NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2021

TECHNICAL SCIENCES: PAPER I

Time: 3 hours 150 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 15 pages and a Data Sheet of 2 pages (i–ii). Please check that your question paper is complete.
2. This paper consists of TWELVE questions. Answer ALL the questions in the Answer Book.
3. Please start each question on a new page of your Answer Book.
4. Number your answers exactly as the questions are numbered.
5. Leave ONE line open between sub-questions, for example between QUESTION 2.1 and QUESTION 2.2.
6. You may use a non-programmable calculator.
7. You may use appropriate mathematical instruments.
8. You are advised to use the attached DATA SHEETS.
9. Show ALL formulae and substitutions in ALL calculations.
10. Round off your final numerical answers to a MINIMUM of TWO decimal places.
11. Give brief motivations, discussions, etc. where required.
12. Read the questions carefully.
13. Do not write in the margin.
14. It is in your own interest to write legibly and to present your work neatly.

QUESTION 1 MULTIPLE-CHOICE QUESTIONS

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

1.1 Which ONE of the following forces always acts vertically downwards on an object?

A Normal force

B Frictional force

C Applied force

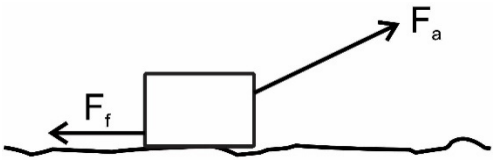
D Gravitational force (2)

1.2 Two objects experience an INELASTIC collision in a closed system. Which ONE of the following combinations regarding the momentum and kinetic energy is correct?

	Momentum	**Kinetic energy**
A	Is not conserved	Is conserved
B	Is conserved	Is not conserved
C	Is not conserved	Is not conserved
D	Is conserved	Is conserved

(2)

1.3 A constant force F_a acts on an object, causing it to move at a constant speed over a rough horizontal surface as shown in the diagram below.



How does the force of friction F_f compare to F_a?

A $F_f = F_a$

B $F_f > F_a$

C $F_f < F_a$

D $F_f = 0$ (2)

1.4 The force acting parallel to a surface and that opposes the motion of a MOVING object relative to the surface is called the …

A static frictional force.

B normal force.

C kinetic frictional force.

D inertia. (2)

1.5 A model car has a motor with variable speed. Which ONE of the following modifications to the motor will NOT increase the speed of rotation of the motor?

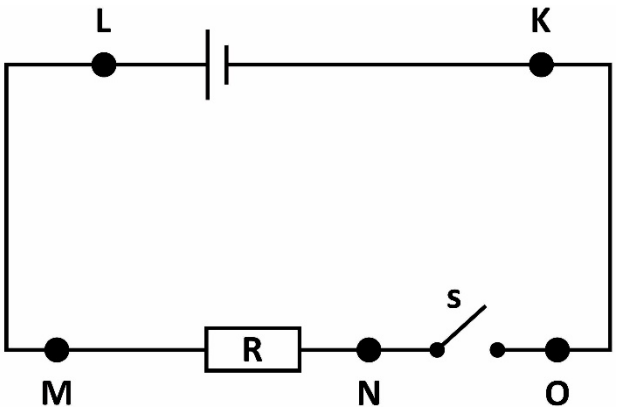
A Increasing the number of turns in the coil of the motor.

B Winding the armature coil around a zinc core.

C Increasing the current flowing through the coil of the motor.

D Increasing the strength of the magnet in the motor. (2)

1.6 A cell is connected to a resistor and an open switch. Five points are labelled K, L, M, N and O respectively.



A voltmeter has a zero reading if it is connected across points …

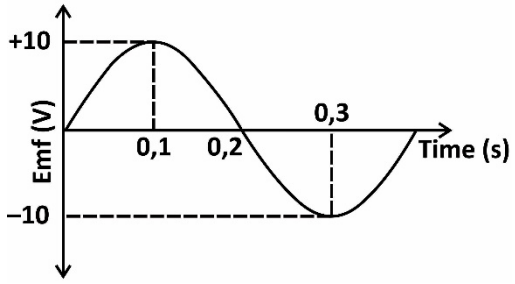
A KL

B MO

C MN

D NO (2)

1.7 The graph below shows the change in the emf generated by a generator versus time.



If the rotation speed of the generator is HALVED, how will this affect the emk and the period represented by the graph?

	emk	Period
A	Smaller than 10 V	0,2 s
B	Larger than 10 V	0,1 s
C	10 V	0,4 s
D	Smaller than 10 V	0,8 s

(2)

1.8 Which one of the following is a source of electromagnetic waves?

A Magnets

B Transverse waves

C Longitudinal waves

D Accelerating charges (2)

1.9 When an object is placed beyond 2F in front of a convex lens, the image that will form has the following properties:

A smaller, upright and real

B smaller, inverted and real

C enlarged, upright and virtual

D enlarged, inverted and real (2)

1.10 Total internal reflection is …

A the change in direction of a wave upon striking the interface between two materials.

B the angle of incidence in the optically denser medium for which the angle of refraction in the optically less-dense medium is 90°.

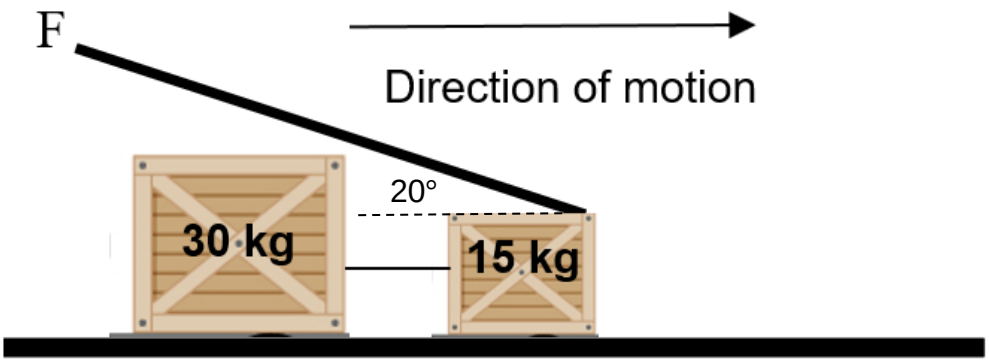
C when the angle of incidence is greater than the critical angle, the ray of light reflects into the original medium.

D when light is refracted, the incident ray, reflected ray and the normal ray all lie in the same plane. (2)

[20]

QUESTION 2

A farmer constructs a method for moving crates in his barn by connecting two crates of masses 15 kg and 30 kg respectively. The crates are connected by a massless, inextensible cord. The farmer then applies a force of 250 N at an angle of 20° to the 15 kg crate by means of a light rigid rod, causing the crates to move across a flat, rough, horizontal surface, as shown in the diagram.



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

2.1 Draw a labelled free-body diagram showing ALL the forces acting on the 15 kg block. (5)

2.2 Calculate the magnitude of the kinetic frictional force acting on the 15 kg block. (3)

2.3 Calculate the magnitude of the acceleration of the system. (4)

2.4 Calculate the tension in the cord connecting the two blocks. (2)

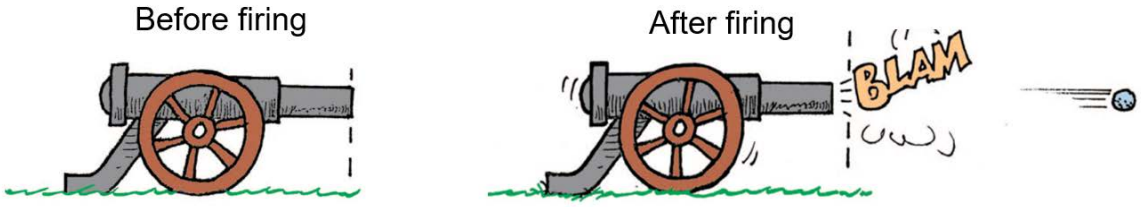
2.5 State in words the *law of motion* that you used to calculate the tension in Question 2.3. (2)

2.6 The farmer's cat jumps onto the 30 kg crate while the farmer is pushing the crates. How will this influence the acceleration of the crates? Choose from INCREASE, DECREASE or STAY THE SAME. Give a reason for your answer. (2)

[18]

QUESTION 3

A cannon has a mass of 1 250 kg. It fires a cannonball at a target. The cannon is loaded with a cannonball that has a mass of 3,2 kg. Directly after the cannon is fired, the cannonball leaves the barrel at a horizontal velocity of 504 km·h^{-1}.



3.1 State the law you would use to explain why the cannon recoils backwards when it is fired. (2)

3.2 Convert the speed of the cannonball leaving the barrel to m·s^{-1}. (2)

3.3 Calculate the maximum velocity with which the cannon moves backwards. (5)

3.4 Define, in words, the term *impulse*. (2)

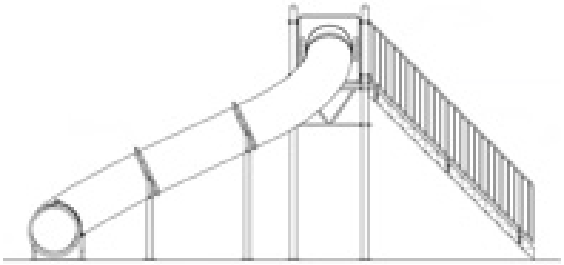
The cannon comes to rest one second after the cannonball was fired.

3.5 Calculate the magnitude of the average net force that causes the cannon to come to rest. (4)

[15]

QUESTION 4

A water slide is constructed so swimmers can slide down the track to the bottom of the slide and fall into a swimming pool. The top of the slide is 5,4 m above the ground. The track along which the swimmer slides is 15,7 m long. The pump supplies enough water to form a frictionless layer of water on which the swimmer slides down the track.



A swimmer with a mass of 55 kg starts from rest at the top of the slide.

Ignore all effects of friction.

4.1 Calculate the increase in gravitational potential energy of the swimmer as he or she reaches the top of the slide. (3)

4.2 State the *law of conservation of mechanical energy*. (2)

4.3 Calculate the speed of the swimmer at the bottom of the slide if the bottom of the slide is 20 cm above the ground. (5)

An electrical pump is used to pump the water vertically up to the top of the slide with a constant velocity. It pumps 100 kg of water to the top of the slide in two minutes.

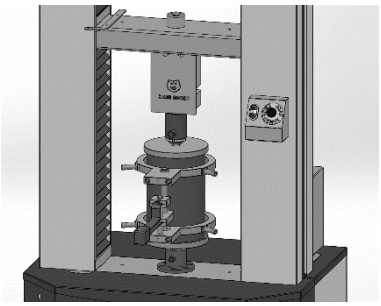
4.4 Calculate the power of the pump while it is pumping the water to the top of the slide. (4)

4.5 The pump is rated 0,135 hp. Calculate the percentage effectivity of the pump. (3)

[17]

QUESTION 5

A hydraulic press is used to do strength testing of a concrete cylinder. The concrete cylinder is compressed until it is destroyed. The amount of force and corresponding change in length of the cylinder is recorded until destruction occurs.



During the compression test of a 150 mm diameter concrete cylinder with a length of 0,2 m, the following force and corresponding change in length readings were recorded. At the exact moment of destruction, the force reading was 596,7 kN and the change in length was 1,08 mm.

5.1 Define the term *elastic limit*. (2)

5.2 Calculate the stress of the concrete cylinder. (4)

5.3 Calculate the strain of the cylinder. (3)

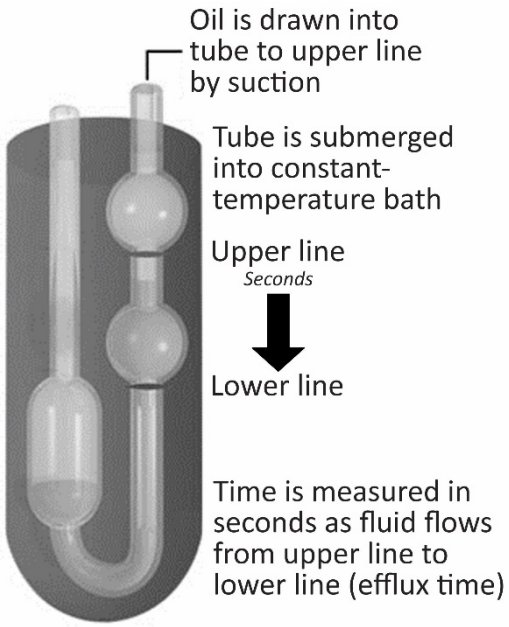
5.4 Give a reason why the answer to Question 5.3 has no unit. (2)

5.5 Determine the elasticity modulus of the concrete. (3)

5.6 Define a *perfectly elastic body* and give an example. (3)
[17]

QUESTION 6

A viscometer is an instrument used to measure fluid viscosity by performing a precise and repeatable viscosity measurement.



Method:

Apply suction to the fluid until the fluid level is at the upper line (which is between the two small bulbs) of the capillary tube.

Measure the time it takes for the fluid level to drop from the upper line to the lower line.

During an experiment to determine the viscosities of single-grade oils, the following data was obtained. The experiments were performed at TWO different temperatures.

	Oil	**Time(s)**	**Temperature**
Experiment 1	A	160 s	40 °C
	B	120 s	40 °C
Experiment 2	A	80 s	X °C
	B	40 s	X °C

Use the data to answer the following questions:

6.1 Define the term *viscosity*. (2)

6.2 Identify the following variables for this experiment.

6.2.1 Controlled variable (1)

6.2.2 Dependent variable (1)

6.3 What is meant by the term *single-grade oil*? (2)

6.4 Why is it important to submerge the viscometer in a constant-temperature bath during the experiment? (2)

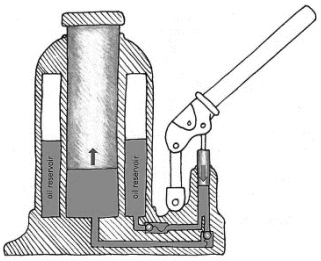
6.5 What is the most likely value for temperature X in Experiment 2? Choose from 20 °C, 40 °C or 80 °C. (1)

6.6 Explain the reason for your choice of temperature in Question 6.5. (3)

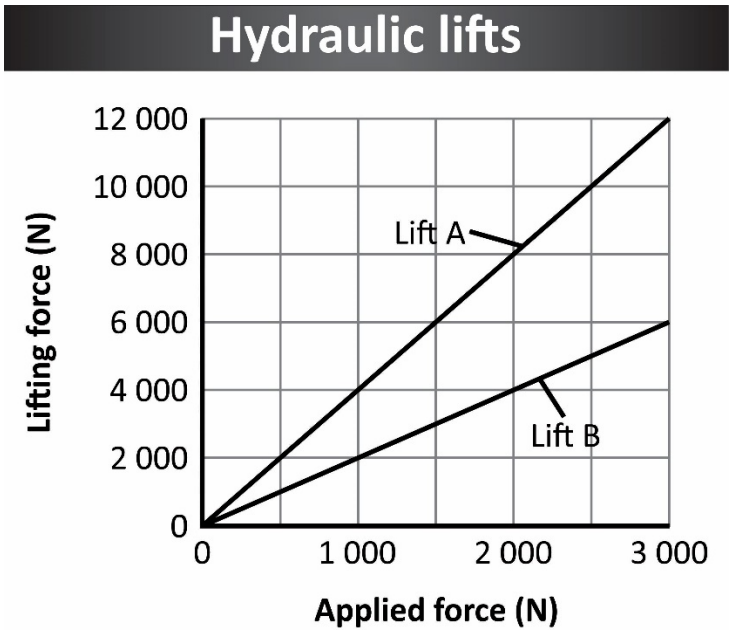
[12]

QUESTION 7

In the adjacent sketch of a hydraulic lift, a force applied on the piston on the right produces a lifting force in the piston on the left.



The following graph shows the relationship between the applied force and the lifting force for two hydraulic lifts A and B, similar to the one in the picture.



7.1 State *Pascal's principle* in words. (2)

7.2 A force of 1 000 N is applied to both lifts. Use the graph to determine the lifting force of each of the lifts A and B. (2)

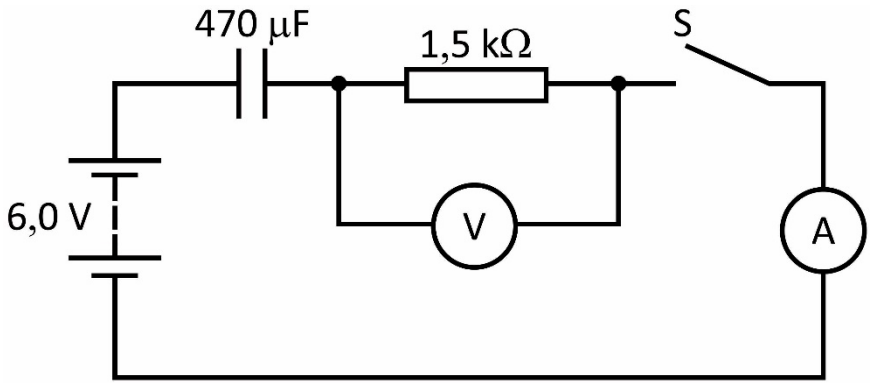
7.3 For lift A, how much force must be applied to lift an object with a mass of 1 020,41 kg? (4)

7.4 What does the gradient of the graph represent? (2)

[10]

QUESTION 8

The following diagram shows a circuit that is used to investigate the charging of a capacitor.



The capacitor is initially uncharged.

The capacitor has a capacitance of 470 μF and the resistor has a resistance of 1,5 kΩ.

The battery has an emk of 6 V with negligible internal resistance.

8.1 Define a *capacitor*. (2)

The switch is now closed.

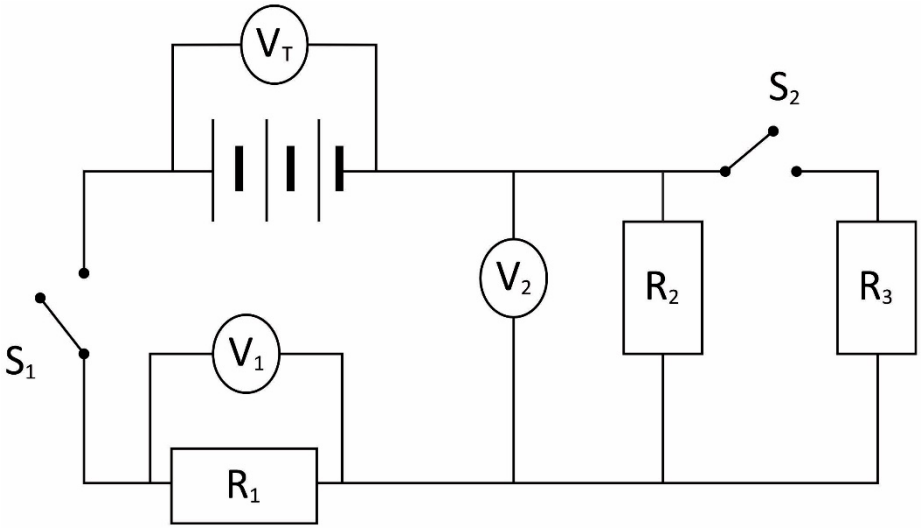
8.2 Calculate the amount of charge that is stored in the capacitor when it is fully charged. (3)

8.3 What change could be made to this circuit to ensure that the same capacitor stores more charge? (1)
[6]

QUESTION 9

Study this circuit diagram and then answer the questions that follow.

Switch S_1 is closed and Switch S_2 is open. The voltmeter V_T gives a reading of 4,5 V.



9.1 What is the potential difference of one of the cells in the circuit? (1)

The reading on voltmeter V_1 is 2,7 V and the resistance of R_1 is 4,5 Ω.

9.2 Calculate the current strength in the circuit. (3)

9.3 Give the reading on voltmeter V_2. (2)

9.4 Calculate the resistance of resistor R_2. (2)

Switch S_2 is now closed.

9.5 What effect will this have on:

9.5.1 The reading on voltmeter V_2?

Choose from INCREASE, DECREASE or STAY THE SAME. (1)

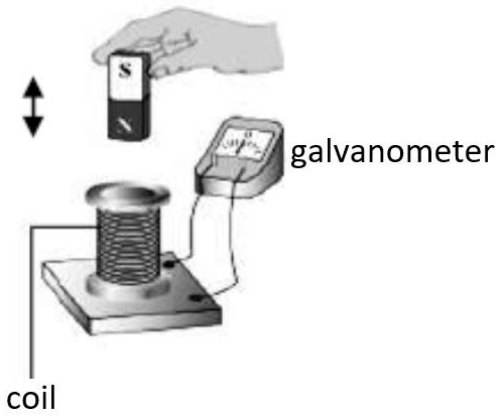
9.5.2 The total resistance in the circuit?

Choose from INCREASE, DECREASE or STAY THE SAME. (1)

[10]

QUESTION 10

In a demonstration of how current can be obtained using a bar magnet, a coil and a galvanometer, the bar magnet is moved up and down, as shown by the arrow in the diagram. The coil has 280 windings and the rate at which the magnetic flux changes is $1,5 \times 10^{-3}\ \text{Wb} \cdot \text{s}^{-1}$.



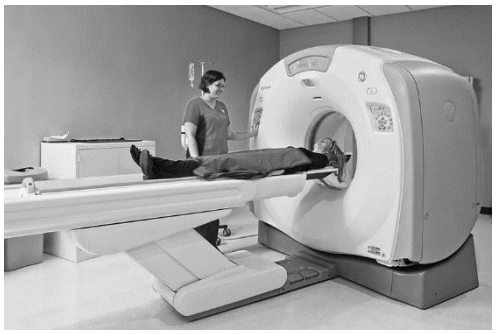
10.1 Briefly describe how the magnet must be moved to obtain a LARGE deflection on the galvanometer. (1)

10.2 State *Faraday's law*. (2)

10.3 Calculate the induced emk. (4)
[7]

QUESTION 11

Study the following pictures and answer the questions below.



11.1 For each of the following inventions, say which type of electromagnetic radiation is used:

11.1.1 Cell phone signal (1)

11.1.2 CT-scanners (1)

11.2 A laser pointer uses red light with a wavelength of 620 nm.

11.2.1 Calculate the frequency of the red light. (3)

11.2.2 Calculate the energy of a photon of red light. (3)

11.3 Gamma rays can be used to kill cancerous tumours.

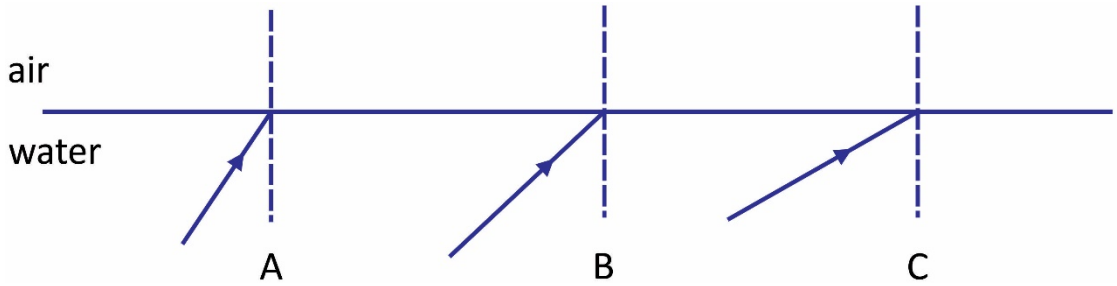
Give a reason why gamma rays have a better penetrating ability than any other electromagnetic radiation. (1)

[9]

QUESTION 12

Study the following diagram and answer the questions below.

Light rays shine through water towards a water–air surface. The incident angle in diagram B is equal to the boundary angle for water.

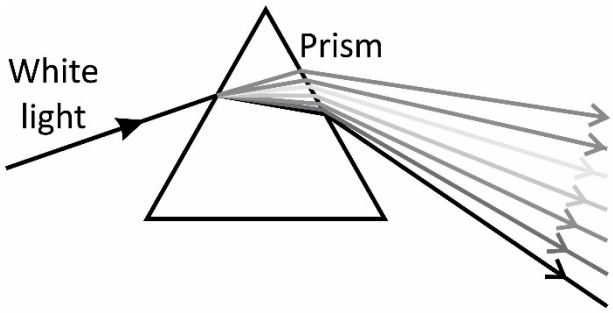


12.1 What phenomenon will occur when the light ray at diagram **A** enters the air? (1)

12.2 The light reflected in diagram C is due to … (1)

12.3 Name two applications of the phenomena that occurs at diagram C. (2)

12.4 Study the following ray diagram and answer the questions that follow.



12.4.1 Define *dispersion of white light*. (2)

12.4.2 State the wave phenomena responsible for dispersion. (1)

12.4.3 What is the observed colour band that forms called? (1)

12.4.4 Which colour light ray is refracted the most? (1)
[9]

Total: 150 marks