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TOTAL MARKS

NATIONAL SENIOR CERTIFICATE EXAMINATION
MAY 2024

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 and hand it in at the end of the examination. Remember to write your examination number in the space provided above.**
4. Use the data and formulae whenever necessary.
5. Show your working in all calculations.
6. Appropriate units must be given, where appropriate, in the answer.
7. Answers must be expressed in decimal format, not left as proper fractions.
8. Where appropriate, express answers to TWO decimal places.
9. It is in your own interest to write legibly and to present your work neatly.
10. TWO blank pages (page 28 and 30) 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 should you answer in this extra space. Spare graph paper is included on page 29.

FOR OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Mark										
Initials										
Question Total	**20**	**20**	**24**	**23**	**23**	**22**	**29**	**24**	**15**	**200**
Re-mark										
Initial										
Code										

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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**

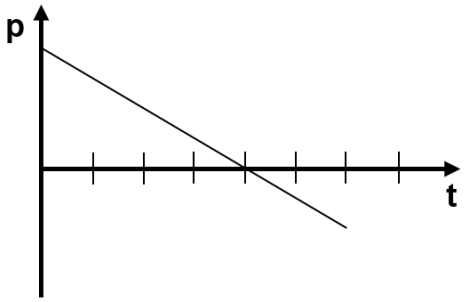
1.1 The formula for electric field $E = \frac{F}{q}$ contains:

A one vector quantity and two scalar quantities
B two vector quantities and one scalar quantity
C three vector quantities
D three scalar quantities

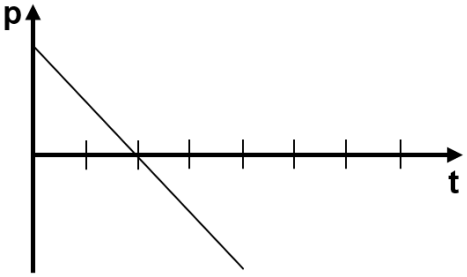
1.2 A trolley is accelerated from rest by a constant net force across a horizontal, frictionless table. The trolley reaches a velocity of **v** in a distance **d**. If the same net force is applied to the trolley starting from rest, it will reach velocity 2**v** in distance:

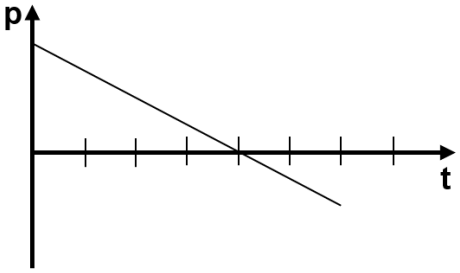
A **d**
B $\sqrt{2}$**d**
C 2**d**
D 4**d**

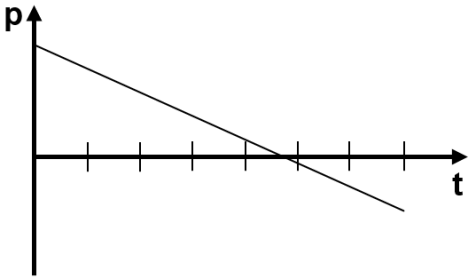
1.3 A ball is dropped onto a cement floor. The graph showing the momentum (**p**) of the ball against time (**t**) while the ball is in contact with the ground is shown below:

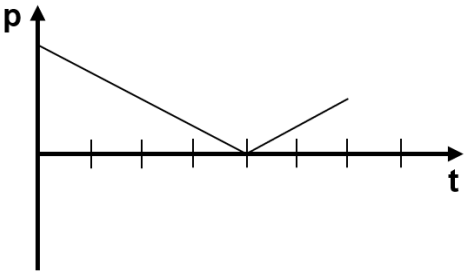


The same ball is dropped from the same height, but lands on a sponge instead of directly on the floor. The graph that shows the momentum (**p**) of the ball against time (**t**) while the ball is in contact with the sponge is:

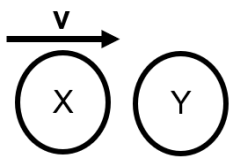
A 

B 

C 

D 

1.4 A ball X, travelling to the right at speed **v**, collides with a stationary ball Y of equal mass. The collision is perfectly elastic.



Which statement correctly describes the motion of ball X and ball Y immediately after the collision?

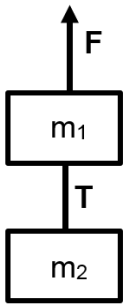
A X comes to rest and Y travels at speed **v**

B X and Y both travel in the same direction at speed $\frac{1}{2}\mathbf{v}$

C X moves to the left at speed **v** and Y remains stationary

D X moves to the left at speed $\frac{1}{2}\mathbf{v}$ and Y moves to the right at speed $\frac{1}{2}\mathbf{v}$

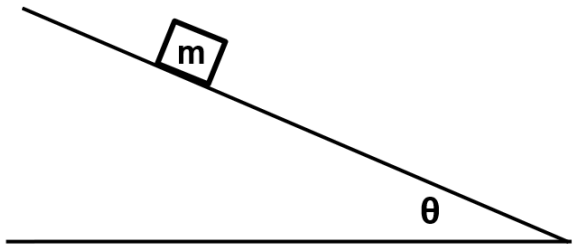
1.5 Two blocks are connected by a piece of string of negligible mass. The blocks are accelerated upwards by a force **F**.



The tension, **T**, in the string between the blocks will be:

A equal to **F**
B equal to m_2g
C less than m_2g
D greater than m_2g

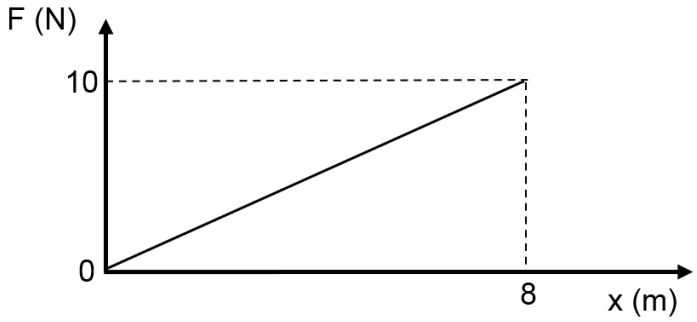
1.6 An object with mass **m** is resting on a slope that is at an angle of **θ** to the ground. The coefficient of maximum static friction between the object and the surface is **μ**.



The **minimum** frictional force that must be acting parallel to the slope to hold the object in place is:

A **m**g sin θ
B **m**g cos θ
C **μ m**g sin θ
D **μ m**g cos θ

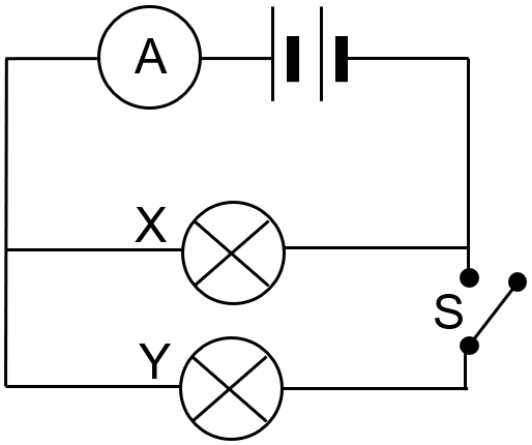
1.7 An object is moved in a straight line across a flat surface by a varying horizontal force. The varying force is plotted against the position of the object on the graph below:



The work done on the object by the applied force from x = 0 m to x = 8 m is:

A 1,25 J
B 40 J
C 80 J
D impossible to determine as the force is not constant

1.8 The internal resistance of the battery shown in the circuit below can be ignored. When the switch is closed, which combination best represents the effect on the reading on the ammeter and the brightness of bulb X?

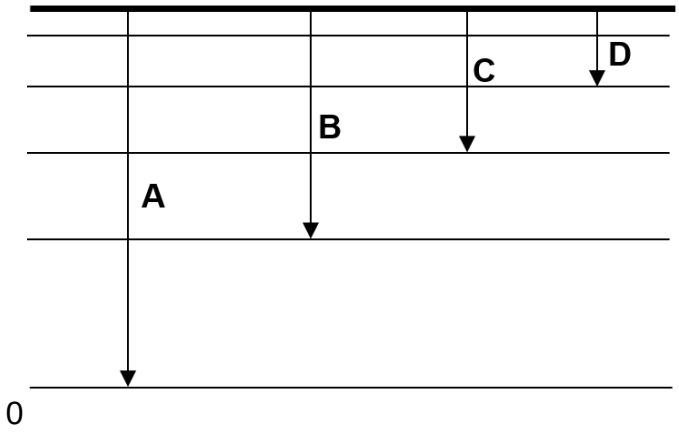


	Reading on ammeter	**Brightness of bulb X**
A	Increases	Increases
B	Stays the same	Increases
C	Stays the same	Stays the same
D	Increases	Stays the same

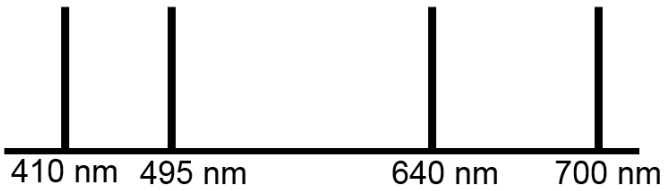
1.9 Which of the following combinations is true for a step-down transformer?

	The number of turns on the primary coil is …	**The current in the primary coil is …**
A	greater than the number of turns on the secondary coil	greater than the current in the secondary coil
B	greater than the number of turns on the secondary coil	less than the current in the secondary coil
C	less than the number of turns on the secondary coil	greater than the current in the secondary coil
D	less than the number of turns on the secondary coil	less than the current in the secondary coil

1.10 Four electron transitions in an atom of an unknown gas are shown on the energy level diagram below. *The diagram is not drawn to scale.*



The diagram below shows these four transitions on the emission spectrum for this gas.

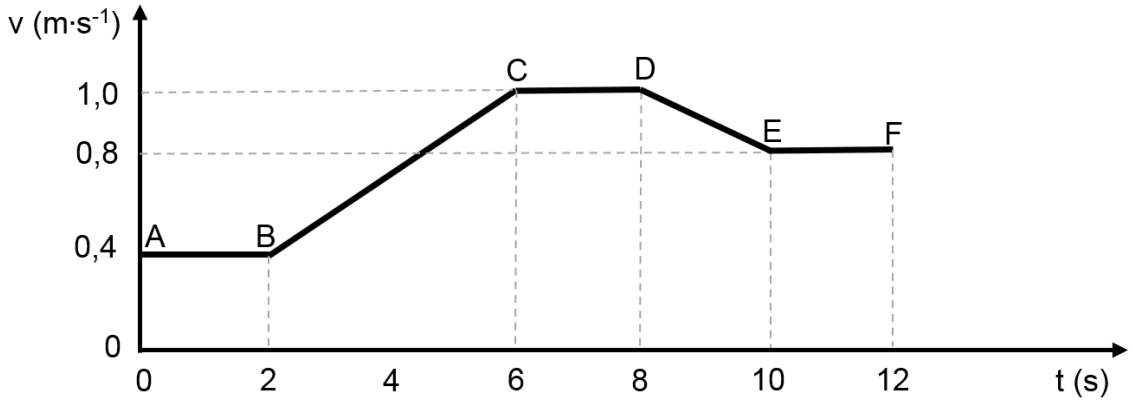


Which of the four electron transitions shown above (**A**, **B**, **C** or **D**) corresponds to the emission line at 410 nm?

[20]

QUESTION 2 KINEMATICS

2.1 A marble rolls along a frictionless track that changes in height. The velocity of the marble as it changes with time is represented on the graph below:



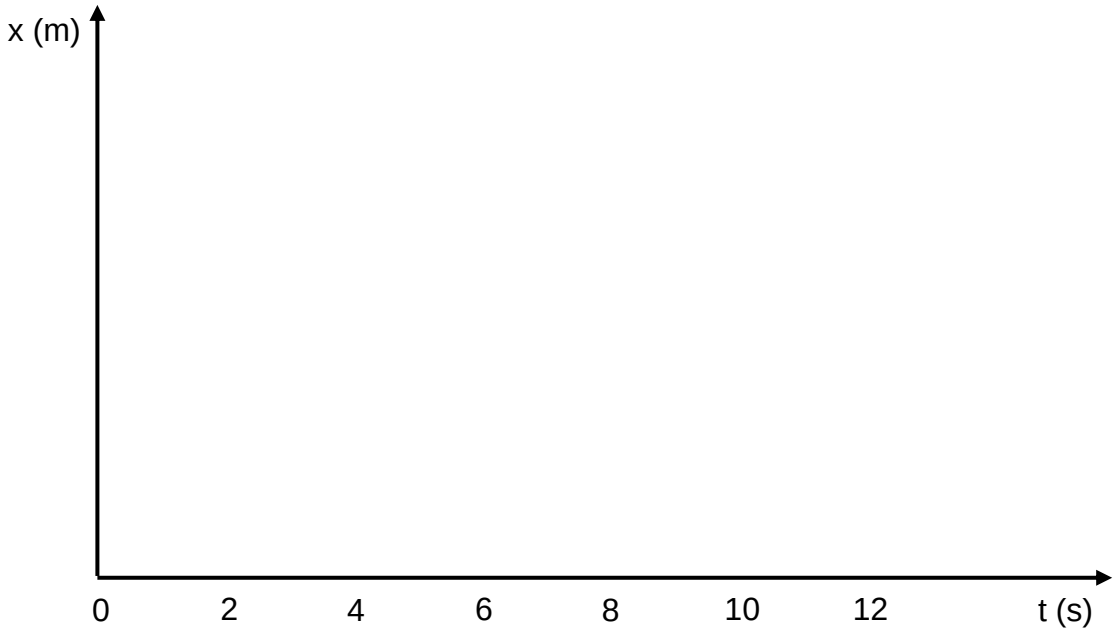
2.1.1 Define *acceleration*. (2)

2.1.2 How far will the marble travel in the first 6 seconds? (3)

2.1.3 Calculate the magnitude of the acceleration of the marble between 2 and 6 seconds. (3)

2.1.4 Over which time period(s), was the marble rolling up the slope of the track? (2)

2.1.5 Draw the position-time graph for the marble, corresponding to the velocity-time graph given. No values need to be given. Label points A to F. (5)



2.2 In a training exercise, an athlete runs a distance of 400 m at an average speed **v** and then runs the same distance at half the speed. The exercise takes a total time of 6 minutes.

2.2.1 Define *speed*. (2)

2.2.2 Determine the athlete's average speed **v** for the first part of the exercise. (3)

[20]

QUESTION 3 KINEMATICS

A toy rocket is launched vertically upwards from rest on the ground. It accelerates upwards for 3 seconds, reaching a height of 10 m above the ground when it runs out of fuel.

3.1 Define *displacement*. (2)

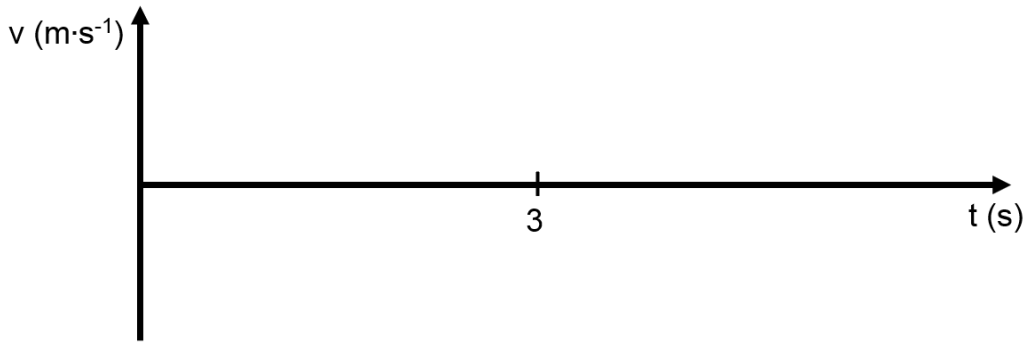
3.2 Calculate the magnitude of the acceleration of the rocket for the first 3 seconds of its journey. (3)

3.3 Calculate the magnitude of the velocity of the rocket when it runs out of fuel. (3)

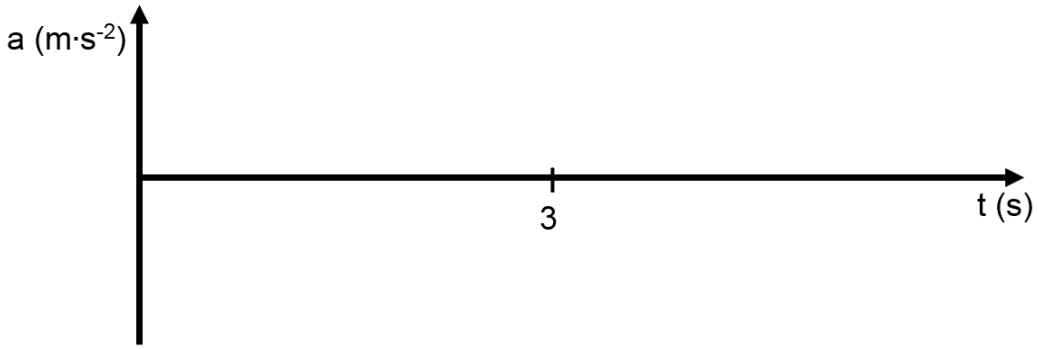
3.4 Calculate the maximum height that the rocket reaches above the ground. (5)

3.5 Calculate the time that the toy rocket spent in the air. (4)

3.6 Draw a velocity-time graph for the rocket. (4)



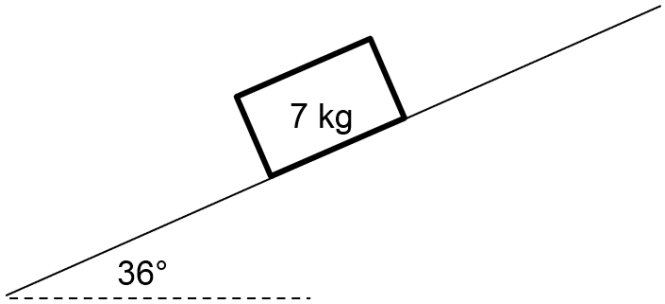
3.7 Draw an acceleration-time graph for the rocket. (3)



[24]

QUESTION 4 APPLICATION OF NEWTON'S LAWS

A box (mass 7 kg) is at rest on a rough slope that makes an angle of 36° to the horizontal, as shown in the diagram below.



4.1 4.1.1 Define *frictional force*. (2)

4.1.2 Draw a labelled free body diagram showing all the forces acting on the box. (3)

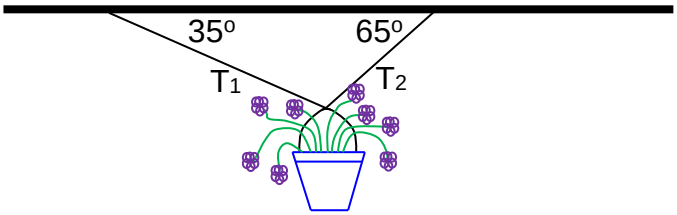
4.1.3 Determine the magnitude of the component of the weight of the box that is perpendicular to the slope. (2)

4.1.4 If the box is just about to slide, determine the coefficient of maximum static friction between the box and the slope. (4)

The 7 kg box is replaced by a box of the same material but with a much smaller mass.

4.1.5 Explain whether the second box with a smaller mass is MORE LIKELY, EQUALLY LIKELY or LESS LIKELY to slide down the slope than the 7 kg box. (2)

4.2 A basket of flowers has a mass of 0,6 kg. It is suspended underneath a shelf by two ropes, as shown in the following diagram.



4.2.1 Draw a labelled free body diagram showing all the forces acting on the basket. (3)

4.2.2 Write an expression for the horizontal component of the tension, T_1. (2)

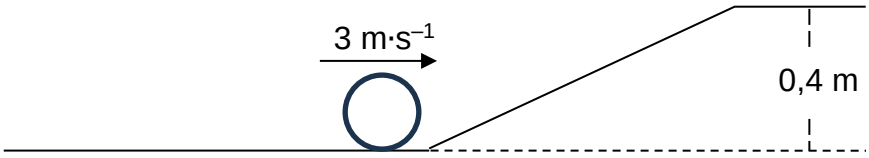
4.2.3 Calculate the tension, T_1 and T_2, in each of the ropes. (5)

[23]

QUESTION 5 MOMENTUM, WORK, ENERGY & POWER

5.1 A ball with an unknown mass **m** rolls along a frictionless horizontal surface. The ball has a speed of 3 m·s^{-1} at the base of a frictionless slope.

The height of the top of the slope is 0,4 m above the horizontal surface as shown in the diagram below.



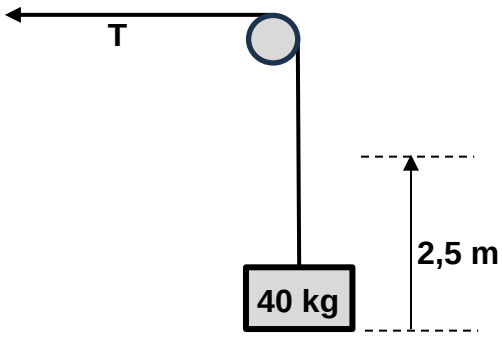
5.1.1 State the *principle of conservation of mechanical energy*. (2)

5.1.2 Calculate the kinetic energy of the ball at the base of the slope, in terms of **m**. (2)

5.1.3 By calculation, determine how fast the ball will be moving when it reaches the top of the slope. (4)

5.1.4 Another ball rolls up the same slope and experiences a frictional force, which results in 0,8 J of energy being transferred to thermal energy. The ball reaches a vertical height of 0,24 m as it rolls up the slope. Determine the mass of this ball. (3)

5.2 A block with a mass of 40 kg is raised through a height of 2,5 m in a time of 4 s at a constant velocity. The block is raised by a motor by causing tension **T** in the horizontal, inextensible cable of negligible mass, which passes over a frictionless pulley, as shown in the diagram below.

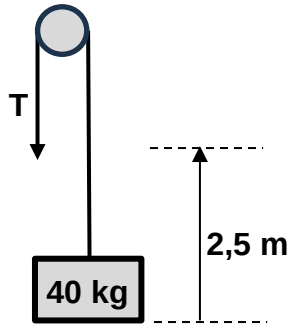


5.2.1 Define the *work* done on an object by a force. (2)

5.2.2 Calculate the amount of work done by the tension **T** to raise the load by 2,5 m. (4)

5.2.3 Calculate the power output of the motor to raise the load by 2,5 m. (3)

5.2.4 The cable is now pulled vertically downwards, as shown in the diagram below, but the tension in the cable remains the same.



Will the total work done on the block as it is raised to 2,5 m be LESS THAN, THE SAME AS or GREATER THAN the amount of work that you calculated in Question 5.2.2, when the cable was horizontal? Briefly explain your answer. (3)

[23]

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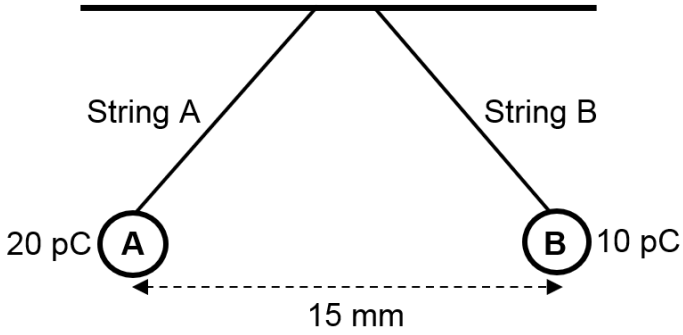
QUESTION 6 FIELDS

6.1 Two light plastic spheres, **A** and **B**, are suspended a distance of 15 mm apart by insulating strings of negligible mass.



The spheres are identical in mass and shape. Sphere **A** holds a static charge of 20 pC, while sphere **B** holds a static charge of 10 pC.

6.1.1 State *Coulomb's law*. (2)

6.1.2 Calculate the magnitude of the force that the two spheres exert on each other. (4)

6.1.3 Draw a labelled free body diagram of all the forces acting on sphere **A**. (3)

6.1.4 Which string (if either) will have the greatest tension? Explain your answer. (3)

6.2 A communication satellite (mass 6 200 kg) is in orbit at a distance of 36 000 km from the surface of the Earth.

The Earth has a mass of 6×10^{24} kg and a radius of $6{,}4 \times 10^{6}$ m.

6.2.1 Define *gravitational field*. (2)

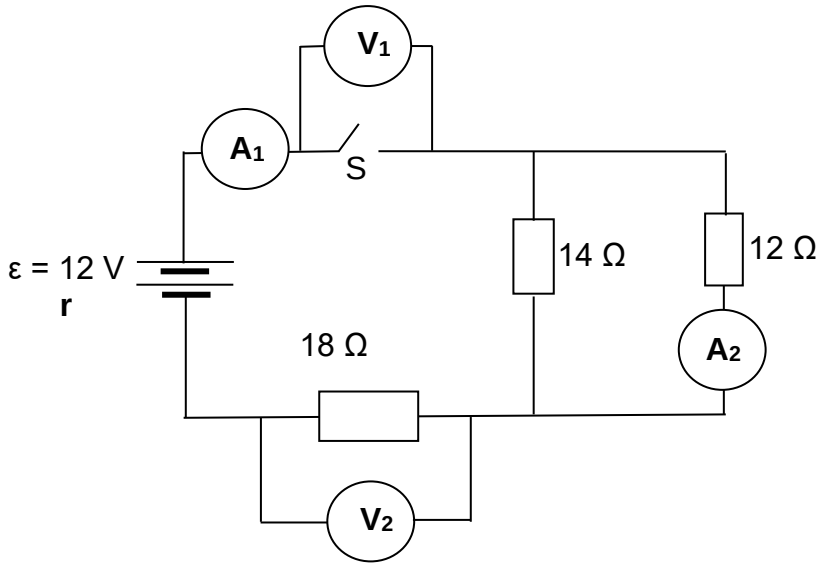
6.2.2 Determine the magnitude of the gravitational field at the distance from the Earth at which the satellite is orbiting. (5)

6.2.3 Calculate the force exerted by the Earth on the satellite in its orbit. (3)

[22]

QUESTION 7 ELECTRIC CIRCUITS

7.1 In the circuit shown below, the battery has a significant, but unknown internal resistance (**r**). The resistance of the ammeters can be ignored and the resistance of the voltmeters is infinitely high.



7.1.1 What will be the reading on voltmeter V_1 when the switch S is open? (2)

The switch S is now closed.

The reading on voltmeter V_2 is 6 V.

7.1.2 Define *current*. (2)

7.1.3 Determine the reading on ammeter A_1. (3)

7.1.4 Determine the effective resistance of the parallel resistors. (3)

7.1.5 Calculate the internal resistance (**r**) of the battery. (4)

7.1.6 At what rate will energy be dissipated as heat in the battery? (3)

7.1.7 Calculate the reading on ammeter A_2. (4)

7.1.8 Calculate the energy dissipated by the 14 Ω resistor in 3 minutes. (4)

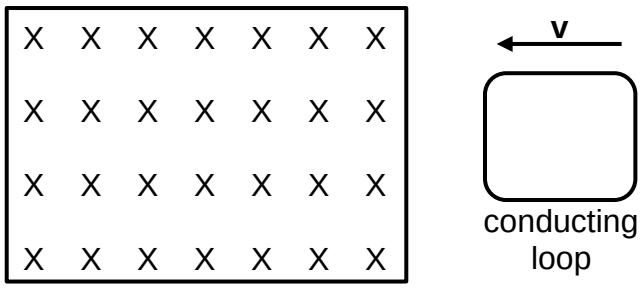
7.2 The cost of electricity is R2,60 per kWh. A 3 000 W electrical oven is used for 45 minutes.

Calculate the cost of using the oven for 45 minutes. (4)

[29]

QUESTION 8 ELECTRODYNAMICS

8.1 A conducting loop is moved into a uniform magnetic field that is directed into the page, as shown.

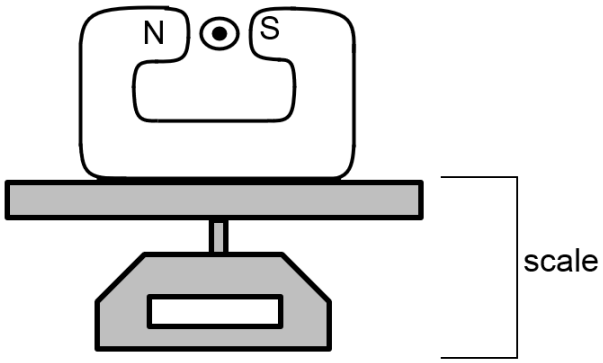


8.1.1 State *Lenz's law*. (2)

8.1.2 In which direction will the current flow in the conducting loop as the loop is moved into the uniform field, as shown? Write only CLOCKWISE or ANTICLOCKWISE. (2)

8.1.3 State one way in which the magnitude of the current in the conducting loop could be increased. (1)

8.2 A horseshoe magnet rests on a scale. A rigid conductor is fixed in place in the uniform field between the poles of the magnet.



When a current flows through a fixed length of the conductor, the conductor experiences a force. This force is given by $F = IB\ell \sin\theta$, but $\theta = 90°$, so this can be simplified to $F = IB\ell$.

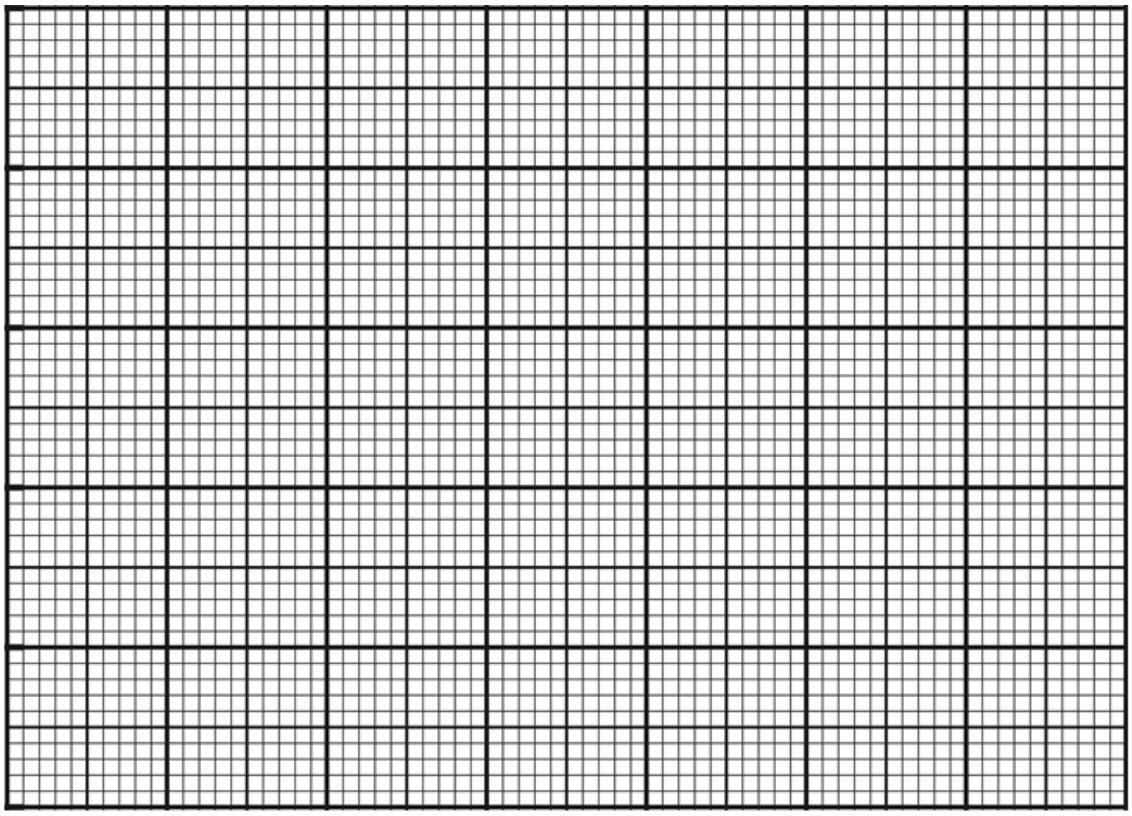
The magnitude of the force is determined as the current is increased and the magnitude of the force experienced by the conductor for different currents is recorded in the table below.

current (A)	**force on conductor (N)**
0,8	0,3
3,2	1,3
4,8	2,0
6,4	2,6
8,0	3,1
9,5	4,0

8.2.1 If the current is flowing out of the page in the conductor as shown, will the conductor experience a force that is vertically UPWARDS or vertically DOWNWARDS? (2)

8.2.2 Does the reading on the scale INCREASE or DECREASE as the current is increased? Briefly explain your answer. (3)

8.2.3 Plot a graph of the force on the conductor (on *y*-axis) vs the current through the conductor (on *x*-axis) on the graph paper below. *Spare graph paper is available on page 29, should you need it.* (7)



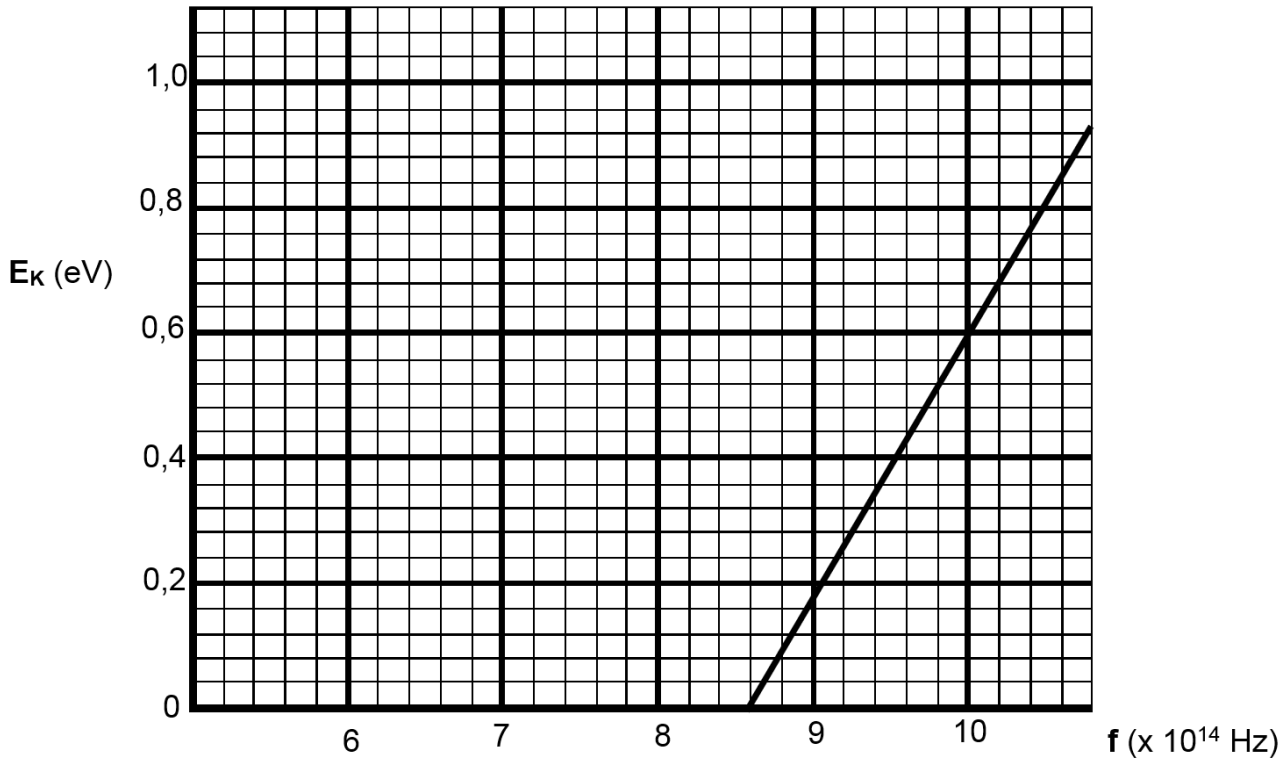
8.2.4 Calculate the gradient of the graph that you have plotted. (4)

8.2.5 Use the equation $F = IB\ell$ and the gradient you calculated in Question 8.2.4 to calculate the magnitude of *B*, the magnetic field strength, in Tesla (T). The length of the conductor in the magnetic field is 1 m. (3)

[24]

QUESTION 9 PHOTONS AND ELECTRONS

The graph below represents the kinetic energy of an electron (E_K) ejected from the surface of a metal as the frequency (**f**) of light shone on it is increased.



9.1 Define *threshold frequency*. (2)

9.2 Determine the threshold frequency of the metal. (2)

9.3 By looking at the table of work functions below, determine which metal was used. (5)

Metal	Potassium	Uranium	Copper	Gold
Work function (eV)	2,30	3,55	4,65	5,10

9.4 On the graph given on page 26, draw a line to represent the relationship between the kinetic energy of the ejected electrons ($\mathbf{E_K}$) and the frequency of the incident light (**f**) for a metal with a lower work function. (2)

9.5 The intensity of the incident light is increased without changing the frequency. State and explain any change in the:

9.5.1 Maximum kinetic energy of emitted electrons. (2)

9.5.2 Rate of emission of electrons. (2)

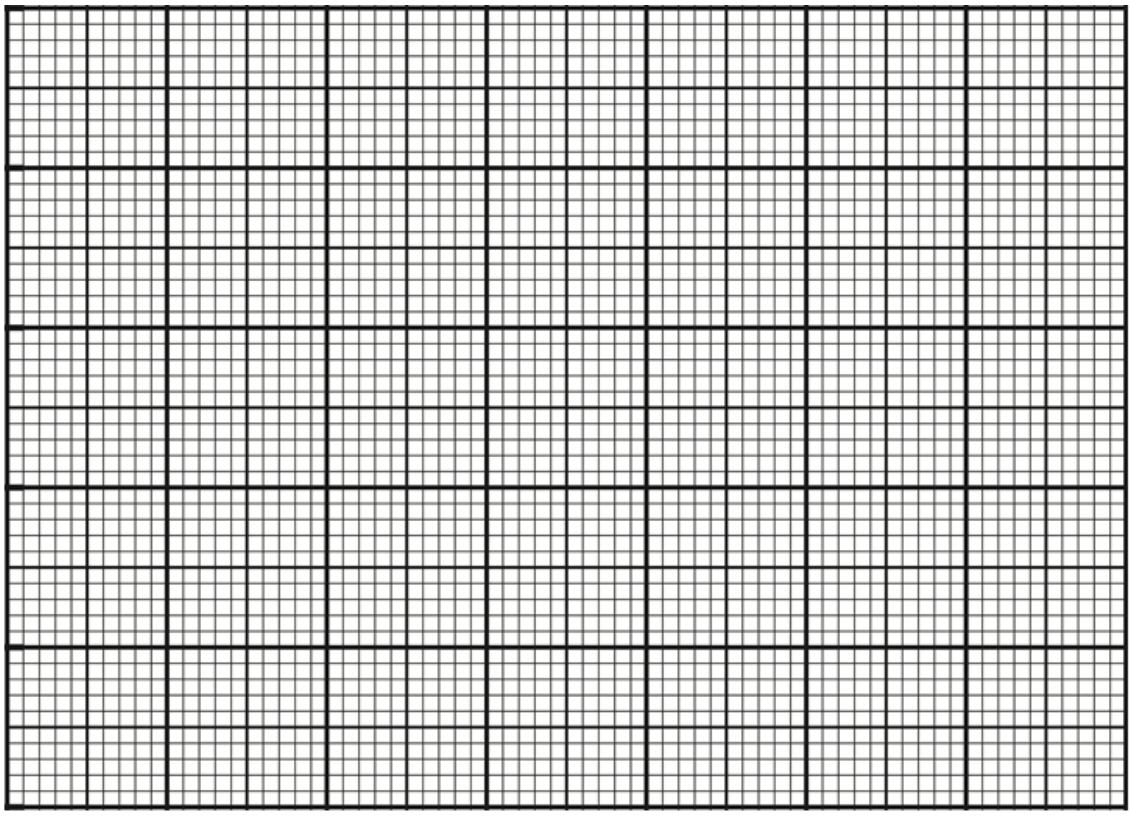
[15]

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 8.2.3 SPARE GRAPH PAPER



ADDITIONAL SPACE (ALL QUESTIONS)

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