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Physical Sciences Preliminary Examination

Paper I – Physics

Friday 1 September 2023

Form V

Marks: 200

Examiners: C. Adelaar and D. du Toit

Time: 3 hours

Moderator: M-J. Blair

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 32 pages, a data sheet of 2 pages (i-ii). Please make sure that your question paper is complete.
2. When you hand in your examination, please do not hand in the data sheet. You may keep it.
3. Answer ALL the questions on the question paper and hand it in at the end of the examination. Remember to write your examination number in the space provided above and on the back page.
4. Use the data and formulae whenever necessary.
5. Show all the necessary steps in calculations.
6. Where appropriate, take your answers to TWO decimal places, unless instructed otherwise.
7. 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.
9. Please make use of point form in explanation questions and be as concise as possible.
10. Extra answer space (pages 30 and 31) is included at the end of the examination paper. If you run out of space for an answer, use this space. If you use this extra space, make sure that you indicate this clearly at the question to ensure that your answer is marked in full.

QUESTION 1**MULTIPLE CHOICE**

Answer the multiple-choice questions on the answer grid below. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct.

Every question has only one correct answer.

A	B	☒	D
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Here the option C has been marked as an example.

1.1	A	B	C	D
1.2	A	B	C	D
1.3	A	B	C	D
1.4	A	B	C	D
1.5	A	B	C	D
1.6	A	B	C	D
1.7	A	B	C	D
1.8	A	B	C	D
1.9	A	B	C	D
1.10	A	B	C	D

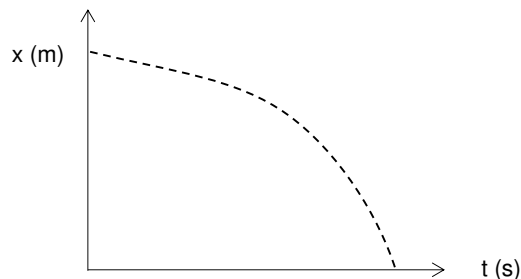
- 1.1 Which one of the following quantities is correctly classified as a scalar or vector and correctly described?

	Quantity	Scalar or vector	Description
A	Distance	Scalar	The change in position of the object
B	Displacement	Vector	The length of path taken by an object
C	Position	Vector	A place relative to a reference point
D	Speed	Vector	The rate of change of position

- 1.2 In which of the following scenarios will the instantaneous velocity of the object at the end of its motion be the same as its average velocity?

- A A ball falls vertically downward from rest.
- B A box slides down a slope with the parallel component of its weight matched by the friction it experiences on the slope.
- C A runner completes a full oval lap of the field running at constant velocity.
- D A car decelerates at a constant rate for a period of 4 seconds.

- 1.3 The change in position of an object is shown in the graph below.

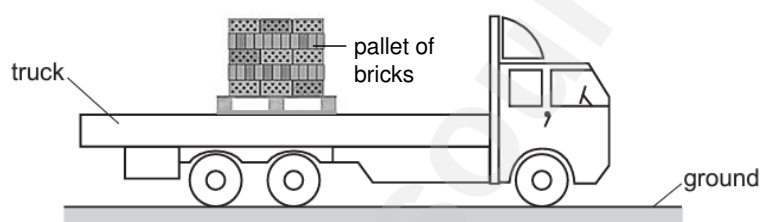


Which statement about the object is NOT CORRECT?

- A The object is slowing down.
- B The position of the object at all times is positive.
- C The average velocity of the object is negative.
- D** The displacement of the object is negative.

Commented [MB1]: I didn't get D. I think this could be level 3 because of the wordiness and the understanding required.

- 1.4 A pallet of bricks (1000 kg) is placed on the back of a flat-bed truck (15000 kg) as shown in the diagram below.



Commented [CA2R1]: I have changed the order of the options, so the first one is incorrect and hence the answer - which reduces the reading load.

As the truck accelerates to the right, the pallet of bricks remains in position on the bed of the truck without sliding.

Which option correctly explains why this happens?

- A Sufficient static friction acts to the right on the pallet of bricks, accelerating it forward with the truck.
- B The net force on the truck is the same as on the pallet of bricks. Thus, both accelerate to the right together.
- C The pallet of bricks will always accelerate with a force directly proportional to μ_s because the normal force is so large.
- D The static friction acts to the left, but the force of the truck on the pallet of bricks is greater, causing it to accelerate to the right.

- 1.5 Two cars are involved in a mild head-on collision. Both cars were moving then came to rest as a result of the impact. The cars do not have the same mass. Car A is heavier than Car B.



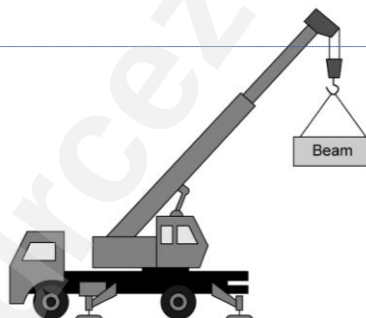
Which option below correctly compares the magnitudes of the given quantities for Car A and B?

	Net force	Change in momentum	Acceleration
A	On A less than on B	A less than B	A less than B
B	On A greater than on B	A greater than B	A greater than B
C	Equal on both	Equal	Equal
D	Equal on both	Equal	A less than B

- 1.6 A crane is used to lift a steel beam, of mass 750 kg, as shown alongside. The crane raises the beam 15 m vertically upwards at a constant speed of $0,50 \text{ m}\cdot\text{s}^{-1}$.

The crane is supplied with 5 kW of power. What is the efficiency of the crane?

- A 22 %
B 44 %
C 74 %
D 136 %



Commented [MB3]: Is this a distractor? I didn't use it.

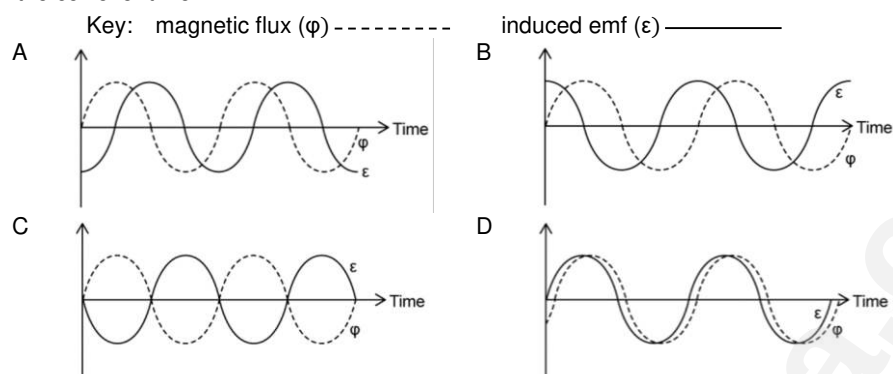
Commented [CA4R3]: Yes, shall I leave it out?

- 1.7 The cost of using a 500 W appliance for 20 minutes is X. What is the cost of electricity per kWh?

- A 6X
B $\frac{3X}{2}$
C $\frac{2X}{3}$
D X

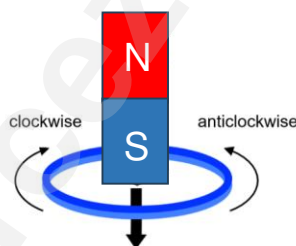
- 1.8 A coil is rotated in a uniform magnetic field. An alternating emf is induced in the coil. What is the correct relationship between the magnetic flux through the coil and the induced emf in the coil over time?

Commented [MB5]: Isn't this concept harder than Level 2? They could so easily put B



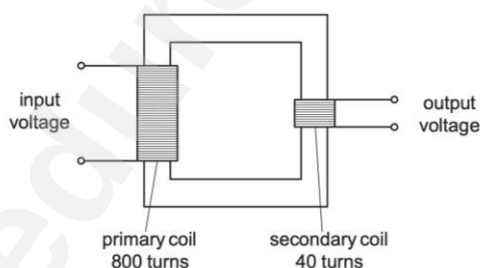
- 1.9 A permanent magnet is dropped, south pole down, through a conducting loop as shown. The magnet falls towards the loop and then away from the loop once it has fallen through.

Which one of the following correctly describes the direction of the current flowing in the loop when the magnet is falling towards the loop and then when falling away from the loop?



	When falling towards	When falling away
A	clockwise	clockwise
B	clockwise	anticlockwise
C	anticlockwise	clockwise
D	anticlockwise	anticlockwise

- 1.10 The diagram below shows a simple transformer.



The input voltage is 240 V. What is the output voltage?

- A 6,0 V B 12 V C 20 V D 40 V

(10 x 2) [20]

QUESTION 2

KINEMATICS – HORIZONTAL FOCUS

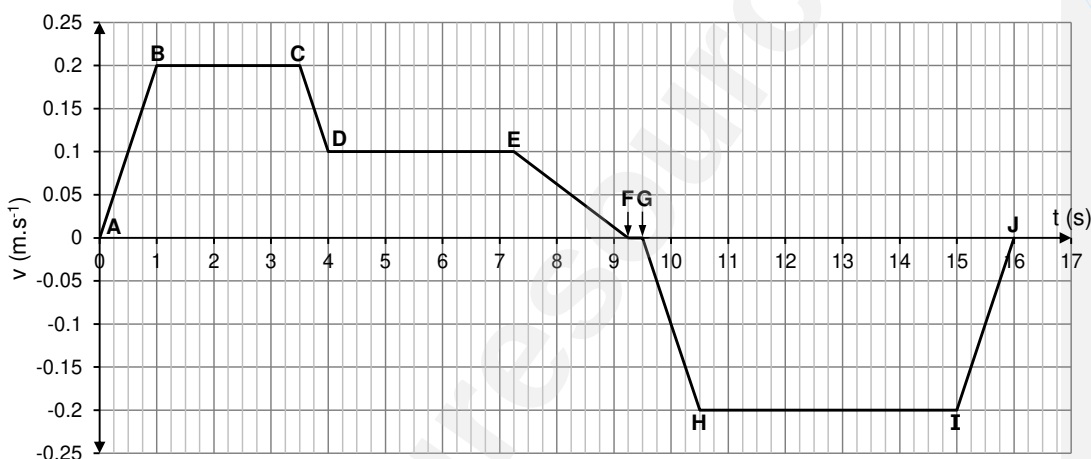
- 2.1 A large format inkjet printer has a printing head that moves in both directions across the paper applying ink as it goes. The speed of the printing head depends on the amount of ink that is being applied to the paper. During periods of acceleration or deceleration of the printing head, it does **not** apply ink. The printing head can apply ink on both its right and left sweeps.

Printing head positioned on the left and able to move right and left across the paper



The velocity time graph below, drawn to scale, shows the movement of the printing head. The printing head initially moves right and returns to its starting position after 16 seconds.

Velocity-time graph for a printer head while printing



2.1.1 Use the letters (A – J) on the graph to identify **intervals** when the printing head:

- is stationary. (1)
- is moving backwards while increasing its speed. (1)
- is printing at the slowest speed. (1)

Commented [MB6]: Perhaps I'm being doff, but why would they need this piece of info?

Commented [CA7R6]: For Q2.1.1 c - so they don't try find the lowest average velocity or pick an interval that starts or ends with v=0

Commented [MB8]: I'm being a bit pedantic, but can we make this as big as the width of the page would allow? Those vertical lines made my eyes go funny and I had to use a highlighter to get the intercepts 😊

Commented [CA9R8]: Done.

2.1.2 Define *acceleration*. (2)

2.1.3 Identify ALL the **intervals** when the **magnitude** of the acceleration of the printing head is identical and non-zero. (2)

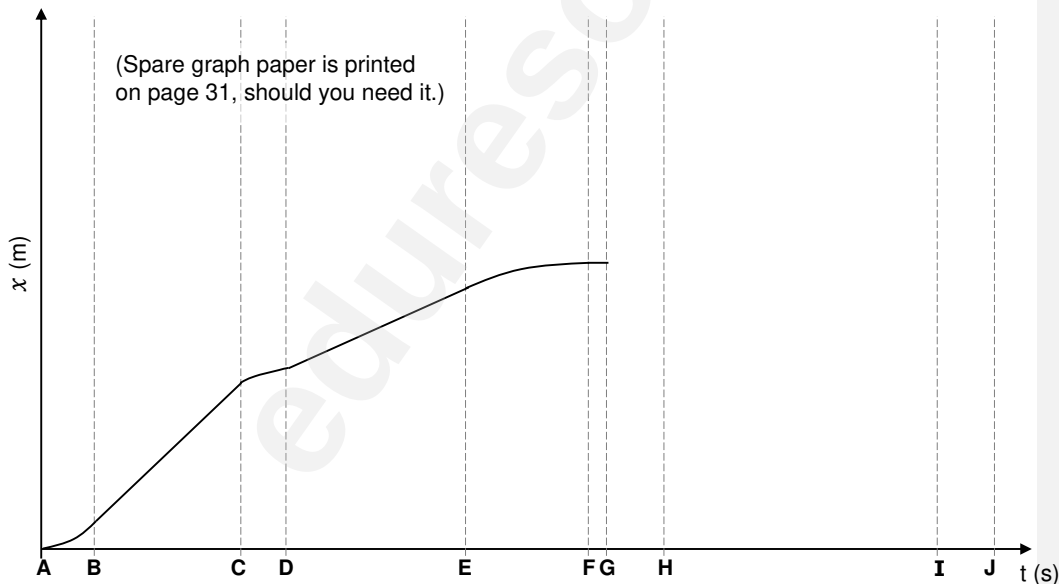
Commented [MB10]: The interval C-D may flummox them. But we mustn't give half marks in a prelim because we never give half marks at the end of the year.

2.1.4 Determine the acceleration of the printing head for the interval **E – F**. (4)

Commented [CA11R10]: OK, there are no 1/2 marks allocated here. Just -1 per error. So if they miss CD they will get 1 out of 2 marks.

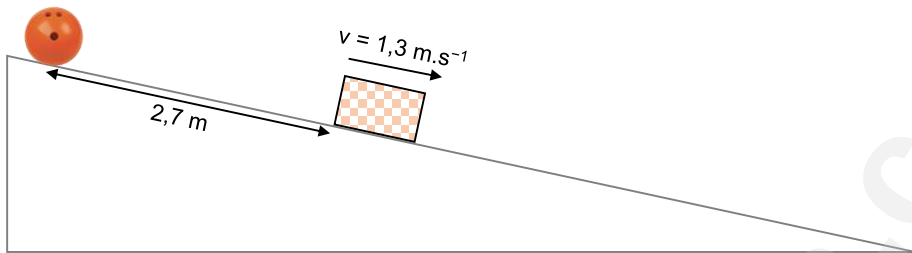
2.1.5 Determine the full distance the printing head moves in its reverse sweep. (4)

2.1.6 Below is the partially completed position versus time graph for the motion of the printing head. Complete the graph for section **G – J**. No values are required, but the sections of motion must align with the labels provided from the v–t graph. (4)



2.2 A box is sliding down a smooth sloped surface with a constant velocity of $1,3 \text{ m.s}^{-1}$.

A heavy bowling ball is placed on the same slope and released from rest when the box is $2,7 \text{ m}$ ahead of it. The ball accelerates at a rate of $2,2 \text{ m.s}^{-2}$.



After what period of time will the bowling ball have caught up with (be at the same place as) the box? (5)

[24]

QUESTION 3

KINEMATICS – VERTICAL FOCUS

- 3.1 A ball is dropped from a height of 9 m. Calculate the magnitude of the final velocity of the ball as it collides with the ground. (3)
- 3.2 The same ball is now thrown upwards from the same height of 9 m with an initial velocity of 4 m.s^{-1} .
- 3.2.1 Will the velocity with which the ball strikes the ground be GREATER THAN, LESS THAN, or EQUAL TO the impact velocity of the ball in 3.1 above? (1)
- 3.2.2 Determine the height of the ball above the ground 0,5 s after the ball was thrown up. (4)
- 3.2.3 When the ball is on its downward journey, what is the magnitude of its velocity when it is 9 m above the ground? (1)

[9]

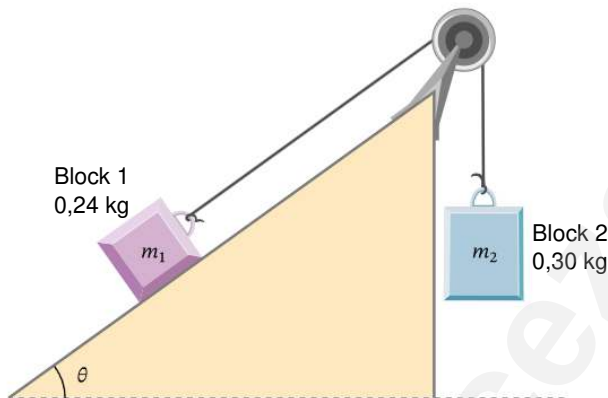
QUESTION 4

NEWTON'S LAWS

Two blocks are connected by a light inextensible string over a frictionless pulley. The surface of the slope is frictionless. Both blocks are initially held stationary.

Block 1 ($m_1 = 0,24 \text{ kg}$) is on the slope while Block 2 ($m_2 = 0,30 \text{ kg}$) hangs vertically.

When released from rest, Block 2 moves $1,47 \text{ m}$ downwards in a time of 1 second .



Commented [MB12]: Just because the picture has a capital B.

4.1 State *Newton's second law*. (2)

4.2 Determine the magnitude of the acceleration of Block 2. (3)

4.3 Calculate the magnitude of the tension in the string connecting the two blocks. (4)

Commented [MB13]: I know that it doesn't really matter as it works both ways but it may prevent some angst amongst the smarties.

4.4 Hence, calculate the value of the angle, θ , of the incline. (5)

4.5 If the angle of the incline is increased, how will the tension in the string be affected? Answer with INCREASES, DECREASES or STAYS THE SAME. (1)

Commented [MB14]: Just checking - its okay to put Stay and not Stays?

[15]

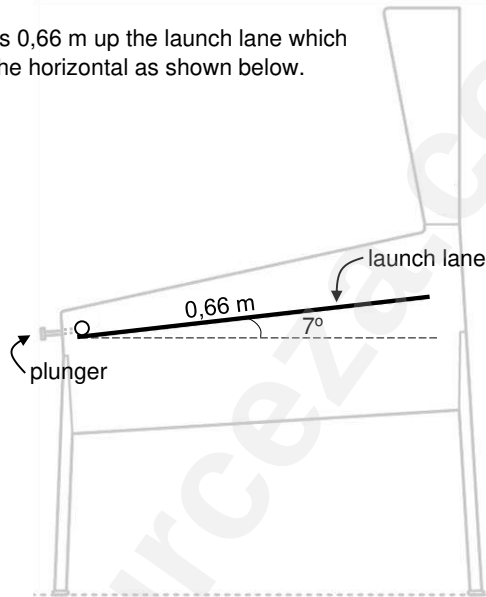
QUESTION 5

IMPULSE, WORK, ENERGY AND FRICTION



The plunger (a compressed spring) of a pinball machine shoots a ball of mass $0,02 \text{ kg}$ up the launch lane by making contact with the ball for $0,03 \text{ seconds}$. As a result, the ball leaves the plunger with a velocity of $37,50 \text{ m.s}^{-1}$.

The ball then moves $0,66 \text{ m}$ up the launch lane which is inclined at 7° to the horizontal as shown below.



Commented [MB15]: I reckon we should use $0,02 \text{ kg}$ to prevent lots of coe. They have to convert to kgs in Q6

5.1 Define *impulse*.

(2)

5.2 Calculate the magnitude of the net force acting on the ball while in contact with the plunger during the ball's launch.

(4)

The ball now moves up the launch lane which offers a little friction. When it reaches the end of the launch lane, its velocity is $37,38 \text{ m}\cdot\text{s}^{-1}$.

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

5.4 Calculate the magnitude and direction of the net force acting on the ball as it moves $0,66 \text{ m}$ up the launch lane. Give your answer to THREE decimal places. (5)

Commented [MB16]: 5 marks? See memo

5.5 Draw a labelled free body diagram of all of the forces acting on the ball while it is moving up the launch lane. Provide a key for your diagram. (3)

Commented [MB17]: Shouldn't we insist on a key nowadays?

- 5.6 Calculate the magnitude of the frictional force acting on the ball in the launch lane. Give your answer to THREE decimal places. (4)
- 5.7 Hence, calculate the co-efficient of kinetic friction for the launch lane surface. Give your answer to TWO decimal places. (3)
- 5.8 Determine the potential energy of the ball at the end of the launch lane. Give your answer to THREE decimal places. (4)

[27]

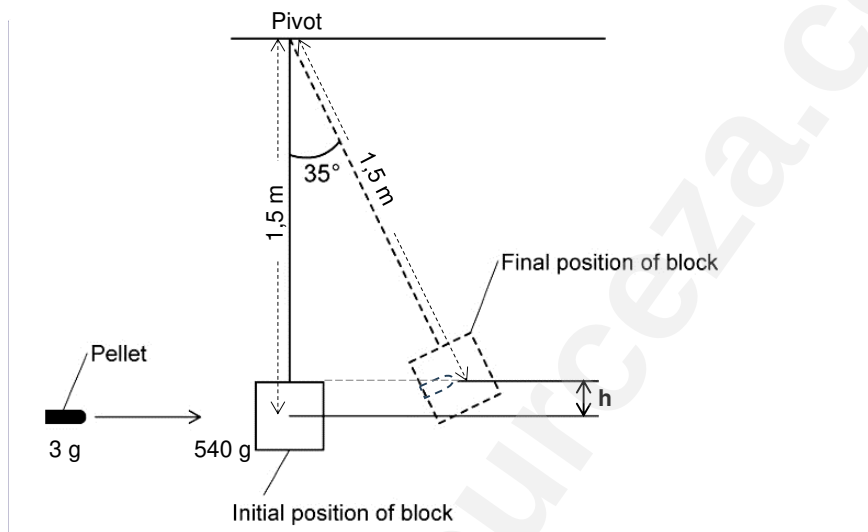
QUESTION 6

MOMENTUM, WORK AND ENERGY

A pellet of mass 3 g is fired into a stationary, suspended block of mass 540 g, as shown below.

The pellet becomes completely embedded in the block. The block with embedded pellet can swing freely at the end of a light inextensible string.

The **distance** from the pivot to the centre of the block is 1,5 m as shown below. This distance remains the same as the block swings up and comes to rest momentarily at its highest point. The centre of the block rises by a vertical height h at an angle of 35° to the vertical.



- 6.1 Use the angle of the string from the vertical and the distance from the pivot to the centre of the block (1,5 m) to show that the vertical change of height of the block, h , is 0,27 m. (2)

Commented [MB18]: Can we make this solid line a dotted line so that they don't confuse it with the inextensible string?

Commented [CA19R18]: Which solid line? I've tried to make it less heavy overall, and broken the length indicator arrows in the middle with the length they represent.

Commented [MB20]: I think this is a level 4 question because the girls have to 'see it'. I don't think many will get it right.

The following information is repeated for your convenience:

- mass of the pellet = 3 g
- mass of the block = 540 g

6.2 Determine the magnitude of the velocity of the pellet and the block immediately after the pellet is embedded. (3)

6.3 Define *linear momentum*. (2)

6.4 Calculate the magnitude of the velocity of the pellet just before it strikes the block. (4)

6.5 Is the collision of the pellet and block ELASTIC or INELASTIC? Explain your answer. No calculations need to be shown. (2)

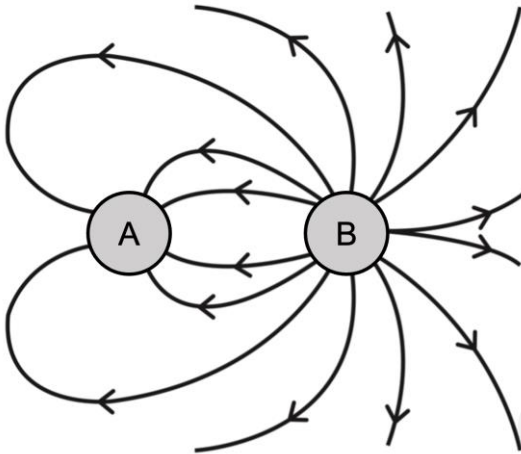
Commented [MB21]: 2 marks? See memo

[13]

QUESTION 7

FIELDS

The following diagram shows the electric field pattern between two charged conductive spheres, A and B in free space. Sphere A is negatively charged, and sphere B is positively charged.



- 7.1 How does the magnitude of the charge on A compare to the charge on B? Circle the correct OPTION below. (1)

The charge on A is GREATER THAN / LESS THAN / EQUAL TO the charge on B.

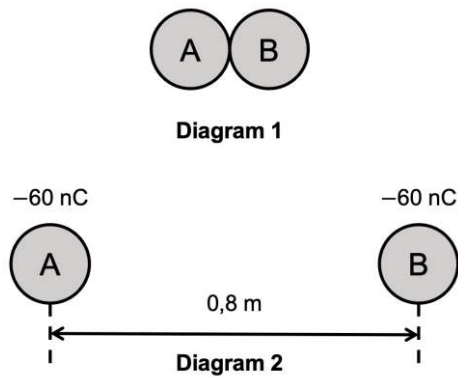
- 7.2 Give a reason for your answer in question 7.1. (1)

- 7.3 How does the magnitude of the force experienced by A compare to the magnitude of the force experienced by B? Circle the correct OPTION below. (1)

The force on A is GREATER THAN / LESS THAN / EQUAL TO the force on B.

The two spheres are brought together and allowed to touch each other (see diagram 1).
The spheres are then separated to a distance of 0,8 m apart (see diagram 2).

The new charge on each sphere is -60 nC .

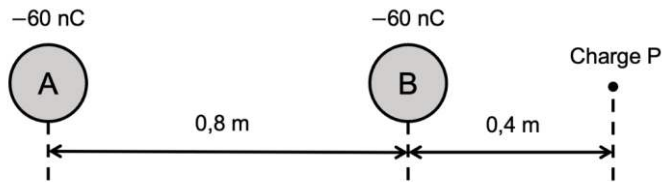


7.4 State Coulomb's Law.

(2)

7.5 Calculate the electrostatic force between spheres A and B when they are 0,8 m apart. (4)

A positive point charge, P, is located 0,4 m to the right of sphere B and is in line with both charges.



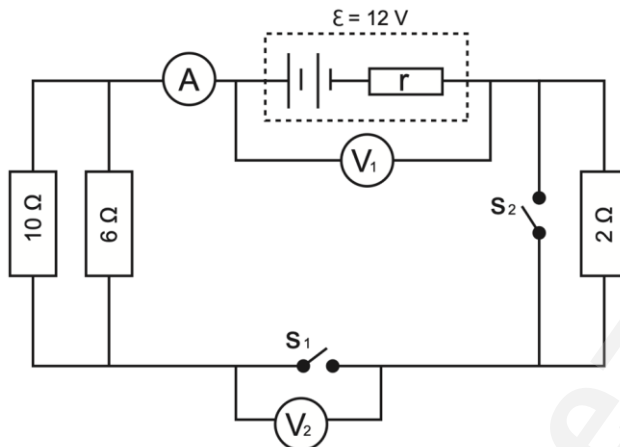
- 7.6 Draw a labelled free-body diagram showing all the electrostatic forces acting on point charge P. The relative size of the forces must be shown. (3)

- 7.7 Calculate the **net electric field** experienced by point charge P. (6)

QUESTION 8

ELECTRIC CIRCUITS

- 8.1 The battery in the circuit represented below has an emf of 12 V and an internal resistance r . Voltmeter V_1 is connected across the battery. The resistance of the connected wires is negligible.



Switches S_1 and S_2 are both open.

8.1.1 What is the reading on voltmeter V_2 ?

(1)

Commented [MB22]: This could be a level 4. Lots of real understanding needed here not to just put 0 V.

Switch S_1 is now closed. Switch S_2 remains open. The reading on V_1 is **10 V**.

8.1.2 What is the new reading on V_2 ?

(1)

8.1.3 Calculate the total external resistance of the circuit.

(4)

8.1.4 Calculate the reading on the ammeter. (3)

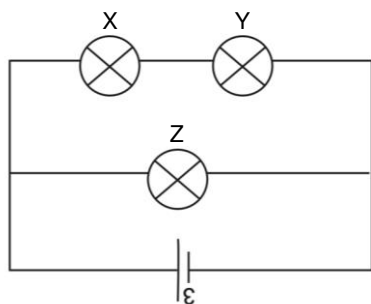
8.1.5 Calculate the internal resistance of the battery. (4)

Both switches S_1 and S_2 are now closed.

8.1.6 How will the reading on V_1 be affected? State either INCREASES, DECREASES or REMAINS THE SAME.
Fully explain your answer using a suitable equation, or equations, to support your answer. (4)

Commented [MB23]: They do these so often that this could actually be a level 3.

- 8.2 In the diagram below, three identical light bulbs, X, Y and Z, with the same resistance are connected to a battery with emf ϵ and negligible internal resistance.



8.2.1 Define *power*. (2)

8.2.2 How does the brightness of bulb X compare with that of bulb Y? (1)

8.2.3 How does the brightness of bulb X compare with that of bulb Z? Give a reason for your answer. (2)

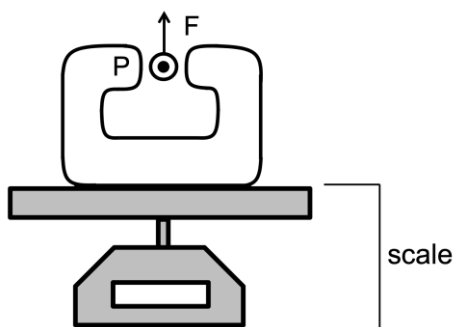
8.2.4 A charge of 180 C flows through bulb Z every 50 seconds. The resistance of bulb Z is $10\ \Omega$. Calculate the power of the bulb. (6)

[28]

QUESTION 9

SCIENTIFIC SKILLS (ELECTRODYNAMICS FOCUS)

A large horseshoe magnet produces a uniform magnetic field, B , between its poles. The magnet is placed on a digital scale and a rigid copper wire, clamped in position, is connected to a potential difference. The wire is placed between the poles of the magnet as shown in the diagram below. One of the poles of the magnet is labelled P.



A direct current is passed through the wire as shown by the convention above. The wire experiences a force upwards.

- 9.1 Explain why the wire experiences a force when set up as described above. (3)

Commented [MB24]: The way that this Q is worded makes it level 2 or level 3. I think its quite difficult to articulate 'the origin'.

- 9.2 What is the polarity of pole P? Circle the correct OPTION below.

NORTH / SOUTH (1)

- 9.3 Using one of Newton's laws, explain why there is an increase in the reading on the scale when current flows through the conductor. (3)

The force on the wire for different currents through the wire is recorded below based on the readings on the scale.

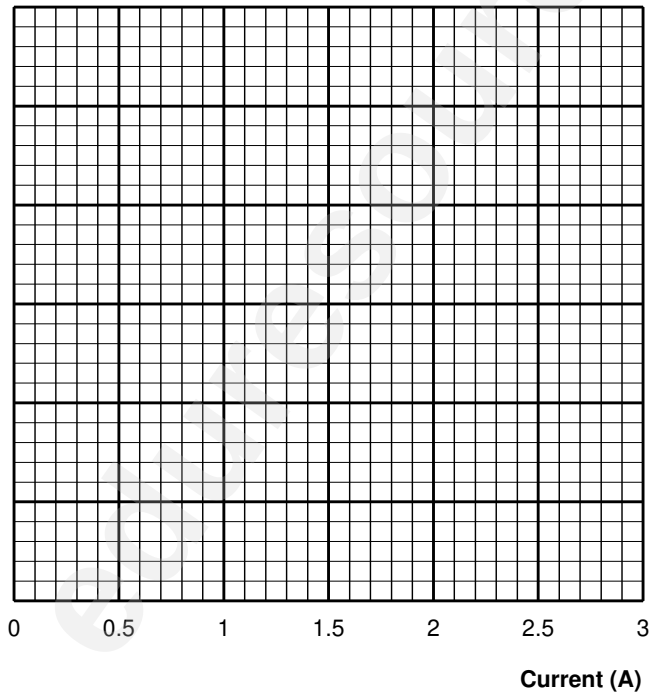
Current (A)	Force ($\times 10^{-3}$ N)
0,5	5,0
1	8,9
1,5	16,4
2	23,5
2,5	28,2

- 9.4 Plot a graph of force (y-axis) vs current (x-axis) on the graph paper below. The x-axis has been scaled for you.

(Spare graph paper is printed on page 31, should you need it.)

(4)

Graph showing the relationship between the force experienced by a conductor in a magnetic field for different currents through the conductor



- 9.5 Calculate the gradient of the graph. A unit is not required. (3)

The magnitude of the force exerted on the wire can be given by the following equation:

$$F = IB\ell$$

Where:

I = current (A)

B = magnetic field strength of the magnet (Wb)

ℓ = length of the wire between the poles of the magnet (m)

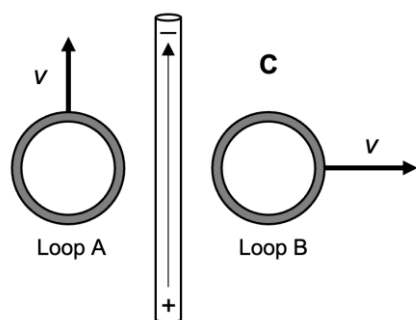
- 9.6 Use the equation and your answer to Question 9.5 to determine the magnetic field strength of the magnet if the length of the wire between the poles of the magnet is 0,1 m. (3)

[17]

QUESTION 10

ELECTRODYNAMICS

- 10.1 Two metal loops, A and B, are moved at the same constant speed, v , relative to a current-carrying conductor as shown below. The direction of the current through the conductor is also shown. **C** is a point to the right of the conductor.



- 10.1.1 In which direction is the magnetic field at **C**? Circle the correct OPTION below.

IN TO THE PAGE / OUT OF THE PAGE (1)

- 10.1.2 Explain why an emf is induced in loop B when it is moved to the right as shown. (2)

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

- 10.1.4 In which direction does current flow in loop B? Circle the correct OPTION below.

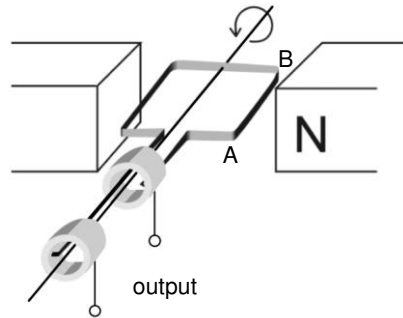
CLOCKWISE / ANTICLOCKWISE (1)

- 10.1.5 What is the magnitude of the current set up in loop A? Circle the correct answer.

The current in loop A is THE SAME AS IN B / GREATER THAN IN B / ZERO (1)

Commented [MB25]: I think that this is quite difficult and should be a level 4

10.2 A simplified diagram of an AC generator is shown below. The coil starts horizontally.



10.2.1 State the energy conversion which takes place in the AC generator. (1)

10.2.2 Using a relevant formula, explain why the flux through the coil is zero when the coil is positioned as shown. (3)

10.2.3 In which direction does current flow in length AB from the moment the generator is rotated in the direction shown? Circle the correct OPTION below.

FROM A TO B / FROM B TO A (1)

10.2.4 What change must be made to the generator to output direct current? (1)

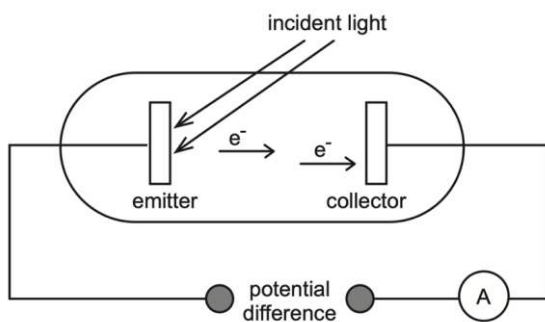
Commented [MB26]: We must make this apparent to our girls when we teach. If they don't know that 'it's a thing' then this would become a level 3 question!

[13]

QUESTION 11

PHOTONS AND ELECTRONS

- 11.1 Blue light of $460 \times 10^{-9} \text{ m}$ is incident on a photocell with a caesium metal emitter as shown below. The threshold frequency of caesium is $5 \times 10^{14} \text{ Hz}$.

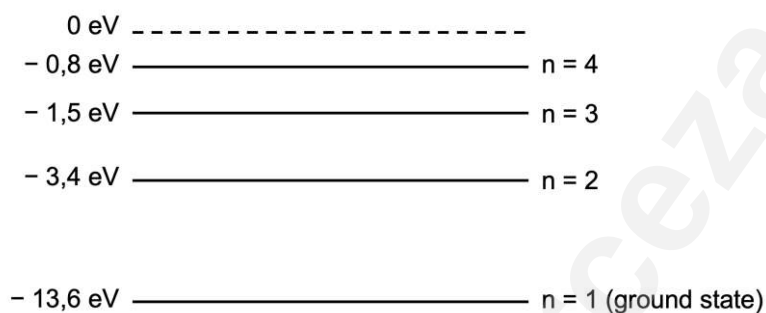


- 11.1.1 How does the above image show that the photoelectric effect is observed? (1)
- 11.1.2 Calculate the work function of caesium. (3)
- 11.1.3 Calculate the magnitude of the maximum velocity of an electron emitted from the caesium when it is irradiated with blue light. (6)

11.1.4 Explain why the emitted electrons have a range of velocities up to a maximum value. (2)

Commented [MB27]: Isn't this level 2 or 3? Its quite a deep undersatnding of it - being able to visualise what is happening even if we have discussed it with them.

11.2 The diagram below shows the energy levels of an atom of a hypothetical element. An electron is excited and moves from ground state to the 4th energy level ($n = 4$).



Calculate the **longest** wavelength of light that could possibly be emitted by this atom. (4)

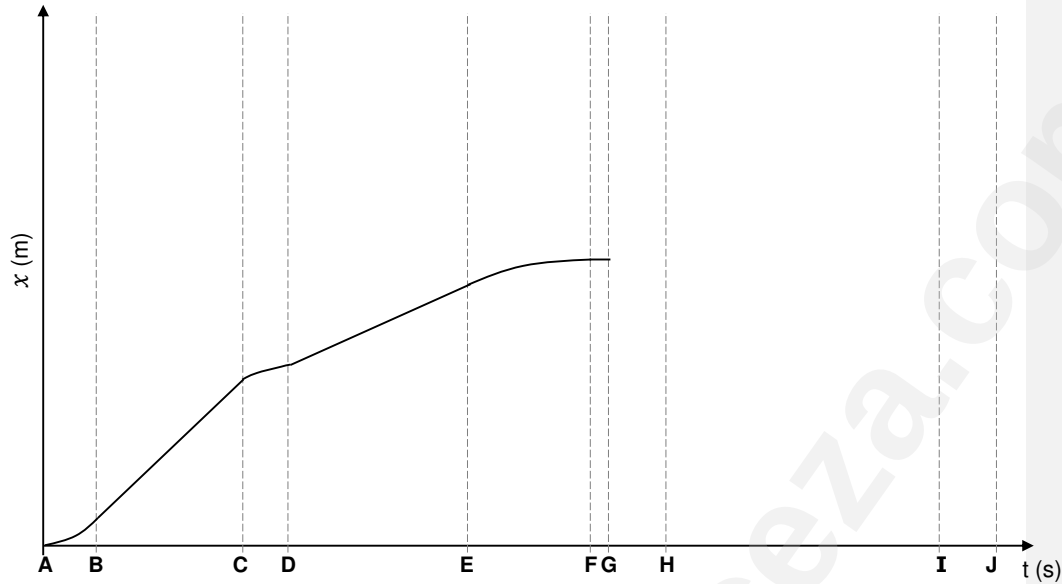
[16]

Total: 200 marks

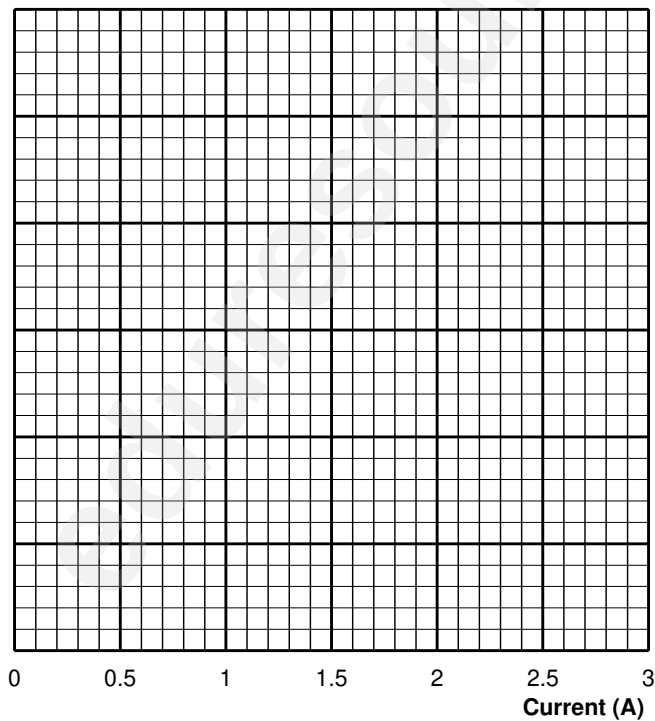
ADDITIONAL SPACE (ALL questions)

**REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED THE
ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.**

SPARE GRAPH PAPER: QUESTIONS 2.1.6 and 9.3



Graph showing the relationship between the force experienced by a conductor in a magnetic field for different currents through the conductor



MARKING GRID FOR EXAMINER'S USE ONLY

Examination number: _____

Paper I: Physics Preliminary Examination 2023

	Topic	Out of	Pupil mark
Question 1	MCQ	20	
Question 2	Kinematics – horizontal focus	24	
Question 3	Kinematics – vertical focus	9	
Question 4	Newton's laws – inclined plane and pulley	15	
Question 5	Impulse, work, energy and friction	27	
Question 6	Momentum, work and energy	13	
Question 7	Fields	18	
Question 8	Electric circuits	28	
Question 9	Scientific skills	17	
Question 10	Electrodynamics	13	
Question 11	Photons and electrons	16	
TOTAL		200	

Sources: Acknowledgements and Thanks:

Question 1.4: image adapted from: <https://www.ocr.org.uk/Images/667483-question-paper-breadth-in-physics.pdf> (AS Level Physics, OCR, October 2021, H156/01 Breadth in physics)

Question 1.6: question adapted from: <https://cdn.savemyexams.co.uk/pdfs/1tVtJln8KRbJhXO0.pdf> (AQA AS Physics, Topic 4 Mechanics & Materials 4.6 Work, energy and power)

Question 1.8

Question 1.9

Question 2: Image from: <https://za.pinterest.com/pin/mimaki-digital-large-format-printer-posters-banners-pop-ups-you-name-we-can-print-it--368098969514097493/>

Question 4: Question adapted from: <https://www.naqwa.com/en/explainers/910161978727/>

Question 5: images adapted from <https://www.dimensions.com/element/pinball-machines> and

<https://www.istockphoto.com/search/2/image-film?mediatype=illustration&phrase=pinball+game>

Question 6: question adapted from: <https://cdn.savemyexams.co.uk/pdfs/3RMdu6ZcQ-qHvZY.pdf> (CIE A Level Physics, Topic 3 Dynamics 3.2 Linear Momentum & Conservation)

Question 6 – 10 images: <https://nect.org.za/materials/physical-sciences>

Question 9: IEB Physical Sciences Paper 1 Final 2022