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Physical Sciences Preliminary Examination

Paper I – Physics

Saturday 4 September 2021

Form V

Marks: 200

Examiner: C Adelaar

Time: 3 hours

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 19 pages, a yellow answer sheet of 3 pages (i-iii) and a green data sheet of 2 pages (i-ii). Please make sure that your question paper is complete.
2. Remove the data and answer sheets from inside this question paper. **Write your examination number on the answer sheet and question paper.**
3. **Please complete the multiple-choice question on your answer sheet:**
There is only one correct answer for each of the multiple-choice questions. The letter corresponding to the answer you think is correct should be marked with a cross, thus:

A	B	C	D
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Here, C is the answer

4. Start each question on a new page, but please write on both sides of the paper.
5. Use the data and formulae whenever necessary.
6. Show all of the necessary steps in calculations.
7. Where appropriate, take your answers to 2 decimal places, unless instructed otherwise. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
8. It is in your own interest to write legibly and to present your work neatly. Please ensure that you number your answers as the questions are numbered.
9. When you hand in your exam, place the yellow answer sheet in the **front** of your answer book and your question paper booklet and green data sheet at the **back** of your answer book.

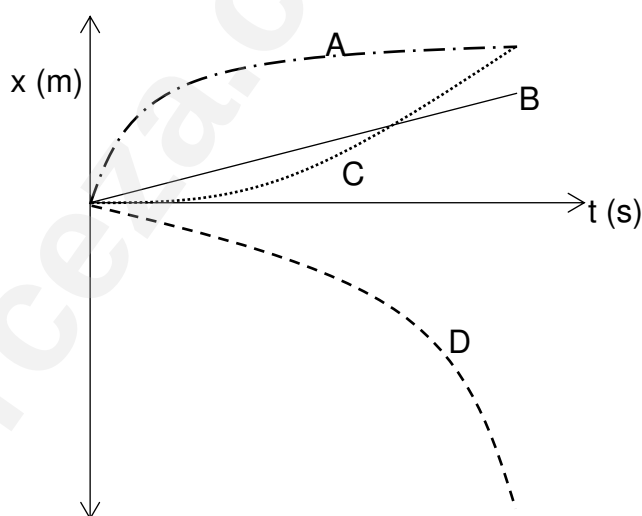
QUESTION 1 **MULTIPLE CHOICE** Downloaded from eduresourceza.com

Answer questions 1.1 – 1.10 on the grid provided on your **answer sheet**. Place a cross over the letter that represents the correct answer.

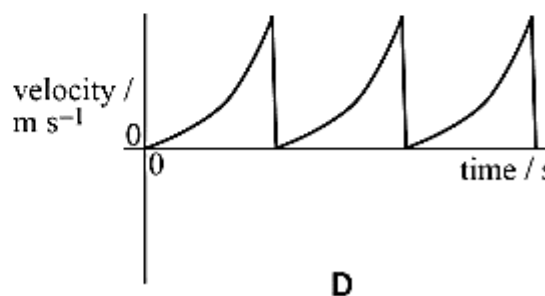
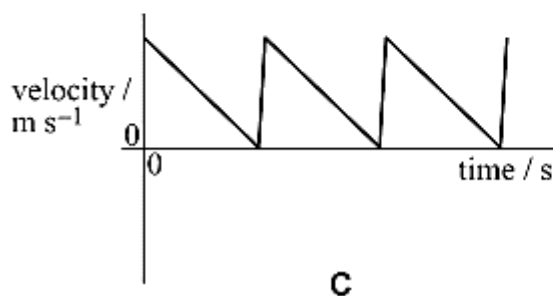
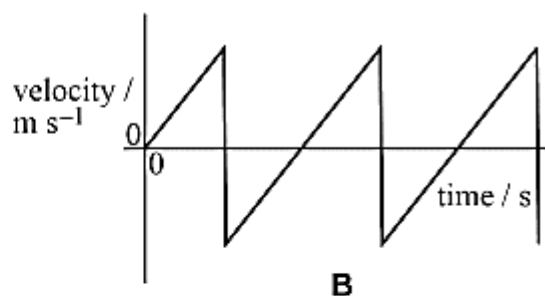
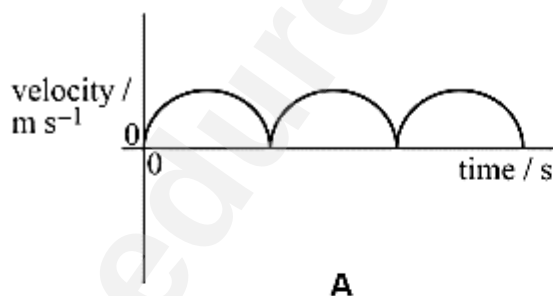
- 1.1 A ball is thrown upwards from a person's hand and rises to a maximum height before dropping back down. At the maximum height above the hand, which of these quantities will have a value of zero?

- A velocity
- B acceleration
- C position
- D displacement

- 1.2 Which curve on the graph alongside indicates the object with the greatest average velocity for the journey shown?



- 1.3 Which graph best represents the velocity–time graph for a ball that is dropped from rest and bounces repeatedly?



- 1.4 Three forces F_1 , F_2 and F_3 act in the same plane, but at a range of different angles relative to each other. They act simultaneously on an object. Which combination of forces can never produce a resultant force of zero?

	F_1 (N)	F_2 (N)	F_3 (N)
A	3	4	5
B	8	8	8
C	2	10	10
D	3	6	10

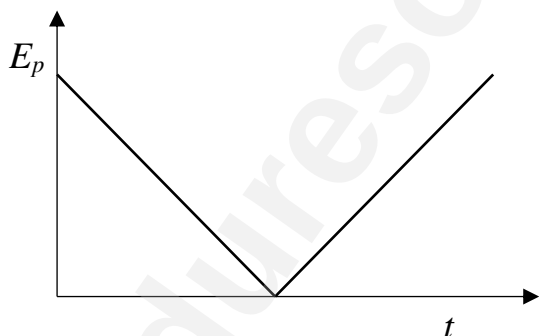
- 1.5 Immediately after take-off from the surface of the Earth, a rocket of mass 12 000 kg accelerates vertically upwards at $1,4 \text{ m.s}^{-2}$

What is the force produced by the rocket motor?

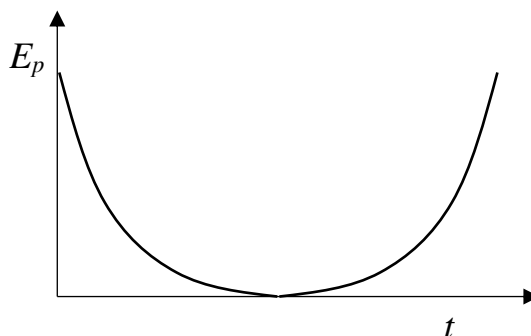
- A $1,68 \times 10^4 \text{ N}$
 B $1,01 \times 10^5 \text{ N}$
 C $1,18 \times 10^5 \text{ N}$
 D $1,34 \times 10^5 \text{ N}$

- 1.6 Which graph shows how the gravitational potential energy, E_p , of a simple pendulum varies with time, t , (for half a swing) when released from its highest position?

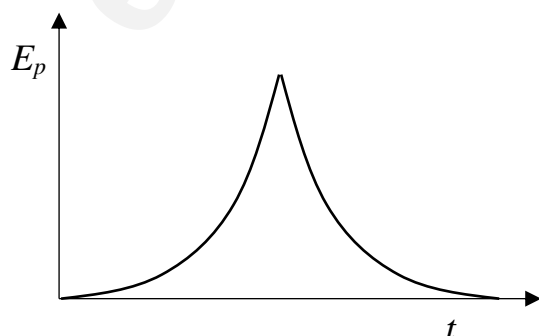
A



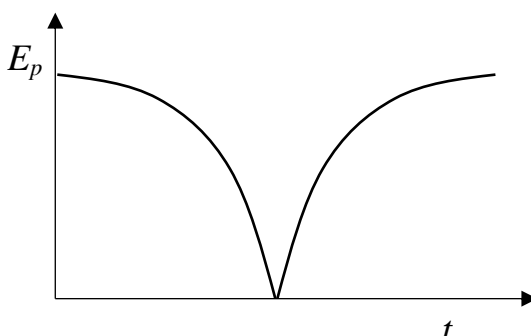
B



C



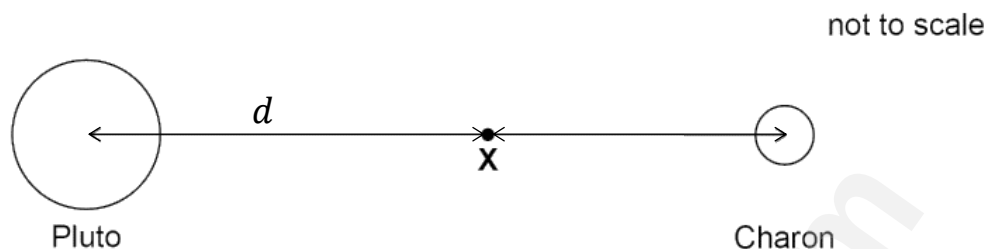
D



- 1.7 Charon is a moon of Pluto that has a mass equal to $\frac{1}{9}$ that of Pluto.

X is the point at which the resultant gravitational field due to Pluto and Charon is zero.

The distance between the centre of Pluto and point **X** is **d**.



What is the distance between the centre of Charon and point **X** in terms of **d**?

- A $\frac{1}{9} d$
- B $\frac{1}{3} d$
- C $\sqrt{9} d$
- D $\sqrt{\frac{1}{3}} d$

- 1.8 A voltmeter is used to measure potential difference for a component **X**.

Which row gives the position and ideal resistance for the voltmeter?

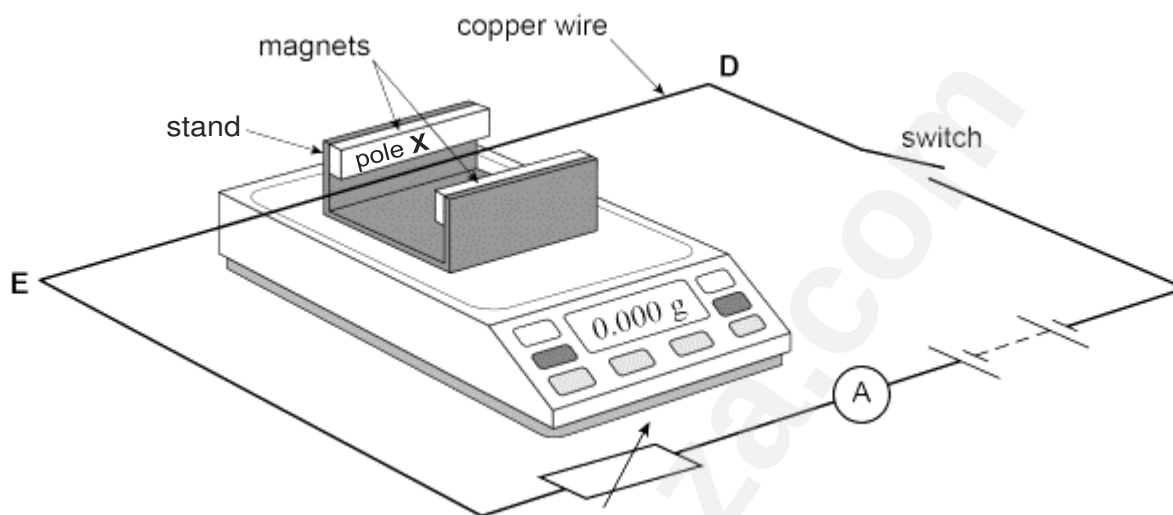
	Position	Ideal resistance
A	In series with X	Infinite
B	In series with X	Zero
C	In parallel with X	Infinite
D	In parallel with X	Zero

- 1.9 A mobile phone operates at a constant power of 200 mW. It has a 3,7 V lithium-ion battery that has a charge capacity of 9400 C.

What is the time taken for the battery to discharge completely?

- A 3,5 hours
- B 4,8 hours
- C 48,3 hours
- D 173,9 hours

- 1.10 The diagram below shows two magnets, supported on a stand, placed on an electronic balance. The magnets produce a uniform horizontal magnetic field in the region between them. A copper wire **DE** is placed in the magnetic field produced by the magnets and connected in the circuit, as shown, but is clamped horizontally (at right angles to the magnetic field) so that it cannot move. When the apparatus is assembled with the switch open, the reading on the electronic balance is set to 0,000 g. This reading changes to a **positive** value when the switch is closed.



Which option below correctly states the direction of the force acting on wire **DE** and the nature of the magnetic pole **X** shown on the diagram when the switch is closed?

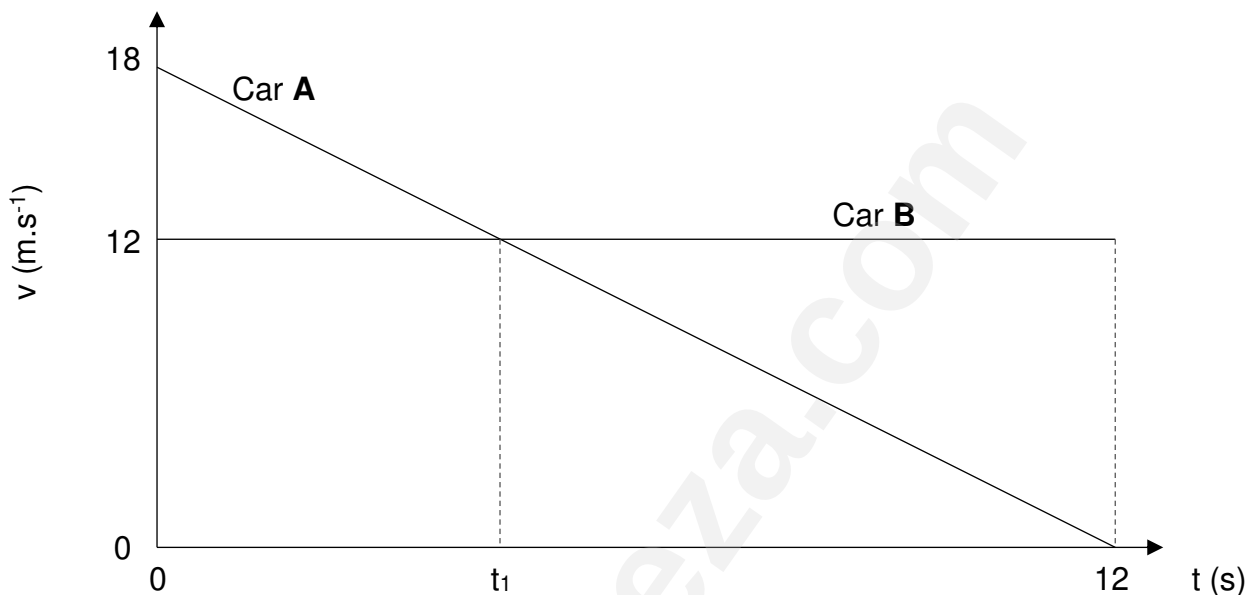
	Direction of the force acting on wire DE	Nature of magnetic pole X
A	vertically up	south
B	vertically down	north
C	vertically up	north
D	vertically down	south

(10 x 2) [20]

QUESTION 2

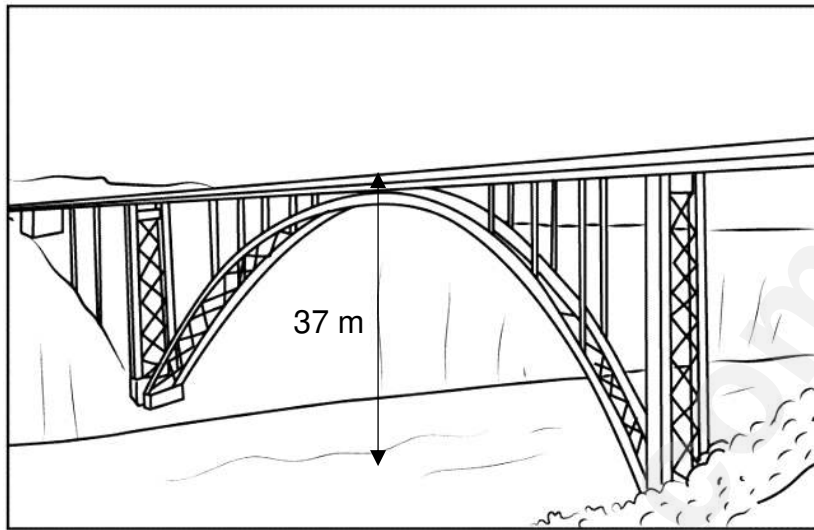
2.1 Two cars are travelling **south** along the same horizontal, straight road.

The velocity-time graph below shows the motion of cars **A** and **B**. At $t = 0$ s, car **A** is ahead of car **B** by 55 m.



- 2.1.1 Define *velocity*. (2)
- 2.1.2 Compare the velocity of car **A** and **B** at time t_1 in terms of both magnitude and direction. (2)
- 2.1.3 Determine the acceleration of car **A**. (4)
- 2.1.4 Determine the value of t_1 . (3)
- 2.1.5 Will car **B** overtake car **A** before car **A** comes to rest? Show all your workings in support of your answer. (6)
- 2.1.6 Sketch a position-time graph for car **A** for the 12 seconds of motion shown. Use car **A**'s final position as the reference point for its motion. Values are not required on the axes. (3)

- 2.2 A small stone is thrown upwards from the railing of a bridge with an initial velocity of $6,5 \text{ m.s}^{-1}$. The water under the bridge is 37 m below the railing.



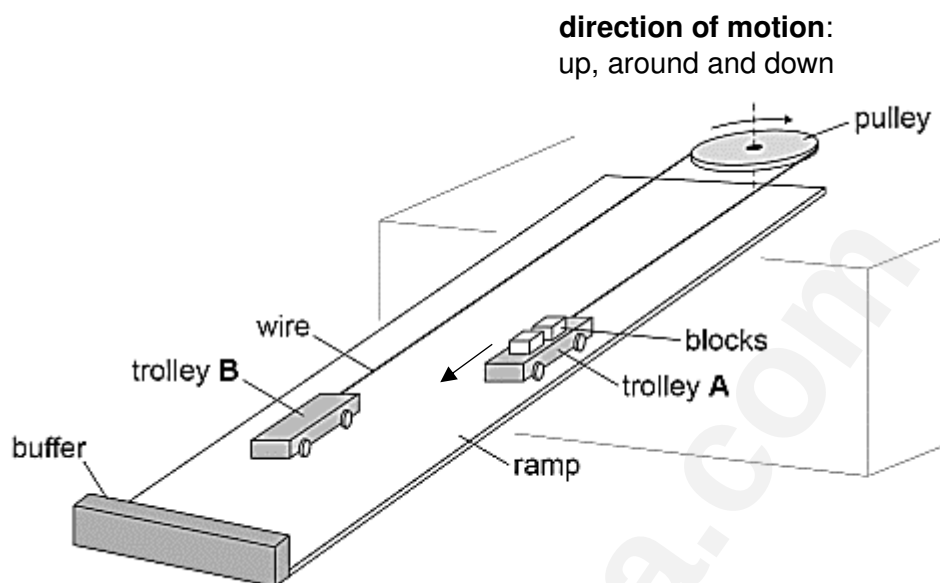
What is the height of the stone above the water, 2 seconds after it is released?

(5)

[25]

QUESTION 3

The first diagram below shows a system being designed to move concrete building blocks from an upper to a lower level.



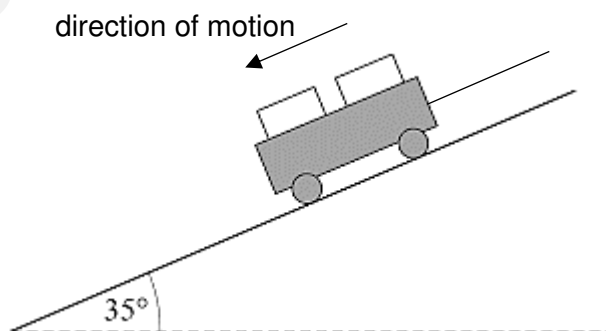
The system consists of two identical trolleys each of mass M on a ramp which is positioned at 35° to the horizontal. The trolleys are connected by a light, inextensible wire that passes around a pulley of negligible mass at the top of the ramp.

Two concrete blocks each of mass m are loaded onto trolley **A** at the top of the ramp. The trolley is released and, under the influence of gravity, g , it accelerates to the bottom of the ramp where it is stopped by a flexible buffer.

The blocks are unloaded from trolley **A** and two blocks are loaded onto trolley **B** that is now at the top of the ramp. The trolleys are released and the process is repeated.

The tension in the wire when the trolleys are moving is T . There is no air resistance or friction at the pulley or experienced by either trolley.

The second diagram below shows the side view of trolley **A** when it is moving down the ramp.



- 3.1 Draw a labelled free body diagram to represent the magnitudes and directions of the forces that act on trolley **A**, **parallel to the ramp** as it travels down the ramp. (2)

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3.2 Assume that the direction of motion as shown on the diagrams on the previous page, is positive.

3.2.1 State *Newton's second law*. (3)

3.2.2 Use Newton's second law to write the equation $F_{net} = ma$ in terms of all the forces acting on trolley **A** which act **parallel** to the ramp. Use all the appropriate variables and angles indicated previously. (3)

3.2.3 Hence, use both trollies **A** and **B** to show that the acceleration a of trolley **A** along the ramp is given by:

$$a = \frac{mg \sin 35^\circ}{M+m} \quad (3)$$

3.3 In practice, for safety reasons, a friction brake is applied to the pulley to reduce the acceleration of the system to $0,34 \text{ m.s}^{-2}$.

The distance travelled by a trolley for each journey down the ramp is 9,0 m.

The following data apply to the arrangement:

Mass of a trolley $M = 95 \text{ kg}$

Mass of a single concrete block $m = 30 \text{ kg}$

3.3.1 Determine the magnitude of the final velocity of loaded trolley **A** at the bottom of the ramp. (4)

3.3.2 Calculate the amount of work done on loaded trolley **A** by the gravitational force in moving it from the top to the bottom of the ramp. (4)

3.4 A motorised winch is used to lift the same two concrete blocks (of mass 30 kg each) upwards vertically from the lower to the upper level at a constant velocity. The winch can lift two concrete blocks together a height of 1 m every second.

During operation, the motorised winch draws 3,6 A from a 220 V supply.

Calculate the power efficiency of the motorised winch. (6)

[25]

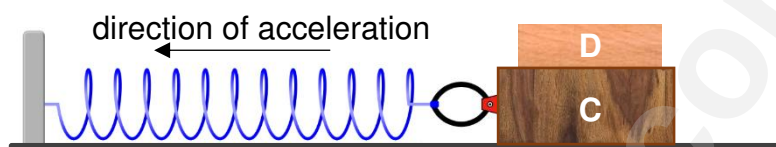
QUESTION 4

Two blocks are placed on top of each other. The bottom one, **C**, is attached to a spring which applies a force to the bottom block, causing it to accelerate to the left.

The spring can be stretched to different lengths in order to apply a greater or lesser force on block **C**.

Block **D** has a mass of 1,1 kg.

The maximum static friction between blocks **C** and **D** is 2 N while kinetic friction between the blocks is 0,7 N.



In the first test, the spring is fully extended and released. As a result, block **C** moves left and block **D** does not move horizontally at all.

- 4.1 Which law explains the outcome of the first test for block **D**? (1)
- 4.2 Which property of block **D** is illustrated in this test? (1)

In the second test, using a different degree of stretch of the spring, block **C** still accelerates to the left, and block **D** remains on top of block **C**, moving with it.

- 4.3 Draw a labelled free body diagram showing all the forces acting on block **D** while block **C** accelerates to the left. (4)
- 4.4 Calculate the magnitude of the maximum acceleration of block **C** so that block **D** does not slide backwards relative to **C**. (3)

[9]

QUESTION 5

The diagram below shows two railway trucks **A** and **B** travelling towards each other on the same railway line which is straight and horizontal.



The trucks are involved in an inelastic collision. They join when they collide and then move together.

Truck **A** has a total mass of 16 000 kg and truck **B** has a total mass of 12 000 kg.

Just before the collision, truck **A** was moving at a speed of $2,8 \text{ m.s}^{-1}$ and truck **B** was moving at a speed of $3,1 \text{ m.s}^{-1}$.

- 5.1 State the quantity that is not conserved in an inelastic collision. (1)
- 5.2 Calculate the speed of the joined trucks immediately after the collision. (5)
- 5.3 Calculate the magnitude of the impulse on truck **A** during the collision. (4)

After the collision, trucks **A** and **B** together, move a distance of 15 m before coming to rest.

- 5.4 Define *frictional force due to a surface*. (2)
- 5.5 Determine the frictional force acting on the trucks together. (5)
- 5.6 Hence determine the kinetic co-efficient of friction between the trucks and the railway track. Express your answer in scientific notation. (4)

[21]

QUESTION 6

The picture shows a toy car, initially at rest, with a piece of modelling clay attached to it.

A pellet, of mass $8 \times 10^{-4} \text{ kg}$, is shot horizontally, with a velocity of v_{fired} , by an air rifle, into the clay and remains in the clay as the toy car moves left.



The motion of the toy car directly after the collision is filmed and analysed. On a particular surface, the toy car and clay with pellet moves 69 cm in a time of 1,3 seconds while coming to rest.

6.1 Show that directly after the collision, the velocity of the toy car was $1,06 \text{ m.s}^{-1}$. (3)

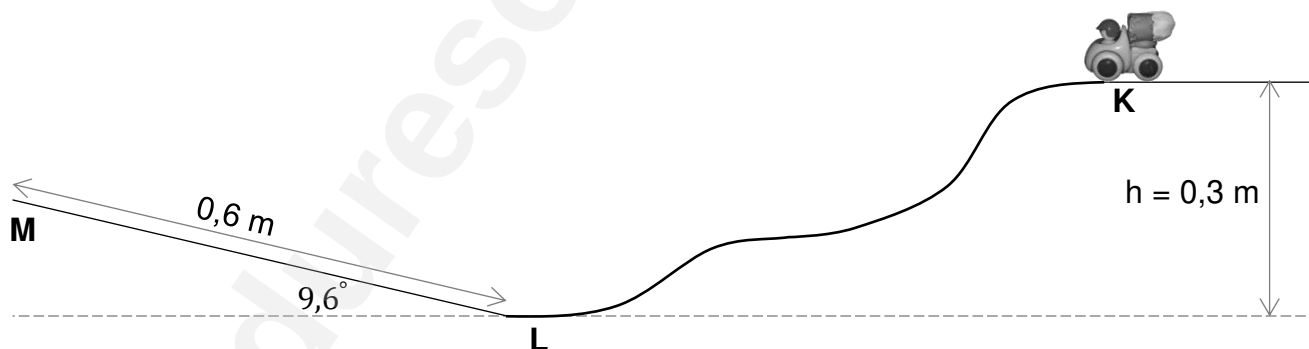
The impulse on the pellet as it embedded in the clay was $0,103 \text{ N.s}$.

6.2 Determine the magnitude of the initial velocity of the pellet, v_{fired} , as it was fired from the air rifle. (4)

The toy car is now placed at the top of a slope as shown in the diagram below. Once again, a pellet is fired into and embeds in the clay causing the toy car to move off with a slightly lower velocity of $1,05 \text{ m.s}^{-1}$.

At the end of the experiment, the toy car (including clay and pellets) is weighed and found to be $9,88 \times 10^{-2} \text{ kg}$. All references to the 'toy car' refer to the toy car, clay and embedded pellets together.

Section **KL** is frictionless but section **LM** does offer a resistive force to the motion of the 'toy car'.



6.3 Calculate the magnitude of the velocity of the 'toy car' at point **L**. (4)

The toy car rises up the slope from **L** and comes to rest at **M**. The length of slope **LM** is 0,6 m and is inclined at $9,6^\circ$ to the horizontal.

6.4 State the *work-energy theorem*. (2)

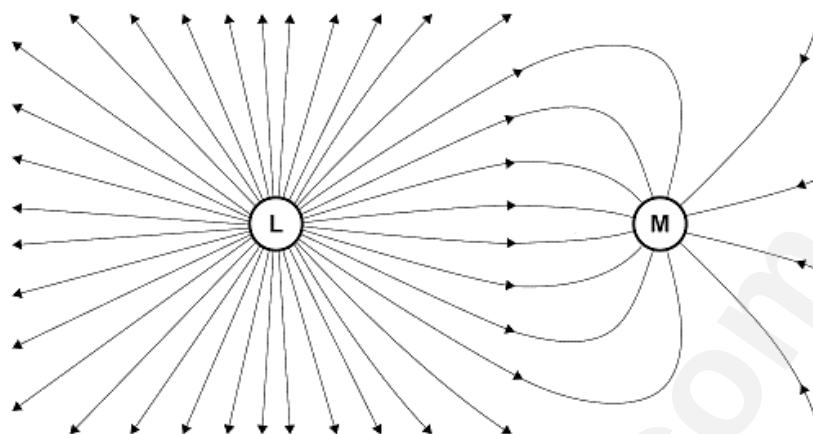
6.5 Determine the net force acting on the 'toy car' as it moves from **L** to **M**. (5)

6.6 Hence, calculate the magnitude of the frictional force acting on the 'toy car' along the slope **LM**. (4)

[22]

QUESTION 7

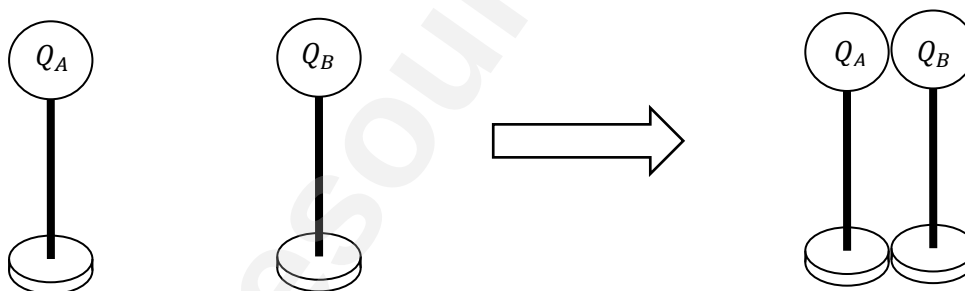
- 7.1 The diagram below shows the field lines for the electric field surrounding two charged objects.



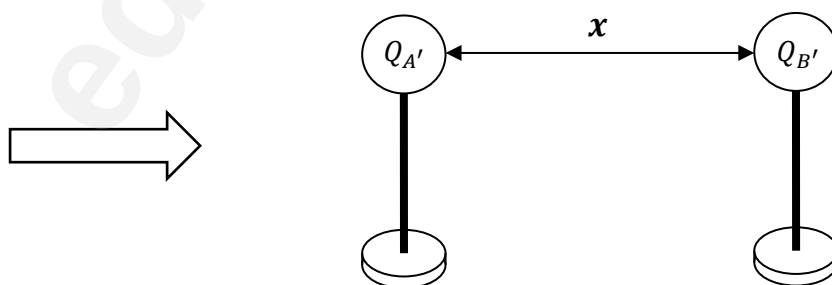
7.1.1 State which object **L** or **M** has a charge with the greater magnitude. (1)

7.1.2 State which object **L** or **M** has a positive charge. (1)

- 7.2 Two charged conducting spheres, supported on insulated stands, are brought together and allowed to touch. The **original** charges are: $Q_A = +55 \mu\text{C}$; $Q_B = -30 \mu\text{C}$



They are then separated to a distance, x , apart where they experience a force of 8,3 N between them.



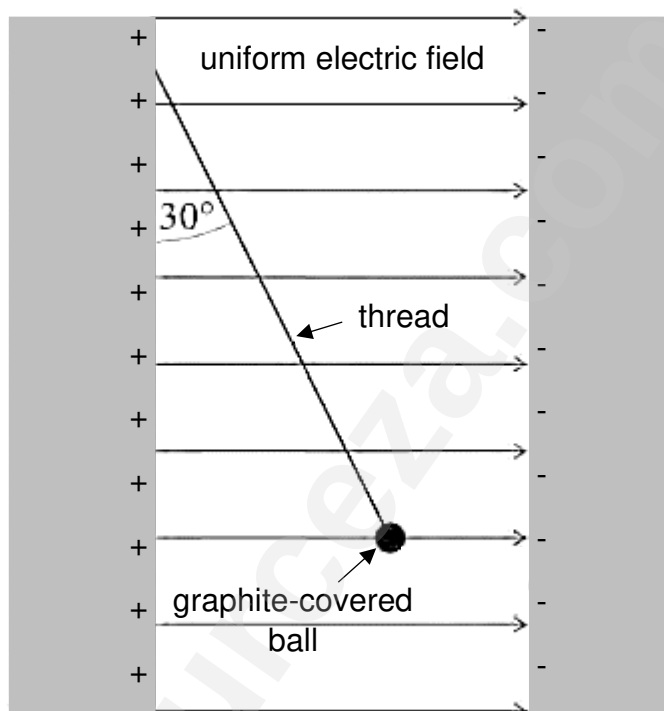
7.2.1 State *Coulomb's law*. (3)

7.2.2 Determine the final distance, x , between the spheres after they have touched and been separated. (6)

- 7.3 A small, graphite-covered ball carries a positive charge of $+5 \times 10^{-6}$ C. The ball has a mass of 0,015 kg. The ball is suspended in equilibrium from a vertical plate by an uncharged non-conducting thread of negligible mass. The left plate is positively charged and, together with the oppositely charged right plate, produces a **uniform** horizontal electric field perpendicular to the plates along the whole of its length.

Note: a uniform field has the same strength throughout the space between the plates.

The diagram below shows that the thread makes an angle of 30° to the left plate.



- 7.3.1 Describe an *electric field*. (2)
- 7.3.2 Draw a labelled force vector diagram (triangle) of the forces with angles acting on the graphite-covered ball while it is suspended in equilibrium. (3)
- 7.3.3 Determine the magnitude of the strength of the electric field at the position where the graphite-covered ball is suspended. (5)

The thread now breaks.

- 7.3.4 **On the answer sheet** provided, draw the path of the graphite covered ball after the thread breaks. (1)

- 7.4 A small mass released from rest just above the surface of Pluto has an acceleration of $0,617 \text{ m.s}^{-2}$. Assume that Pluto has no atmosphere that could provide any resistance to motion.

The radius of Pluto = $1,19 \times 10^6 \text{ m}$. Calculate the mass of Pluto. (4)

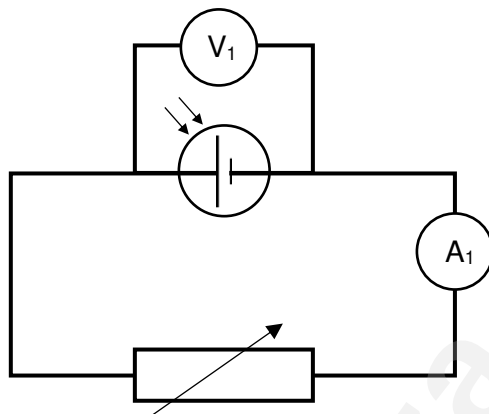
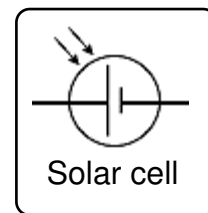
[26]

QUESTION 8

A solar cell is a cell that produces a voltage by converting sunlight into electrical energy. It is a real cell that has a constant internal resistance.

The symbol for a solar cell is similar to a conventional cell, but indicates the input of light, as shown alongside, to generate a small potential difference.

A student investigates the emf and internal resistance of a single solar cell under typical operating conditions by constructing the circuit shown below.

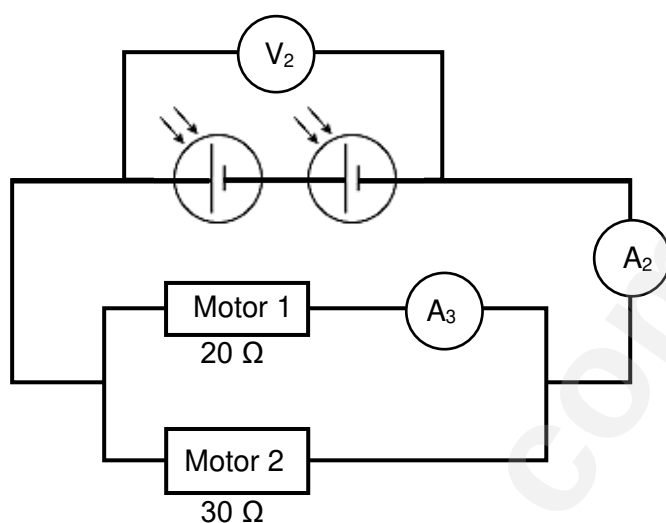


The student determines how the potential difference across the solar cell varies with the current flowing through it. The results of the investigation are recorded in the table below:

Current (A)	Reading on V_1 (V)
0,02	0,55
0,03	0,45
0,04	0,38
0,05	0,32
0,06	0,23
0,07	0,14

- 8.1 State *Ohm's law*. (2)
- 8.2 Describe what the student must do to the circuit in the experiment above in order to change the current from 0,02 A to 0,07 A. (2)
- 8.3 **On the answer sheet** provided, complete the graph for the investigation using the data from the table above. Provide an appropriate y-axis label, plot the points, and include a line of best fit. A heading is not required. (4)
- 8.4 The student wishes to use the graph to deduce the emf and internal resistance of a single solar cell. Answer both questions below **on the answer sheet** provided.
- 8.4.1 What is the emf of the solar cell? Use a different colour **on your graph** to show how the student would have determined this value. (2)
- 8.4.2 Use your graph to determine the internal resistance of the solar cell. Clearly indicate any relevant data points used **on your graph**. (4)

- 8.5 The student now uses two different solar cells (each: $\text{emf} = 0,9 \text{ V}$, $r = 5,0 \Omega$) to run two small, but different motors as shown in the circuit below. Motor 1 has a resistance of 20Ω while Motor 2 has a resistance of 30Ω .



- 8.5.1 Calculate the effective resistance of the external circuit. (3)
- 8.5.2 Calculate the current measured by ammeter A_2 . (4)
- 8.5.3 Calculate the current measured by ammeter A_3 . (5)

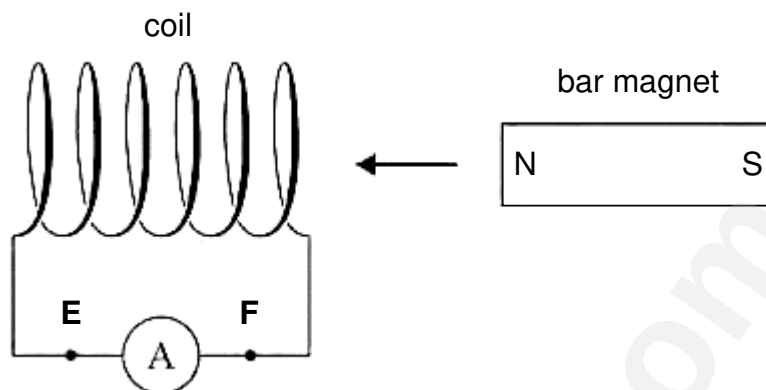
The student decides to remove Motor 2 from the circuit but continues to run Motor 1.

- 8.5.4 Will the reading on voltmeter V_2 , increase, decrease or remain the same when Motor 2 is removed? Explain your answer fully, referring to any appropriate relationships. (4)

[30]

QUESTION 9

- 9.1 Lenz's law can be demonstrated using a bar magnet and a coil of wire connected to a sensitive ammeter as shown in the diagram below.



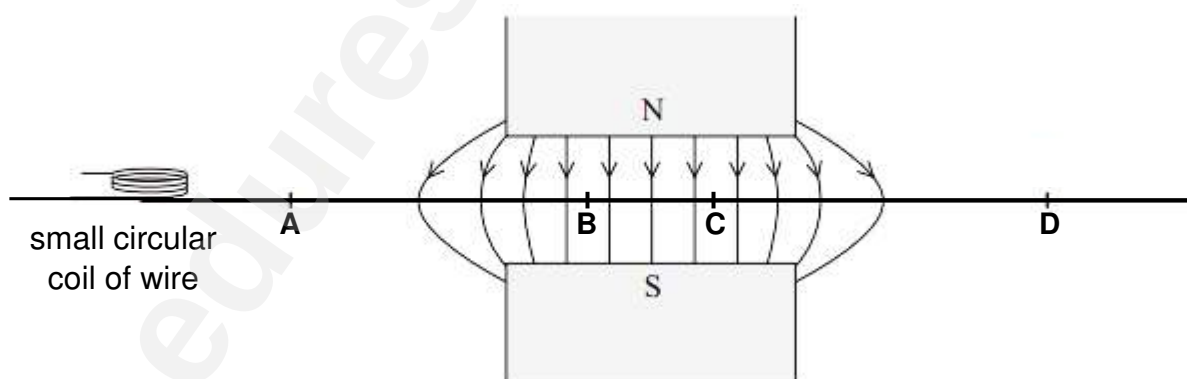
- 9.1.1 State *Lenz's law*. (2)

The bar magnet is moved towards the coil and is then brought to a halt before entering it.

- 9.1.2 Describe how the reading on the ammeter changes during the process described above. (2)

- 9.1.3 During the demonstration an induced current is detected by the ammeter. The induced current moves through the ammeter from **E** to **F**. Explain how this demonstrates Lenz's law. (2)

- 9.2 A U-shaped magnet is placed so that its north pole is vertically above its south pole. A small coil of wire is moved horizontally from **A** → **B** → **C** → **D** along the line shown which is midway between the poles. The coil is moved at constant velocity.

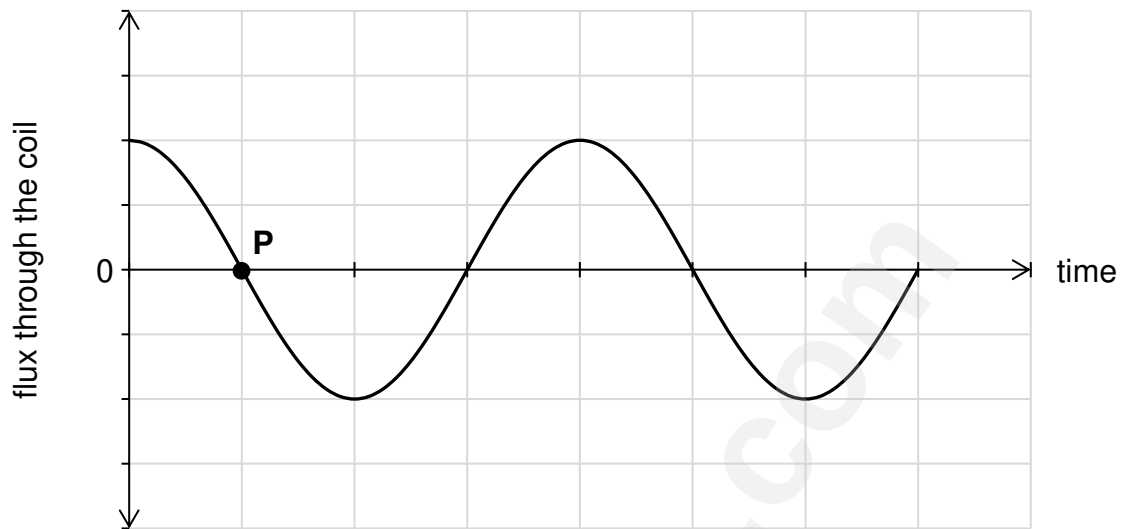


- 9.2.1 State *Faraday's law of electromagnetic induction*. (2)

- 9.2.2 Between which two consecutive positions (marked by letters **A**, **B**, **C** and **D**) will there be **no** induced current in the coil? (1)

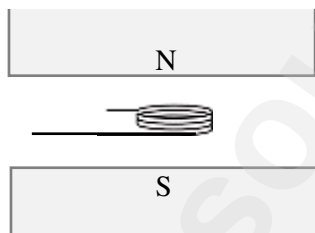
- 9.2.3 Explain why there is no induced current during this particular section of the coil's motion. (3)

- 9.2.4 The small circular coil of wire is now placed between **B** and **C** and is rotated about the axis of the **B-C** line. The following graph shows the flux through the coil at different times during the rotation.

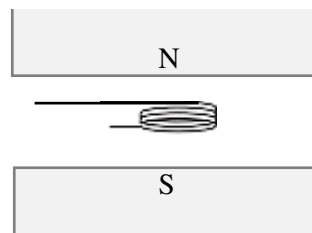


- (a) Which one of the images below represents the position of the coil in the field in order to have a flux through the coil as shown at point **P** on the graph?
Write down only the letter that represents the correct answer. (1)

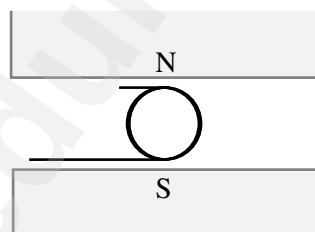
A



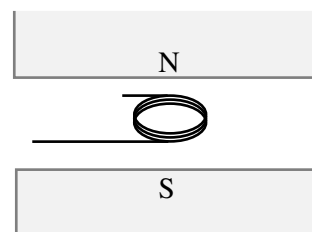
B



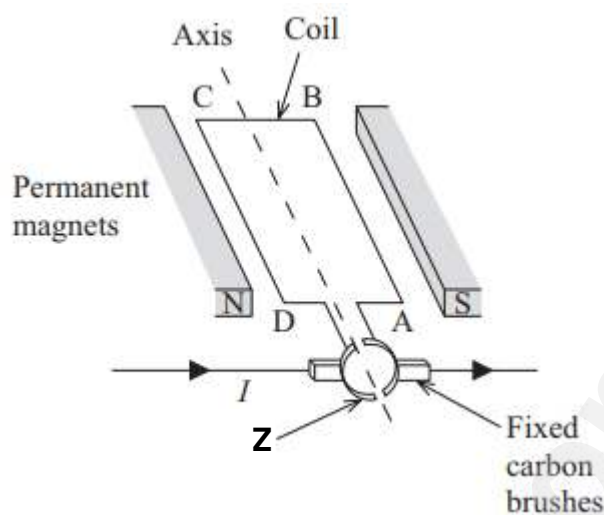
C



D



- (b) **On the answer sheet** provided, draw a second line on the graph to represent the induced emf produced in this coil during the rotation shown. Label this line '(b)'. (2)
- (c) **On the answer sheet** provided, draw a third line on the graph to show the changing flux through the coil if the coil is rotated twice as fast. The coil starts its rotation in the same orientation as the first rotation given. Label this line '(c)'. (2)



- 9.3.1 What is indicated in the diagram by letter **Z**? (1)
- 9.3.2 In which direction will the coil rotate in this motor? Answer with **clockwise** or **anticlockwise**. (1)
- 9.3.3 Explain why wire **AB** of the coil experiences the force which creates the rotation described in 9.3.2 above. You may make use of a simple diagram to help you. (3)
- [22]**

TOTAL MARKS: 200

Sources: Acknowledgements and Thanks:

Questions: 1.3; 3.1-3.3; 7.1-7.4: Adapted from AQA A-level Physics Paper 1 June 2017 from <https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2017/june/AQA-74081-QP-JUN17.PDF>

Questions: 1.4-1.5 & 1.8-1.9; 4.1: Adapted from AQA A-level Physics Paper 1 June 2018 from <https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2018/june/AQA-74081-QP-JUN18.PDF>

Question: 4.2: Adapted from the IEB Grade 12 Final NSC Physics Examination 2020

Question: 5.1 & 5.2: Adapted from <https://cdn.savemyexams.co.uk/uploads/5/0/8/7/50878855/21.1 - momentum qp.pdf>

Questions: 6.3 & 8.1: Adapted from AQA A-level Physics Paper 2 June 2018 from <https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2018/june/AQA-74082-QP-JUN18.PDF>

Questions: 1.7 & 1.10; 6.1 & 6.4: Adapted from AQA A-level Physics Paper 2 June 2017 from <https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2017/june/AQA-74082-QP-JUN17.PDF>

Questions: 8.2 & 8.3: Adapted from Edexcel A level resources accessed from:

<https://cdn.savemyexams.co.uk/uploads/5/0/8/7/50878855/26.2 - electromagnetic induction qp.pdf>