmeter reading) and velocity. Use the graph paper provided on the **answer sheet**. (6)
- 9.2.5 Using your graph determine the induced emf when the velocity of the magnet is 12 m·s⁻¹. (2)
- 9.2.6 On the same set of axes on the answer sheet (question 9.2.4), draw another sketch graph, labelled N, to show what effect a reduced number of turns will have on the induced emf. (2)

[21]

QUESTION 10

A specific photoelectric cell has a lithium cathode with a work function of $4,64 \times 10^{-19}$ J. The lithium cathode is illuminated with monochromatic GREEN light of wavelength of 550 nm.

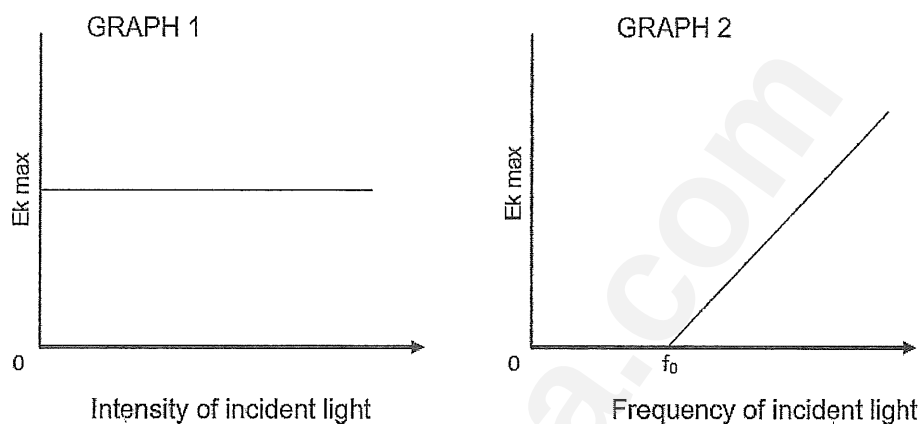
- 10.1 Define *work function*. (2)
- 10.2 Use the given information and an appropriate calculation to indicate why electrons are not ejected from the lithium cathode. (4)
- 10.3 Calculate the velocity of an electron that is ejected from lithium if light with a frequency of $7,5 \times 10^{14}$ Hz shines on the metal. (4)
- 10.4 After a learner looked at the electromagnetic spectrum shown below, he made the following comment.
"The light, used in question 10.3, caused electrons to be ejected is possibly orange light."



Is this statement correct? Explain your answer.

(2)

- 10.5 GRAPH 1 is derived from incident light with a constant frequency, which is higher than the threshold frequency of lithium, which is shone on the lithium cathode.
GRAPH 2 is derived from incident light of different frequencies shone onto the lithium cathode.



Use the graphs to state the relationship between:

- 10.5.1 kinetic energy of the photoelectrons and the intensity of the incident light. (2)
- 10.5.2 kinetic energy of the photoelectrons and the frequency of the incident light. (2)

[16]

TOTAL 200

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EXAMINATION DATA SHEET FOR THE PHYSICAL SCIENCES (PHYSICS)

TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Acceleration due to gravity	g	$9,8 \text{ m}\cdot\text{s}^{-2}$
Speed of light in a vacuum	c	$3,0 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
Universal gravitational constant	G	$6,7 \times 10^{-11} \text{ N}\cdot\text{m}^2\cdot\text{kg}^{-2}$
Coulomb's constant	k	$9,0 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}$
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Planck's constant	h	$6,6 \times 10^{-34} \text{ J}\cdot\text{s}$
1 electron volt	eV	$1,6 \times 10^{-19} \text{ J}$

TABLE 2 PHYSICS FORMULAE

MOTION

$v = u + at$ or $v_f = v_i + a\Delta t$	$s = \left(\frac{v+u}{2}\right)t$ or $\Delta x = \left(\frac{v_f+v_i}{2}\right)\Delta t$
$v^2 = u^2 + 2as$ or $v_f^2 = v_i^2 + 2a\Delta x$	$s = ut + \frac{1}{2}at^2$ or $\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$

FORCE AND MOMENTUM

$F_{\text{net}} = ma$	$F_{\text{net}} = \frac{\Delta p}{\Delta t}$ or $F_{\text{net}}\Delta t = m\Delta v$	$J = \Delta p = mv - mu$ or $J = \Delta p = mv_f - mv_i$
$p = mv$	$F_g = mg$	$F_{\text{fs}}^{\text{max}} = \mu_s F_N$ $F_{\text{fk}} = \mu_k F_N$

WORK, ENERGY AND POWER

$W = Fs$ or $W = F\Delta x$ or $W = F\Delta x \cos \theta$	$P = \frac{W}{t}$	$P = Fv$
$E_p = mgh$	$E_k = \frac{1}{2}mv^2$	$W_{\text{net}} = \Delta E_K$
efficiency = $\frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}} \times 100$		

GRAVITATIONAL AND ELECTRIC FIELDS

$F = G \frac{m_1 m_2}{r^2}$	$g = \frac{F}{m}$	$g = G \frac{M}{r^2}$
$F = k \frac{q_1 q_2}{r^2}$	$E = \frac{F}{q}$	$E = \frac{kQ}{r^2}$

ELECTRIC CIRCUITS

$I = \frac{q}{t}$	$V = \frac{W}{q}$
$R = \frac{V}{I}$	$emf = I(R_{ext} + r)$ or $emf = V_{load} + V_{internal\ resistance}$
$R_s = R_1 + R_2 + \dots$	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$
$P = \frac{W}{t} \quad \text{or} \quad W = Pt$	
$W = VIt \quad \text{or} \quad W = I^2 R t \quad \text{or} \quad W = \frac{V^2}{R} t$	
$P = VI \quad \text{or} \quad P = I^2 R \quad \text{or} \quad P = \frac{V^2}{R}$	

ELECTRODYNAMICS

$\Phi = BA \cos \theta$	$emf = -\frac{N \Delta \Phi}{\Delta t}$	$F = Il \sin \theta$
$V_p I_p = V_s I_s$	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$	

PHOTONS AND ELECTRONS

$c = f \lambda$	$E = hf$ or $E = \frac{hc}{\lambda}$	
$E = W_0 + E_{K(max)}$	$W_0 = hf_0$	$E_{K(max)} = \frac{1}{2}mv_{max}^2$