NATIONAL SENIOR CERTIFICATE EXAMINATION
SUPPLEMENTARY EXAMINATION 2015

PHYSICAL SCIENCES: PAPER I

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of:
   - a question paper of 15 pages;
   - a yellow Answer Sheet of 3 pages (i – iii); and
   - a green Data and Formulae booklet of 2 pages (i – ii).

   Please make sure that your question paper is complete.

2. Remove the Data Booklet and Answer Sheet from the middle of this question paper. **Write your examination number on the yellow Answer Sheet.**

3. Read the questions carefully.

4. Use the data and formulae whenever necessary.

5. Question 1 consists of 10 multiple-choice questions. There is only one correct answer to each question. These questions are answered on the inside front cover of your Answer Book. The letter that corresponds with your choice of the correct answer must be marked with a cross as shown in the example below:

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

   Here the answer C has been marked.

6. Start each question on a new page.

7. An approved calculator (non-programmable, non-graphical) may be used.

8. Show your working in all calculations.

9. Where appropriate take your answers to 2 decimal places.

10. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.

11. It is in your own interest to write legibly and to set your work out neatly.

12. Please hand in this question paper.

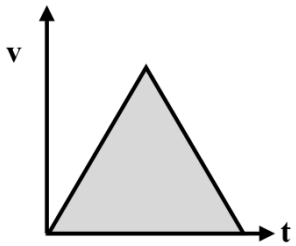
QUESTION 1 MULTIPLE CHOICE

Answer these questions on the inside front cover of your Answer Book. Make a cross (X) on the letter of the response which you consider to be the most correct.

1.1 Which one of the following pairs consists of two vector quantities?

A work and power
B distance and displacement
C momentum and force
D acceleration and time

1.2 The graph below shows how the velocity of an object varies with time.



The shaded area represents the object's …

A acceleration.
B displacement.
C impulse.
D average velocity.

1.3 A book rests on a table. According to Newton's 3rd law what is the reaction force to the weight of the book?

A The force of the table on the book
B The normal force
C The force of the Earth on the book
D The force of the book on the Earth

1.4 A ball is thrown vertically upwards. Neglecting air resistance, which one of the following statements is correct?

A The kinetic energy of the ball is greatest at the greatest height attained.
B By the principle of conservation of mechanical energy, the total mechanical energy of the ball is constant throughout its motion.
C By the principle of conservation of momentum, the momentum of the ball is constant throughout its motion.
D The gravitational potential energy of the ball increases uniformly with time as it goes up.

1.5 Car X is travelling at half the speed of car Y. Car X has twice the mass of car Y. The kinetic energy of car X is E.

	Car X	**Car Y**
Speed	v	2v
Mass	2m	m
Kinetic energy	E	?

The kinetic energy of car Y is …

A 2E.
B 4E.
C E/2.
D E.

1.6 One watt is defined as the power when one joule of …

A work is done to move an object of mass 1 kilogram a distance of 1 metre.
B energy is transferred by a force of 1 newton.
C energy is transferred to a mass of 1 kilogram.
D work is done in one second.

1.7 The diagram shows two point masses X and Y, of mass **2 m** and **m** respectively.

A third point mass (Z) is placed on the straight line between the centres of X and Y. When is the net gravitational field strength (g) experienced by Z zero?

A Never
B When Z is midway between X and Y
C When Z is closer to X
D When Z is closer to Y

1.8 Ohm's Law only applies when the …

A temperature of the conductor is constant.
B potential difference across the conductor is constant.
C current through the conductor is constant.
D conductor is connected in a series circuit.

1.9 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

1.10 The work function of a metal is the _____ _____ needed to emit an electron from the surface of a metal.

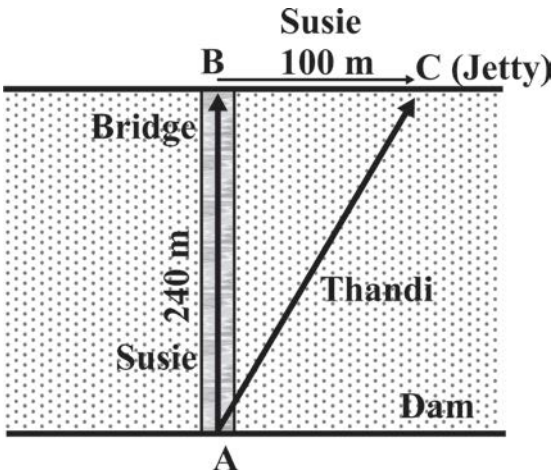
A maximum frequency
B minimum frequency
C minimum energy
D maximum energy

[20]

QUESTION 2 KINEMATICS – VECTORS

Thandi drives a motor boat in still water across a dam directly from point A to a jetty at point C, as shown in the diagram below. Susie walks 240 m at an average speed of 1,5 $m.s^{-1}$ across a bridge from point A to point B and then jogs for 100 m from B to meet Thandi at the jetty at point C. It takes Susie a total time of 3 minutes to get from point A to the jetty at point C.

Diagram is not to scale



2.1 Define *distance* and hence state who travels the greater distance in going from A to C. *(Thandi, Susie* or *neither)* (2)

2.2 Define *displacement* and hence state whose displacement from A is greatest upon arriving at C. *(Thandi, Susie* or *neither)* (2)

2.3 Calculate Susie's average speed between B and C. (Give your answer in $m.s^{-1}$.) (6)

2.4 Calculate Susie's average speed from A to C. (Give your answer in $m.s^{-1}$.) (3)

2.5 Calculate the magnitude and direction of Susie's average velocity from A to C. (Give your answer in $m.s^{-1}$.) (5)

[18]

QUESTION 3 KINEMATICS – MOTION

On January 21, 2013, the Hennessey Venom GT set a new Guinness World Record by accelerating from 0 to $83,3\ m.s^{-1}$ in a time of $13,63$ s. The Hennessey Venom GT is shown in the photograph opposite.

[<pt.wikipedia.org>]

3.1 Convert 83,8 $m.s^{-1}$ to $km.h^{-1}$. (2)

3.2 Calculate the distance covered (in metres) during this period of rapid acceleration. (4)

3.3 The stopping distance is the sum of the reaction distance and the braking distance. The reaction distance is how far the car travels before the driver reacts and applies brakes. The table below shows typical stopping distances given in the Highway Code (rules of the road).

Speed ($m.s^{-1}$)	Reaction distance (m)	Braking distance (m)	Stopping distance (m)
10	7	7	14
20	14	28	42
30	21	63	84
40	28	112	140

[http://www.thedrivingtests.co.uk>]

3.3.1 State the relationship between **reaction** distance and speed. (2)

3.3.2 The equation $v_f^2 = v_i^2 + 2a\Delta x$ (or $v^2 = u^2 + 2as$) can be used to derive the mathematical relationship between the **braking** distance and the initial speed of a car which brakes uniformly to rest. Use the equation to prove that braking distance is directly proportional to initial speed squared. (2)

3.3.3 Use the data in the table to prove that these results obey the relationship given in Question 3.3.2. (4)

3.3.4 The stopping distances given in the table are just a general guide.

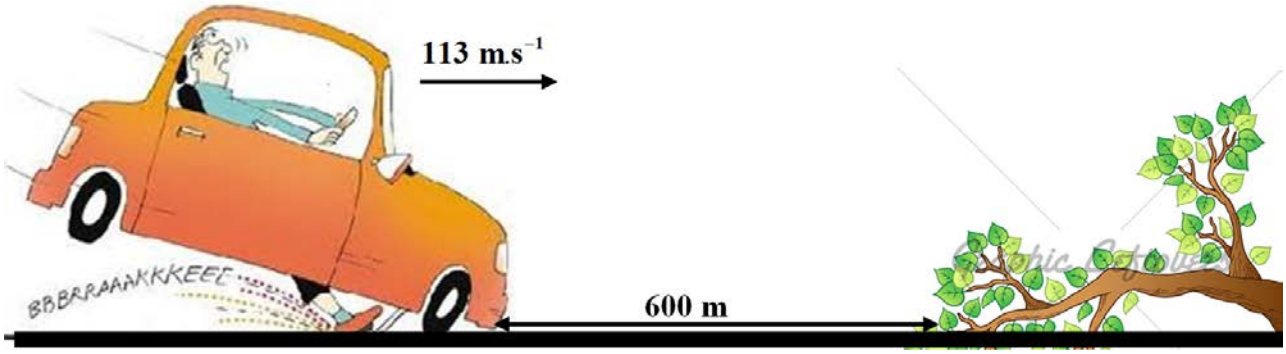
(a) Give one factor (other than speed) which would affect the **reaction** distance. (1)

(b) Give one factor (other than speed) which would affect the **braking** distance. (1)

3.4 The Bugatti Veyron is known for its ultra-fast deceleration. James is test driving the Bugatti Veyron. Whilst travelling at its top speed of $113\ m.s^{-1}$ James sees a fallen tree in the road 600 m ahead. He takes $0,7$ s to react before slamming on brakes and decelerating at $12,1\ m.s^{-2}$. By means of suitable calculations determine whether or not James hits the tree.

Bugatti Veyron

[<worldcarallpaper.com>]

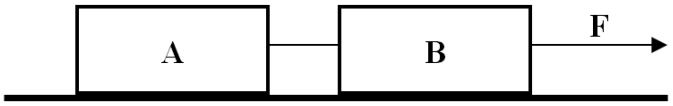


(6)

[22]

QUESTION 4 NEWTON'S LAWS

4.1 Two identical blocks, A and B, joined by a light inextensible string are pulled by a constant force, F, across a frictionless horizontal surface as shown in the diagram below.



After they have been pulled for a certain time, t, the string between the blocks snaps. Force F continues to act on block B.

Draw a velocity-time sketch graph on the axes provided on your ANSWER SHEET to represent the motion of blocks A and B before and after the string snaps.

Clearly label the following lines on your graph;

- **A and B** together before time t
- **A** after time t
- **B** after time t (3)

4.2 The same two identical blocks, A and B, joined by a light inextensible string are now pulled by a constant force, F, across a **rough** horizontal surface at **constant speed**.

After they have been pulled for a certain time, t, the string between the blocks snaps. Force F continues to act on block B.

Draw a velocity-time sketch graph on the axes provided on your ANSWER SHEET to represent the motion of blocks A and B before and after the string snaps.

Clearly label the following lines on your graph;

- **A and B** together before time t
- **A** after time t
- **B** after time t (3)

4.3 Two different blocks A and B of masses 16 kg and 24 kg respectively are pulled across a smooth (frictionless) surface by means of a light inextensible rope, Y, inclined at $64°$ to the horizontal.

The rope, Y, exerts a constant force of 120 N on block B. The blocks are joined by a light inextensible bar, X.

The masses of rope Y and bar X are negligible compared with those of blocks A and B.

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

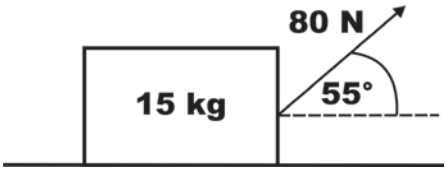
4.3.2 Calculate the magnitude of the acceleration of both blocks A and B. (4)

4.3.3 Draw a labelled free-body diagram to represent the forces acting on block A only. The labels must have the **names** of the forces, not just symbols. (4)

4.3.4 Calculate the magnitude of the tension in the bar, X, between blocks A and B. (4)

4.3.5 Calculate the work done by rope Y on the system as it pulls the blocks for a distance of 5 m. (4)

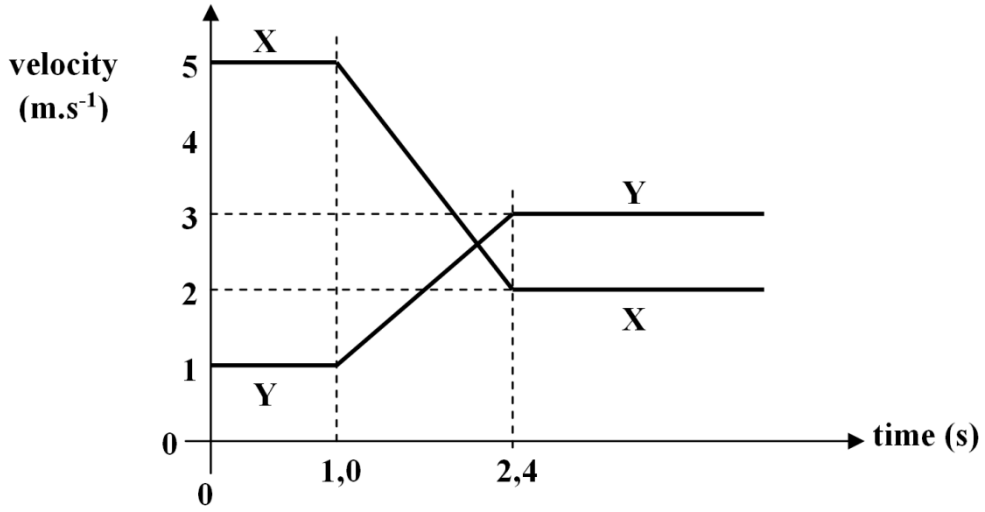
4.4 A block of mass 15 kg is at rest on a rough horizontal surface. The block is pulled by means of a light inextensible rope which exerts a force at an angle of $55°$ to the horizontal. The maximum force which the rope can exert before the block starts to move is 80 N. Calculate the co-efficient of static friction between the block and the surface.



(6)
[31]

QUESTION 5 MOMENTUM, ENERGY AND POWER

5.1 Railway carriage X, of mass 21 000 kg, crashes into the back of railway carriage Y which is travelling in the same direction as X on a straight level track. The graph shows how the velocity of each railway carriage varies with time.



Ignore frictional forces between the railway carriages and the track during the collision. Ignore air resistance.

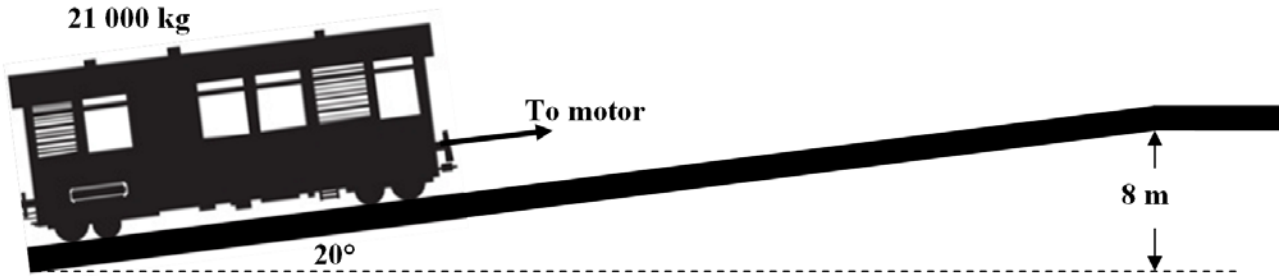
5.1.1 Calculate the distance travelled by carriage **Y** between 1,0 s and 2,4 s. (4)

5.1.2 Calculate the magnitude of the change in momentum of railway carriage **X** between 1,0 s and 2,4 s. (4)

5.1.3 Calculate the net force experienced by railway carriage **X** between 1,0 s and 2,4 s. (4)

5.1.4 Calculate the mass of railway carriage **Y**. (4)

5.2 After the collision railway carriage X (mass 21 000 kg) is taken to the repair yard where it is pulled up a track inclined at 20° to the horizontal. It is pulled up the track at a constant speed of $1,4\ m.s^{-1}$ by means of a cable attached to a motor. The gain in vertical height is 8 m.



5.2.1 Calculate the gain in gravitational potential energy of the carriage when it moved from the bottom to the top of the slope. (3)

5.2.2 Calculate the magnitude of the force applied by the cable to the carriage if the frictional force between the carriage and the track is a constant 21 kN. (5)

5.2.3 Calculate the output power of the motor. (4)

5.2.4 Explain why the work done by the cable on the carriage between the bottom and top of the slope is greater than the gain in gravitational potential energy of the carriage. (2)

[30]

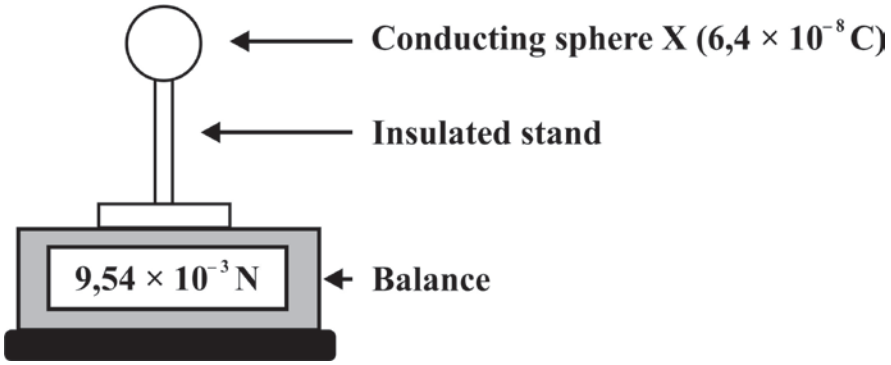
QUESTION 6 FIELDS

6.1 Mercury, the smallest planet in our solar system, has a radius of $2,44\times10^{6}$ m and a mass of $3,3\times10^{23}$ kg.

6.1.1 Calculate the magnitude of the acceleration due to gravity on the surface of Mercury. (4)

6.1.2 Calculate the magnitude of the weight of a 250 kg spaceship on Mercury. (3)

6.2 The diagram shows a conducting sphere X of radius 40 mm carrying a charge of $6,4\times10^{-8}$C. The sphere is at the top of an insulated stand which is placed on a digital balance. The weight of the sphere and stand is $9,54\times10^{-3}$ N as shown by the reading on the balance.



6.2.1 Draw an electric field line diagram to represent the field set up by sphere X. (3)

6.2.2 Calculate the magnitude of the electric field strength at the surface of the sphere X. (4)

6.2.3 Another sphere, Y, carrying a charge of $-4,8\times10^{-8}$C is held so that its centre is 60 mm vertically above the centre of sphere X.

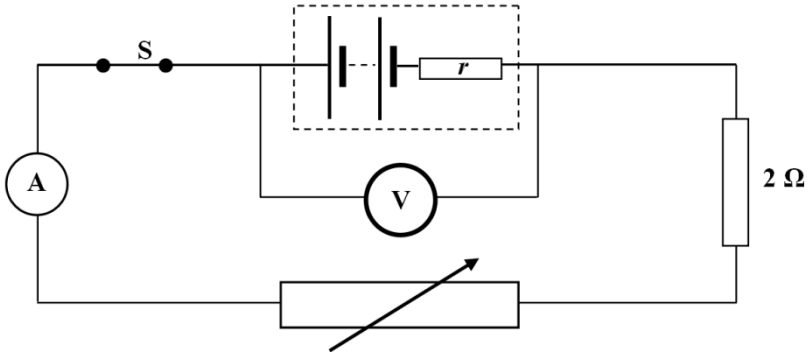
(a) Calculate the magnitude of the electric force of sphere X on sphere Y. (4)

(b) Calculate the new reading on the balance. (2)

[20]

QUESTION 7 ELECTRIC CIRCUITS

Ayanda and Cindy conduct an experiment to determine how the potential difference across the terminals of a battery is affected by the size of the current through the battery. They set up the circuit shown below. They change the current through the battery by adjusting the resistance of the rheostat (variable resistor). They record the potential difference across the terminals of the battery as given by the reading on the voltmeter. The battery has significant internal resistance. The resistances of the wires and ammeter is negligible. The voltmeter has high resistance.



Results

Current (A)	Potential difference (V)
0,0	15,0
0,6	13,5
1,2	12,0
2,0	10,0
2,6	8,5
3,2	7,0

7.1 Define *emf.* (2)

7.2 What is the emf of the battery used in this experiment? (1)

7.3 What is the dependent variable in this experiment? (2)

7.4 Plot a graph on the ANSWER SHEET to show the relationship between the potential difference across the terminals of the battery and the current through the battery. The x-axis has been labelled for you. (6)

7.5 Use the graph to determine the reading on the voltmeter when the current is 2,3 A. (1)

7.6 Determine the internal resistance of the battery. (4)

7.7 Explain why the potential difference across the battery decreases as the current through the battery increases. Make reference to one or more suitable formulae to support your answer. No calculations are required. (3)

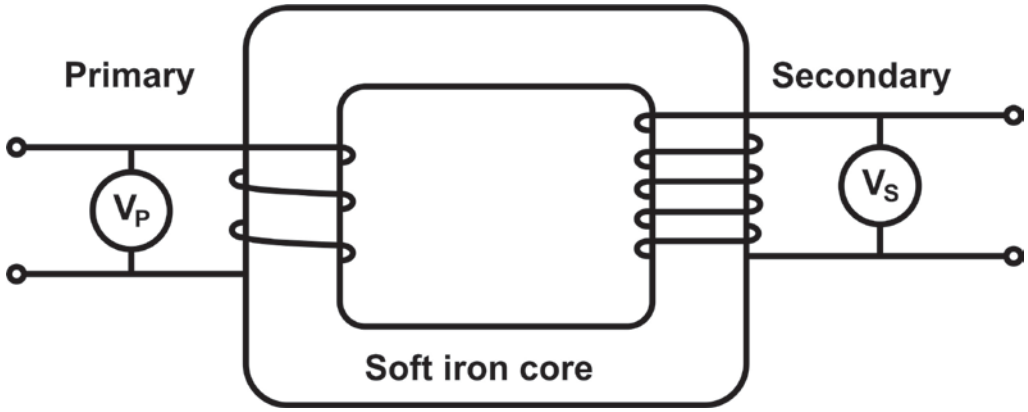
7.8 Define *resistance*. (2)

7.9 Calculate the resistance of the rheostat when the current is 2,0 A. (4)

[25]

QUESTION 8 ELECTRODYNAMICS

The diagram below represents a simple step-up transformer. An alternating current is supplied to the primary (input) coil.



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

8.2 Explain how the transformer works when an alternating current is supplied to the primary coil. (3)

8.3 Use the equation for Faraday's law to explain how this transformer steps **up** the voltage. (2)

$$\text{emf} = -\frac{N\Delta\phi}{\Delta t}$$

8.4 Power stations produce electricity at 25 000 V. Electricity is sent through the national grid cables at 400 000 V. Transformers are used to step-up the voltage from the power stations to the cables of the national grid.

8.4.1 If the number of turns on the primary coil is 500 then how many turns are required on the secondary coil? (3)

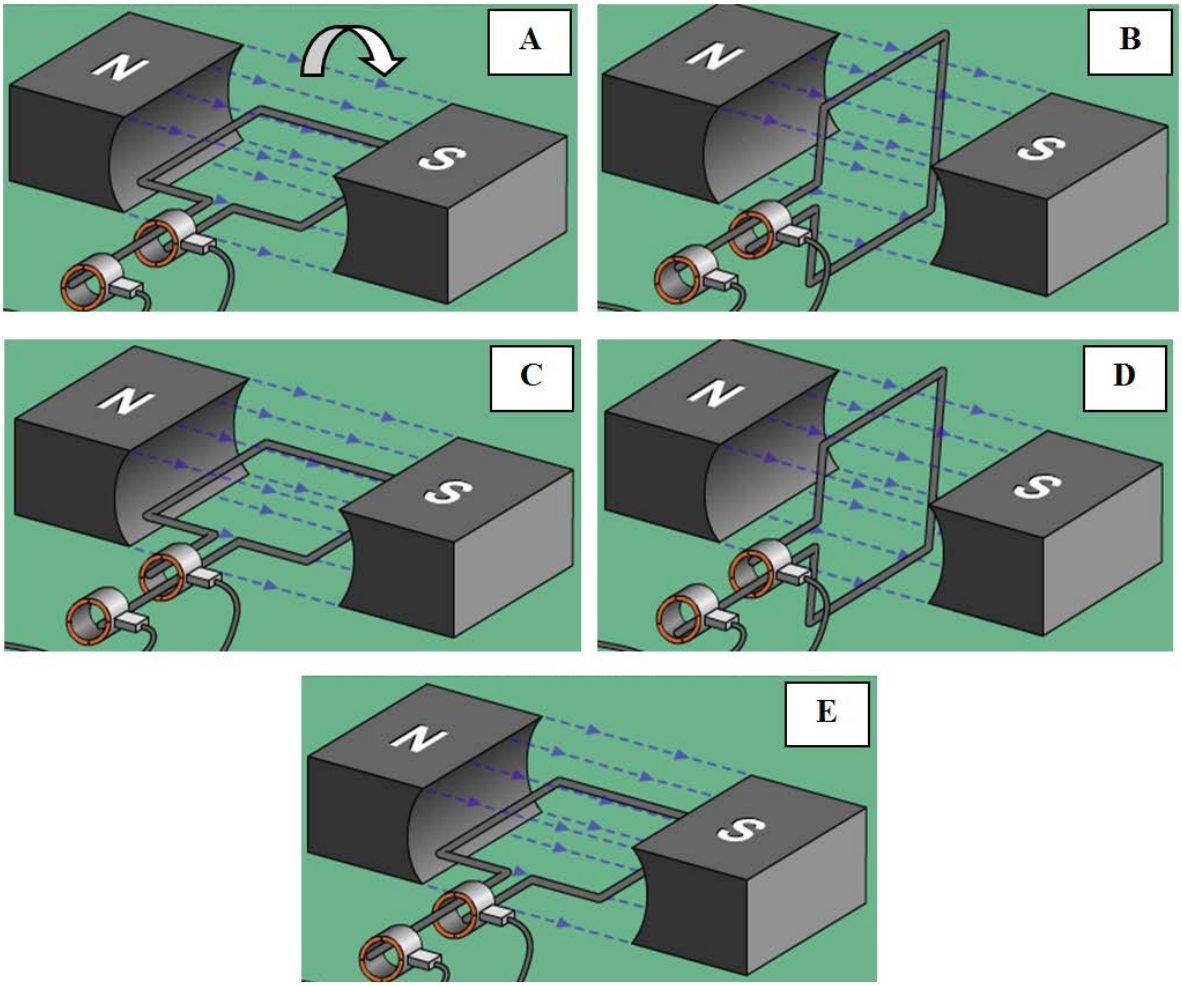
8.4.2 The input current to the primary coil of the transformer is 0,5 A. Calculate the current in the cables of the national grid. Assume no loss of power in the transformer. (4)

8.4.3 Use scientific principles to explain why it is an economic advantage to transmit electrical energy through the national grid at high voltages and low currents. Use a suitable formula to assist your explanation. No calculation is required. (3)

8.5 Consider the diagram below which shows five positions of the coil for one complete rotation of a simple generator. On the ANSWER SHEET draw the corresponding sketch graphs of …

8.5.1 emf (ε) vs time; and (3)

8.5.2 flux (φ) vs time. (3)

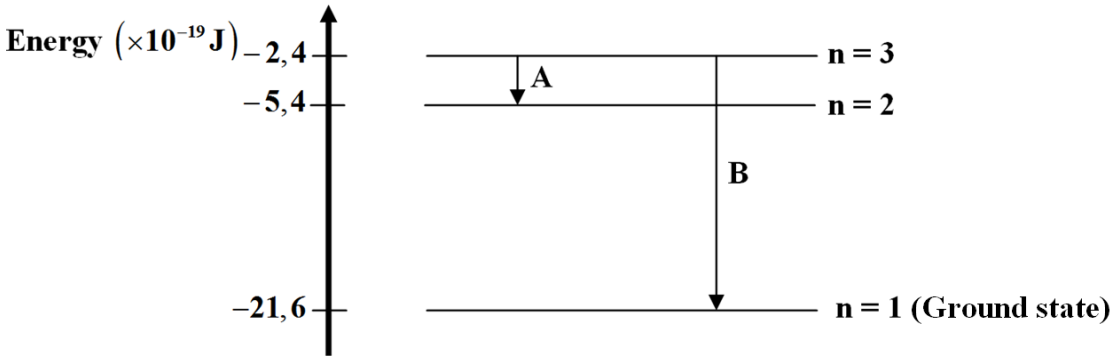


[Multimedia Science School 11 – 16, PLATO learning]

[23]

QUESTION 9 PHOTONS AND ELECTRONS

The diagram shows some of the energy levels of an isolated hydrogen atom. The arrows, labelled A and B, represent transitions of electrons between the energy levels.



The lowest energy level of an atom is known as the ground state. Each energy level is assigned an integer number n, known as the principal quantum number.

9.1 Calculate the frequency of the photon emitted when an excited electron falls from energy level $n = 3$ to energy level $n = 2$. (4)

9.2 Is the wavelength of the photon emitted in transition A ***greater than, less than or equal to*** the wavelength of the photon emitted in transition B? (1)

9.3 Explain your answer to Question 9.2, making reference to one or more suitable formulae. No further calculations are required. (3)

9.4 Use the energy level diagram given for hydrogen to prove that the energy (E) of an energy level is inversely proportional to the principal quantum number squared (n^2). (3)

[11]

Total: 200 marks