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TOTAL MARKS

NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2023

PHYSICAL SCIENCES: PAPER I

EXAMINATION NUMBER

Time: 3 hours

200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 30 pages and a Data Sheet of 2 pages (i–ii). Please check that your question paper is complete.
2. Read the questions carefully.
3. Answer ALL the questions on the question paper.
4. Use the data and formulae whenever necessary.
5. Show your working in all calculations.
6. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
7. Answers must be expressed in decimal format, not left as proper fractions. Express answers to TWO decimal places, where appropriate.
8. It is in your own interest to write legibly and to present your work neatly.
9. TWO blank pages (pages 28–29) are included at the end of the paper. If you run out of space for a question, use these pages. Clearly indicate the question number of your answer should you use this extra space. Spare graph paper is included on page 30.

FOR OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
Mark											
Marker Initial											
Moderated Mark											
Moderator Initial											
Question Total	**20**	**17**	**21**	**19**	**19**	**21**	**20**	**27**	**18**	**18**	**200**
Re-mark											
Initial											
Code											

QUESTION 1 MULTIPLE CHOICE

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

A	~~**B**~~	**C**	**D**

Here the option B 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 The unit for power is the watt. This may also be written as follows:

A $kg{\cdot}m{\cdot}s^{-3}$

B $kg{\cdot}m{\cdot}s^{-2}$

C $kg{\cdot}m^2{\cdot}s^{-3}$

D $kg{\cdot}m^2{\cdot}s^{-2}$

1.2 A ball is dropped from a height *h* and hits the ground with a speed *v*. The speed of the ball at the moment when it reaches half its initial height is:

A v B $\frac{v}{\sqrt{2}}$ C $\frac{v}{2}$ D $\frac{v}{4}$

1.3 A heavy ball of mass $6m$ is travelling along a straight horizontal surface at a speed v. It collides with a stationary light ball of mass m. The surface on which they collide is frictionless. The heavy ball continues at half its original speed after the collision. The speed of the light ball after the collision will be equal to:

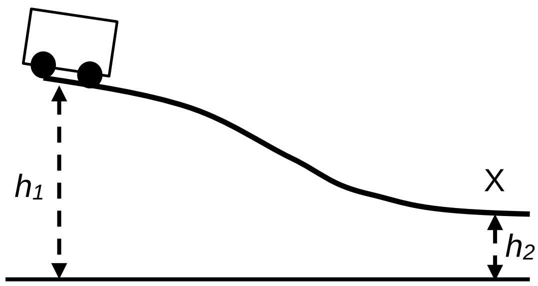
A $2v$ B $4v$ C $3v$ D $6v$

1.4 A person weighs 750 N. This person stands on a scale placed on the floor of a lift. The lift travels up and down in a tall building.

Which row in the table below describes the motion of the lift at the moment when the scale reads 700 N?

	Direction of movement	**Type of motion**
A	Upwards	Slowing down
B	Upwards	Constant speed
C	Downwards	Constant speed
D	Downwards	Slowing down

1.5 The diagram below shows a trolley held at rest at the top of a frictionless slope.



What information is required to calculate the speed reached by the trolley at point X after it has been released?

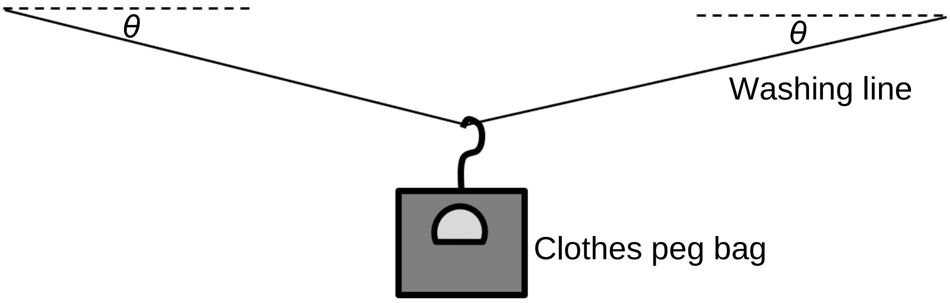
A the mass of the trolley
B the difference in height ($h_1 - h_2$)
C the length of the slope (distance travelled by the trolley)
D all of the above

1.6 An athlete runs up a flight of stairs at a constant velocity v, gaining a certain vertical height from start to finish. The mass, m, of the athlete can be treated as a point mass. It took time t to complete the climb.

The average power output of the athlete is:

A mgv B $\frac{mgv}{t}$ C $\frac{\frac{1}{2}mv^2}{t}$ D $\frac{1}{2}mv^2$

1.7 A bag of clothes pegs with a mass of m hangs on a washing line. This causes the line to sag so that the washing line is at an angle θ with the horizontal.



The tension in the washing line can be expressed as:

A $\frac{2mg}{\sin\theta}$

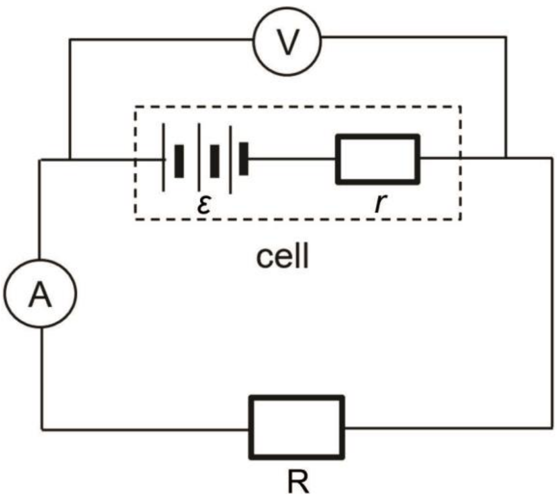
B $\frac{mg}{2\sin\theta}$

C $\frac{mg\sin\theta}{2}$

D $2mg\sin\theta$

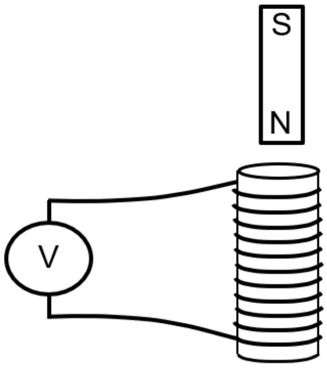
1.8 A battery with an emf ε is connected across a resistor R, as shown. An ammeter is connected in series with the resistor and a voltmeter is connected across the battery.

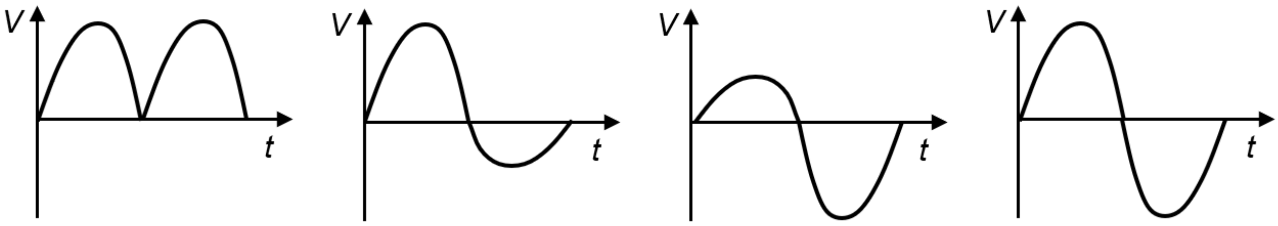
As the temperature of the battery increases, the internal resistance, r, increases. What will happen to the reading on the ammeter and the reading on the voltmeter as the internal resistance increases?



	Reading on ammeter	**Reading on voltmeter**
A	Increase	Increase
B	Increase	Decrease
C	Decrease	Increase
D	Decrease	Decrease

1.9 A magnet is dropped through a vertical coil. What will the output on the voltmeter connected to the coil look like?





A **B** **C** **D**

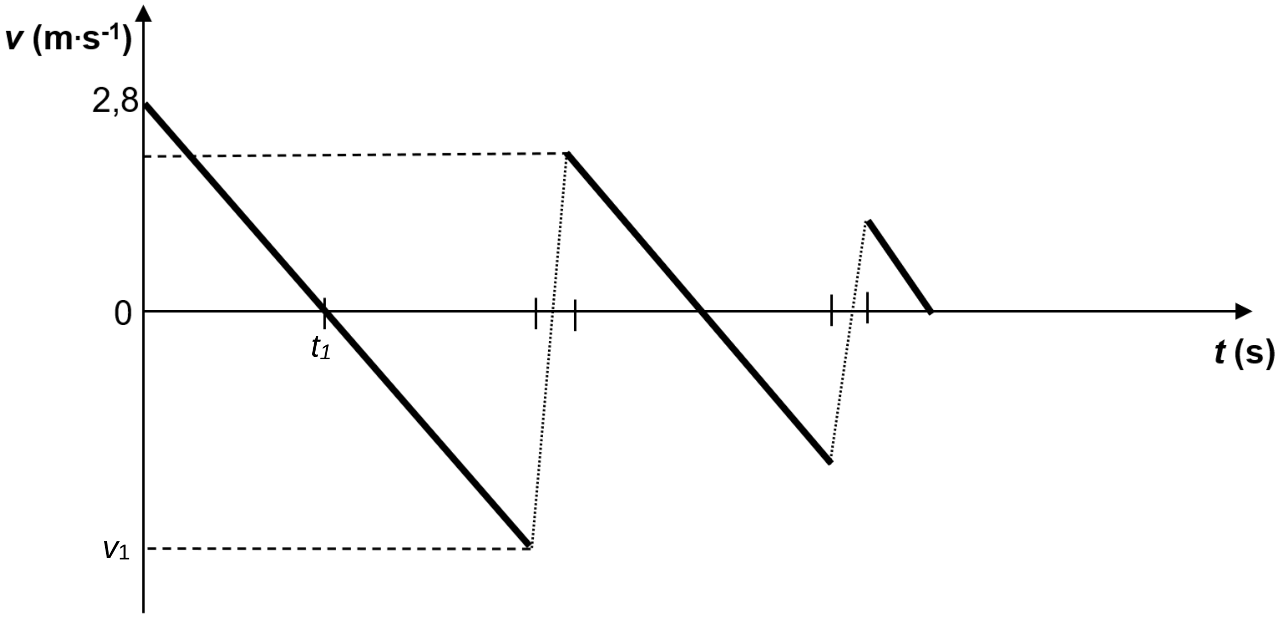
1.10 High-energy light is shone onto a copper plate. Electrons are emitted from the plate. Which combination will be true when the wavelength of the light is decreased?

	The kinetic energy of the emitted electrons	**The number of emitted electrons**
A	Decreases	Decreases
B	Increases	Decreases
C	Decreases	Stays the same
D	Increases	Stays the same

[20]

QUESTION 2 KINEMATICS

A ball is initially thrown vertically upwards at 2,8 m·s^{-1} from a distance of 0,9 m above the ground. It bounces on the ground. The motion of the ball is represented on the velocity–time graph below. Ignore the effects of air resistance. *The graph is not drawn to scale.*



2.1 Why are the bold lines on the graph parallel to one another? (2)

2.2 On the axes provided, sketch a position–time graph for the entire motion of the ball represented on the velocity–time graph. No values are necessary. (3)

2.3 On the graph you sketched in Question 2.2, label t_1 that is shown on the velocity–time graph. (2)

2.4 Calculate t_1. (3)

2.5 Calculate the velocity v_1 with which the ball hits the ground on its first bounce. (4)

2.6 Calculate the time from when the ball is thrown to when it first hits the ground. (3)

[17]

QUESTION 3 KINEMATICS

A group of students investigate the motion of a trolley. The trolley starts from rest and is accelerated in a straight line along a frictionless horizontal surface. The students measure the change in position (Δx) of the trolley during various time intervals (t).

3.1 State the independent variable for this investigation. (2)

The change in position of the trolley measured during each time interval is shown in the table below:

t (s)	t^2 (s^2)	Δx (m)
0,5	0,3	0,2
1,0	1,0	0,4
1,7	**missing value**	1,2
2,0	4,0	1,6
2,6	6,8	2,8
3,0	9,0	3,6

3.2 In the block below, write down the value for t^2 that is missing from the table. Round off your answer to one decimal place. (2)

3.3 Plot a graph of change in position Δx (on y-axis) vs time squared t^2 (on x-axis) on the graph paper provided on the next page. (7)

3.4 Calculate the gradient of the graph that you have plotted. Include units in your answer. (5)

3.5 Use an equation of motion and the gradient that you calculated in Question 3.4 to determine the acceleration of the trolley. (3)

Graph paper for Question 3.3.

(Spare graph paper is printed on page 30, should you need it.)

3.6 Use your graph to determine how long it will take the trolley to travel a distance of 3 m. (2)

[21]

QUESTION 4 FORCES

A bus is accelerating uniformly forward along a level road. A book lying on the floor experiences negligible friction while the bus accelerates.

An identical book lying in the middle of a flat seat in the bus experiences a significant frictional force and remains at rest on the seat as the bus accelerates.

4.1 Define *frictional force*. (2)

4.2 Is there a **resultant (net)** force acting on the book that is on the floor as the bus accelerates? Explain your answer. (2)

4.3 Draw a labelled free-body diagram showing the forces that act on the book resting on the seat as the bus accelerates forward. *Forward is to the right on your page.* (3)

4.4 Describe the motion of the book on the **floor** as observed by a passenger on the bus while the bus is accelerating forward. (2)

The mass of each book is 0,1 kg. The coefficient of static friction between the book and the **seat** is 0,4.

4.5 Calculate the magnitude of the frictional force that must be overcome for the book to slide. (4)

4.6 Calculate the magnitude of the minimum forward acceleration of the bus that would cause the book on the seat to slide. (3)

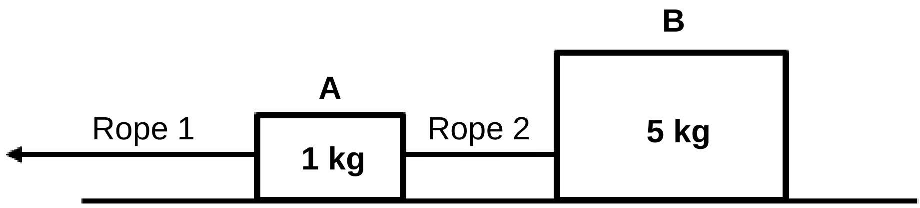
4.7 The bus accelerates with an acceleration greater than the value that you calculated in Question 4.6.

Will the book on the seat slide towards the FRONT of the bus or towards the BACK of the bus? Briefly explain your answer. (3)

[19]

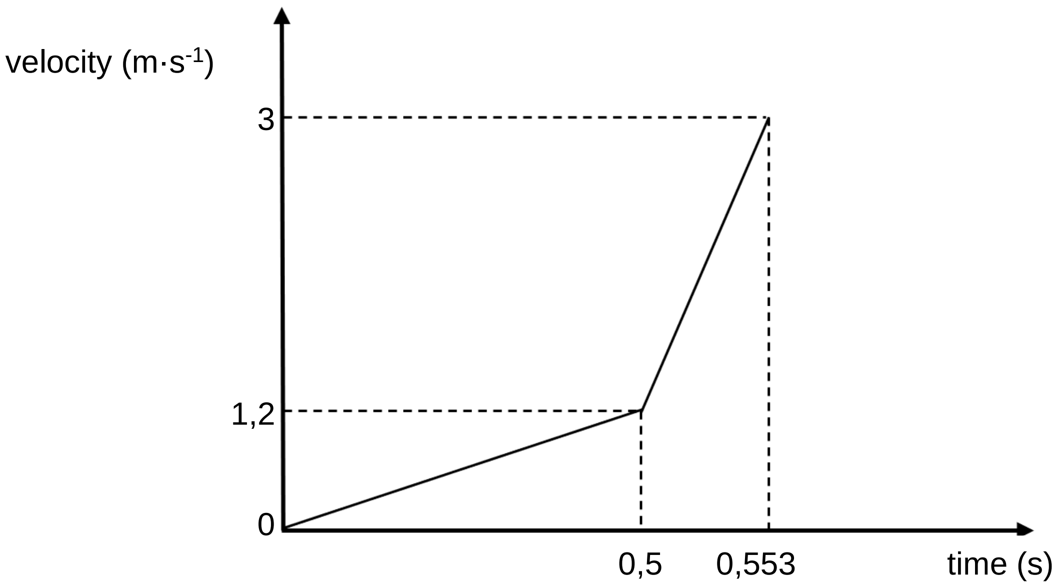
QUESTION 5 NEWTON

Two blocks, **A** (mass 1 kg) and **B** (mass 5 kg), are pulled along a horizontal surface by Rope 1. They are connected by Rope 2. While they are moving, Block **A** experiences a frictional force of 3,9 N and Block **B** experiences a frictional force of 19,6 N.



After Rope 1 has pulled the system for 0,5 seconds, Rope 2 snaps.

The velocity of Block **A** is represented against time on the graph below, which is not drawn to scale.



5.1 Define *acceleration*. (2)

5.2 Use the velocity–time graph to calculate the magnitude of the acceleration of the system while the force of Rope 1 is being applied, before Rope 2 snaps. (3)

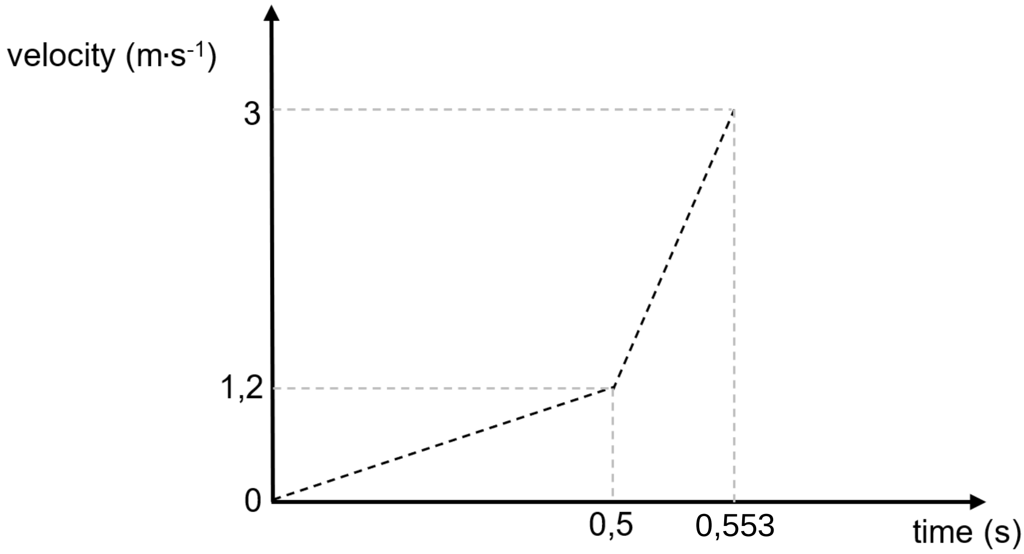
5.3 State *Newton's second law*. (2)

5.4 Draw a labelled free-body diagram showing the **horizontal** forces acting on Block **B** in the first 0,5 seconds described. The relative sizes of the forces must be clear. (3)

5.5 Calculate the tension in Rope 2 before it snapped. (4)

5.6 Determine the magnitude of the force that Rope 1 was exerting during the first 0,5 seconds of motion. (3)

5.7 The velocity of Block **A** (from the graph on page 12) is shown as a dashed line on the set of axes below. On this set of axes, draw the graph to represent the velocity of Block **B** over the same time period. No velocity values are needed. (2)



[19]

QUESTION 6 MOMENTUM, WORK, ENERGY & POWER

A ball is kicked along the ground towards a wall. It hits the wall travelling at 4,5 $m{\cdot}s^{-1}$ horizontally. The ball bounces off the wall with a horizontal velocity of 2 $m{\cdot}s^{-1}$ away from the wall. The ball is in contact with the wall for 0,26 seconds.

The ball has a mass of 0,8 kg.

6.1 Define *impulse*. (2)

6.2 Calculate the change in momentum of the ball as it bounces off the wall and state the direction of this change in momentum. (4)

6.3 Calculate the magnitude of the average net force experienced by the ball as it bounces off the wall. (3)

6.4 If the time of contact between the ball and the wall was reduced, would the magnitude of the force that the ball experiences be GREATER THAN, THE SAME AS or LESS THAN the magnitude of the force that you have just determined? *Write only the appropriate phrase.* (2)

The ball is kicked again, but this time hits a glass door instead of the wall.

The ball hits the glass with a horizontal velocity of 5 $m \cdot s^{-1}$ and breaks the glass.

After breaking the glass, the ball rolls a distance of 0,9 m before coming to rest. The ball experiences a frictional force with a magnitude of 5,5 N as it rolls.

6.5 State the *work–energy theorem*. (2)

6.6 Calculate the magnitude of the velocity of the ball just after the glass broke. (4)

6.7 How much energy was transferred from the ball when it broke the glass? *The time and displacement during the glass-breaking can be ignored.* (4)

[21]

QUESTION 7 FIELDS

7.1 The planet Mars has a mass of $6,4 \times 10^{23}$ kg and a radius of 3 390 km. Mars has a small moon, Deimos, which orbits at a distance of $20,1 \times 10^{6}$ m above the surface of Mars. The mass of Deimos is $1,48 \times 10^{15}$ kg.

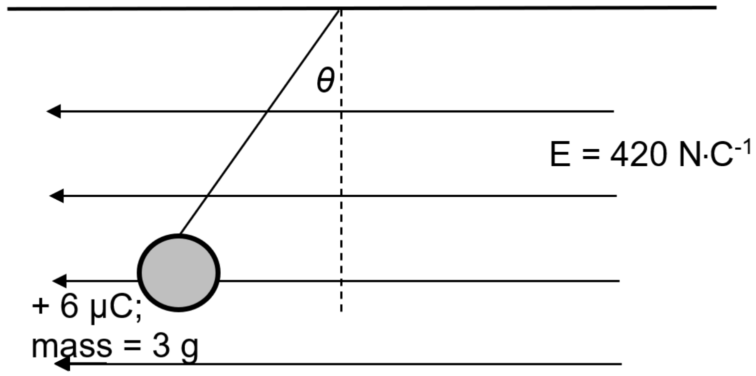
7.1.1 Calculate the magnitude of the force that Mars exerts on Deimos. (5)

7.1.2 Three statements are given about the force that Mars exerts on Deimos:

A	Mars exerts a greater force on Deimos than Deimos exerts on Mars.
B	Mars exerts a smaller force on Deimos than Deimos exerts on Mars.
C	Mars exerts the same magnitude of force on Deimos as Deimos exerts on Mars.

Indicate whether A, B or C is the correct statement and give a reason for your answer. (2)

7.2 A charged ball with a mass of 3 g is suspended by a light, non-conducting string in a uniform, horizontal electric field of 420 $N \cdot C^{-1}$. The ball is carrying a charge of +6 μC. *The diagram is not drawn to scale.*



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

7.2.2 Determine the magnitude of the force experienced by the charged ball in the uniform horizontal electric field. (3)

7.2.3 Define *weight*. (2)

7.2.4 Calculate the angle θ between the light string and the vertical. (4)

The same ball is now given a new charge of –12 μC and reaches a new equilibrium.

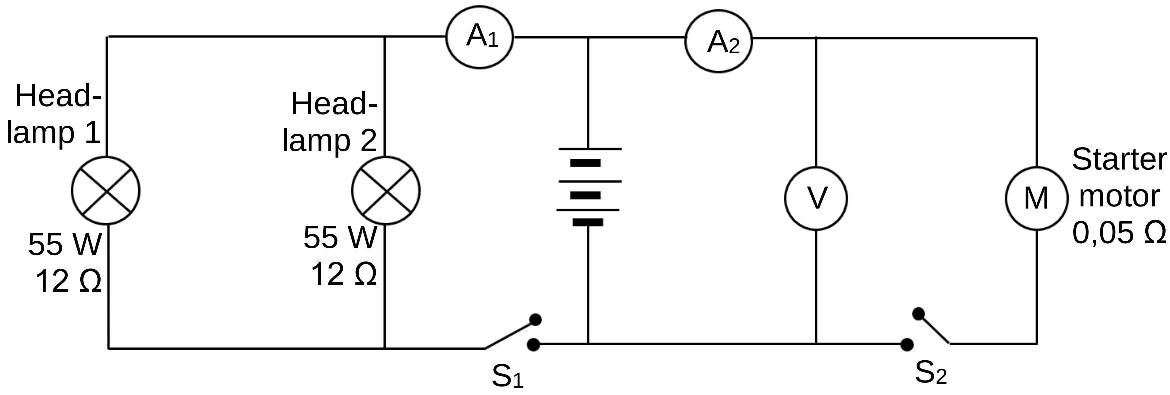
7.2.5 Briefly describe the changes in the angle between the light string and the vertical.

(2)

[20]

QUESTION 8 ELECTRIC CIRCUITS

The circuit below is a simplified diagram of the set-up of the headlamps and starter motor in a car.



The headlamps are identical. Each headlamp has a constant resistance of 12 Ω and is rated at 55 W. The starter motor has a resistance of 0,05 Ω.

The battery has an unknown *emf* and a significant internal resistance ***r***.

8.1 Define *emf*. (2)

Switch S_1 is kept open while switch S_2 is closed.

The reading on ammeter A_2 is 10 A.

8.2 Calculate the reading on the voltmeter when switch S_1 is open and switch S_2 is closed. (3)

Switch S_1 is now closed and switch S_2 is opened.

8.3 Calculate the current through each headlamp when switch S_1 is closed and switch S_2 is open. (3)

8.4 Determine the reading on ammeter A_1. (2)

8.5 Determine the effective resistance of the headlamps connected in parallel. (2)

8.6 Write an expression for the *emf* of the battery in terms of the current through ammeter A_1, the resistance of the external circuit and the internal resistance when switch S_1 is closed and S_2 is open. (2)

Switch S_1 is now opened and switch S_2 is closed.

8.7 Write an expression for the *emf* of the battery in terms of the current through ammeter A_2, the resistance of the external circuit and the internal resistance when switch S_1 is open and S_2 is closed. (2)

8.8 Use your expressions from Question 8.6 and Question 8.7 to determine both the *emf* **and** the internal resistance of the battery shown. (4)

The headlamps are on (switch S_1 is closed).

The starter motor is **then** switched on (switch S_2 is closed).

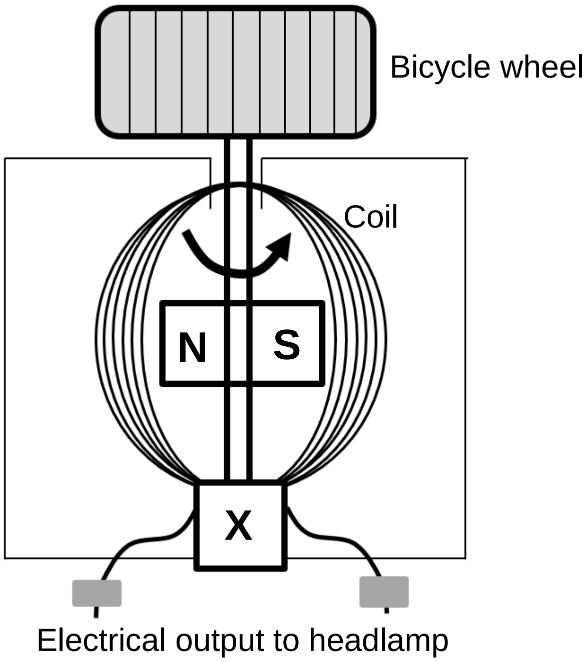
8.9 When both switches are closed, would the brightness of the headlamps INCREASE, STAY THE SAME or DECREASE compared to when only switch S_1 is closed? Briefly explain your answer. (5)

8.10 The headlamps are connected in parallel. Why is it important that they are connected in parallel, rather than in series? (2)

[27]

QUESTION 9 ELECTRODYNAMICS

9.1 The headlamp of a bicycle is powered by the spinning wheel of the bicycle. The wheel turns a magnet inside a coil as it spins. A simplified diagram of the AC generator that powers the headlamp is shown below:



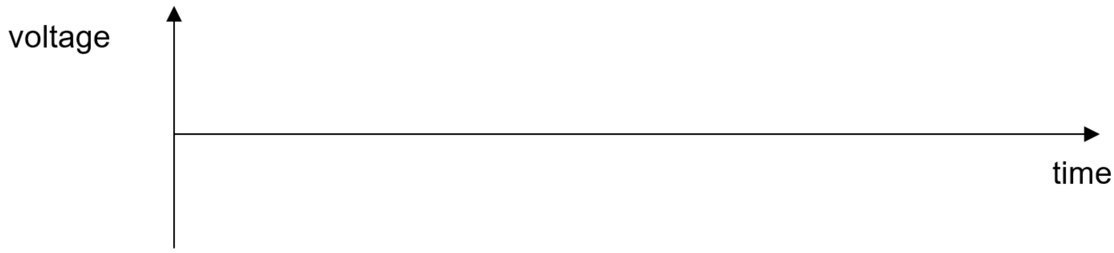
9.1.1 State the energy change that happens in a generator. (2)

9.1.2 This is an AC generator. Name the component that could be connected inside box **X** to convert this to a DC generator. (2)

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

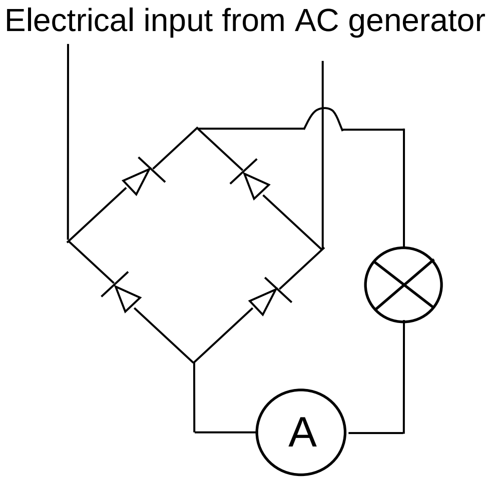
9.1.4 Explain how the spinning magnet generates a current. (3)

9.1.5 On the axes given, sketch the graph of voltage vs time to show the output of this generator. Show two full rotations of the magnet. Label this graph 9.1.5. (2)



9.1.6 On the same set of axes (above), draw the graph of voltage vs time for the output of the generator when the wheel turns at half the speed. Label this graph 9.1.6. (2)

The headlamp is connected to this generator with a number of diodes, as shown below:



9.1.7 On the axes given, sketch the graph of the reading on the ammeter vs time when the wheel is spinning to show the current through the headlamp as the wheel spins. (2)

9.2 A transformer has 11 000 turns on the primary coil and 4 000 turns on the secondary coil. If the output of the transformer is 240 V, what was the input voltage? (3)

[18]

QUESTION 10 PHOTONS AND ELECTRONS

The work functions of certain metals are given in the table below:

Metal	Work function (eV)
Aluminium	4,3
Calcium	2,9
Copper	4,7
Sodium	2,3

Light with a frequency of 9×10^{14} Hz is shone on a sample of these metals in turn.

10.1 Define *work function*. (2)

10.2 Determine the energy of a photon of light with a frequency of 9×10^{14} Hz. (3)

10.3 Hence, showing any necessary calculations, justify which metal(s) will emit electrons when light of this frequency is shone on them. (5)

10.4 The intensity of the incident light is halved. Explain which metals will emit electrons now. (3)

Light with a wavelength of 420 nm is shone on a sample of sodium metal.

10.5 Determine the maximum velocity of the electrons that this light ejects. (5)

[18]

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.

QUESTION 3.3 SPARE GRAPH PAPER