NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2018

PHYSICAL SCIENCES: PAPER I

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 17 pages, an Answer Sheet of 3 pages (i–iii), and a Data Sheet of 2 pages (i–ii). Please make sure that your question paper is complete.
2. Answer ALL the questions.
3. Read the questions carefully.
4. Use the data and formulae whenever necessary.
5. Start each question on a new page.
6. Show your working in all calculations.
7. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
8. Answers must be expressed in decimal format, not left as proper fractions.
9. Where appropriate express answers to TWO decimal places.
10. It is in your own interest to write legibly and to present your work neatly.

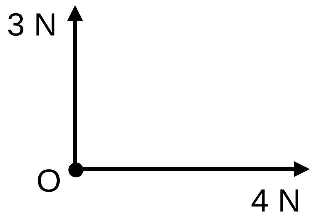
QUESTION 1 MULTIPLE CHOICE

Answer these questions on the multiple-choice Answer Sheet on the inside front cover of your Answer Book. Make a cross (X) in the box corresponding to the letter that you consider to be correct.

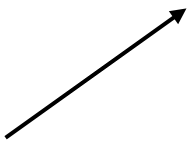
1.1 Newton's second law can be expressed mathematically as $F_{net} = ma$. This equation consists of:

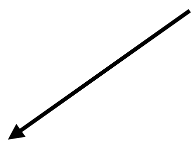
A one vector quantity and two scalar quantities
B two vector quantities and one scalar quantity
C three vector quantities
D three scalar quantities

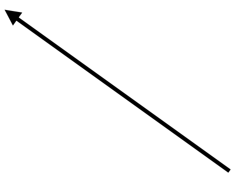
1.2 The vector diagram shows two forces in the same plane acting on an object O.

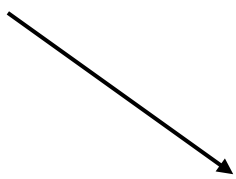


Another 5 N force, in the same plane as the other forces, is applied on the object O. Which of the following represents the direction at which the 5 N force must be applied to ensure object O is in equilibrium?

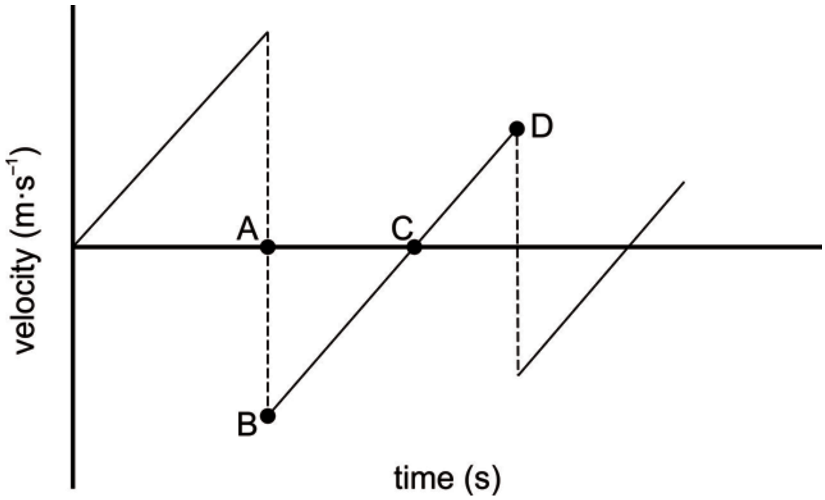
A


B


C


D


1.3 A ball is dropped vertically from rest above a hard, horizontal surface. The motion for the bouncing ball is represented on the velocity vs time graph shown below. Air resistance is negligible.



At which point labelled on the graph does the ball reach its maximum height after the first bounce?

1.4 A speedboat tows a water-skier, as shown in the diagram, so that the skier accelerates.

[Image from: <http://moziru.com/images/skiing-clipart-vector-6.jpg>]

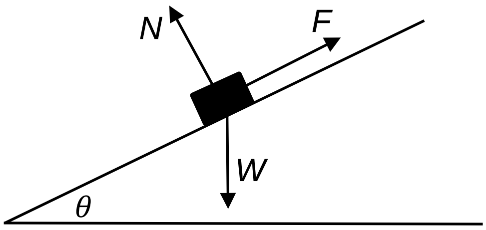
The magnitude of the force exerted on the skier by the tow rope is

I greater than the total resistive force acting on the skier.
II equal to the magnitude of the force exerted on the tow rope by the skier.
III equal to the magnitude of the force causing the boat to accelerate.

Which of the above is/are correct?

A I and II only
B I and III only
C II only
D III only

1.5 A block of weight *W* slides at a constant speed down a plane inclined at an angle θ to the horizontal.



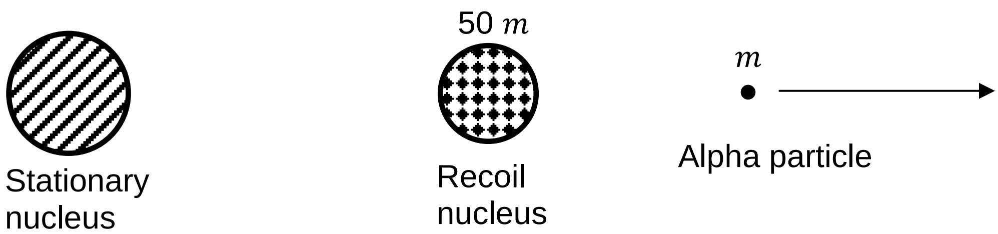
The normal force acting on the block is *N* and the frictional force between the block and the plane is *F*. What is the magnitude of *F*?

A $N \cos \theta$
B $N \sin \theta$
C $W \cos \theta$
D $W \sin \theta$

1.6 A ball of mass *m* travels horizontally with speed *v* before colliding with a vertical wall. The ball rebounds at a speed *v* in a direction opposite to its initial direction. What is the magnitude of the change in momentum of the ball?

A 0
B $\frac{mv}{2}$
C mv
D $2mv$

1.7 A stationary nucleus decays and emits an alpha particle of mass m. The alpha particle is emitted with momentum *p* and kinetic energy *E*. The mass of the recoiling nucleus is 50 times greater than the mass of the alpha particle.



What are the magnitudes of the momentum and kinetic energy of the recoiling nucleus?

	Momentum	Kinetic Energy
A	p	E
B	p	$\frac{E}{50}$
C	$\frac{p}{50}$	E
D	$\frac{p}{50}$	$\frac{E}{50}$

1.8 A small charge *q* is placed in the electric field of a large charge *Q*. Both charges experience a force *F*.

What is the correct expression for the magnitude of the electric field of the charge *Q* at the position of charge *q*?

A $\frac{F}{Qq}$

B $\frac{F}{Q}$

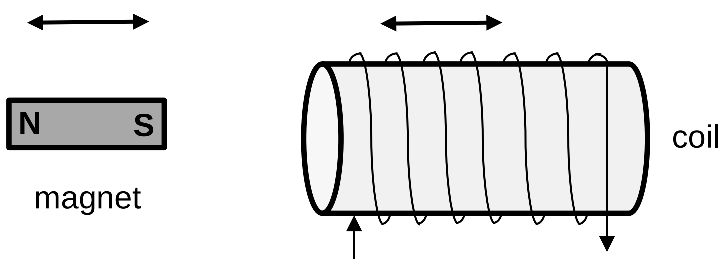
C FqQ

D $\frac{F}{q}$

1.9 An ideal ammeter is used to measure the current in a conductor. Which of the following describes the resistance of an ideal ammeter and the way the ammeter is connected to the conductor?

	Resistance	**Connection**
A	Zero	In series
B	Zero	In parallel
C	Infinite	In series
D	Infinite	In parallel

1.10 A coil and a magnet can each move horizontally to the left or to the right simultaneously at the same speed.



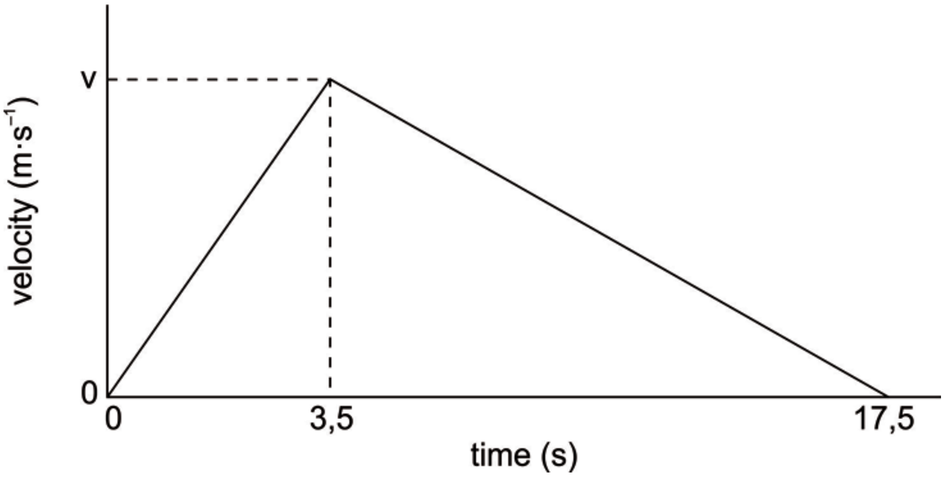
In which of the following will a conventional current be induced in the coil in the direction shown in the diagram when both the magnet and the coil are moving?

	Direction of motion of magnet	**Direction of motion of coil**
A	To the left	To the right
B	To the left	To the left
C	To the right	To the right
D	To the right	To the left

[20]

QUESTION 2 CARS

2.1 A toy car is pushed in a **northerly** direction along the ground for several seconds and then released. The car continues to move until friction brings it to rest. The velocity-time graph shown below represents the motion of the toy car.



The total distance travelled by the toy car in 17,5 s is 29,8 m.

2.1.1 Define *velocity*. (2)

2.1.2 Calculate the magnitude of the maximum velocity of the car. (4)

The car has a mass of 20 kg. The only forces acting on the car during the last 14 s are weight and friction.

2.1.3 Calculate the frictional force on the car during the last 14 s. (6)

2.2 In 1997, a high-speed car broke the world land-speed record. The car accelerated uniformly in two stages as shown by the information provided in the table. The car started from rest.

	Time (s)	Speed at end of stage ($m \cdot s^{-1}$)
Stage 1	0,0–4,0	44
Stage 2	4,0–12,0	280

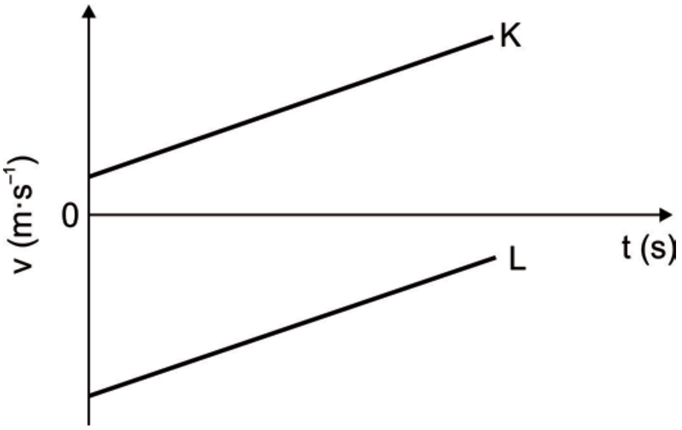
2.2.1 Calculate the average acceleration during stage 1. (3)

2.2.2 Calculate the total distance travelled by the car in 12 s. (6)

[21]

QUESTION 3 FRICTION, SLIDING AND HAILSTONES

3.1 The velocity vs time graph shows the motion of two different objects sliding in a straight line across a horizontal surface.



3.1.1 Could friction be the cause of the change in the velocity for object K? Explain your answer. (3)

3.1.2 Could friction be the cause of the change in velocity for object L? Answer yes or no. (1)

3.2 A hail stone of mass 0,7 kg falls from rest from the top of a storm cloud. The average acceleration of the hail stone while falling through air is 0,21 $m{\cdot}s^{-2}$. The hail stone reaches the ground with a speed of 34 $m{\cdot}s^{-1}$.

3.2.1 Define *acceleration*. (2)

3.2.2 Calculate the distance the hail stone travelled from the top of the storm cloud to the ground. (4)

3.2.3 Falling objects normally have an acceleration of 9,8 $m{\cdot}s^{-2}$. Explain why the acceleration of the hail stone is much less. (2)

On reaching the ground, the hail stone pierces 12 cm into the ground before coming to rest.

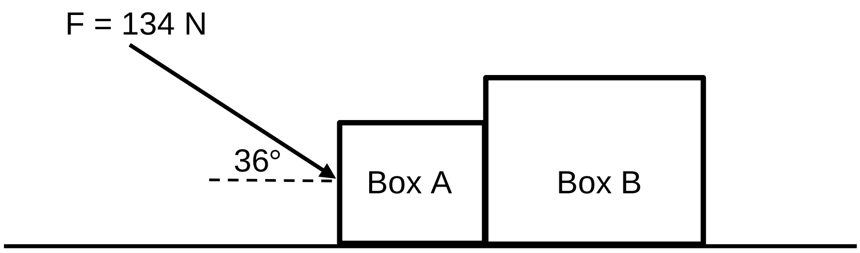
3.2.4 Calculate the acceleration of the hail stone while piercing the ground. (4)

3.2.5 Hence, calculate the magnitude of the force the ground exerts on the hail stone. (5)

[21]

QUESTION 4 AN ATHLETE IN TRAINING

An athlete trains by pushing a heavy box A of mass 23 kg, which is in contact with an even heavier box B of mass 31 kg, across the rough surface of a field as shown in the diagram below. The athlete exerts a force F = 134 N at an angle of 36° to the horizontal on box A and each box experiences a frictional force of 45 N. The boxes accelerate horizontally.



4.1 Draw a labelled free-body diagram for box A. (5)

4.2 Draw a labelled free-body diagram for box B. (4)

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

4.4 Use Newton's second law to write the equation $F_{net} = ma$ in terms of all the horizontal forces acting on **box A**. (4)

4.5 State *Newton's third law*. (2)

4.6 Calculate the force that box B exerts on box A. (3)

4.7 Define *frictional force due to a surface*. (2)

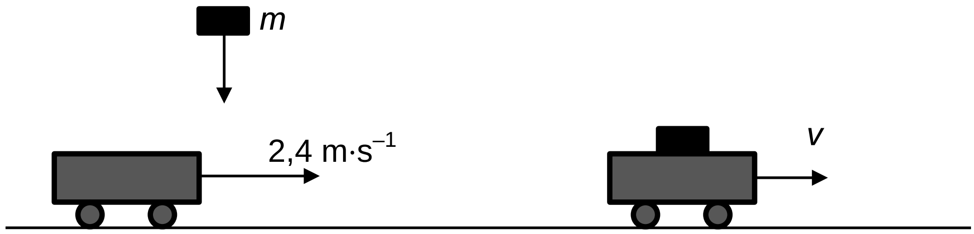
Box A and box B are made of identical material, yet each box experiences the same frictional force.

4.8 Use a suitable equation to help you explain why box A experiences the same magnitude frictional force even though box A has a smaller mass than box B. (3)

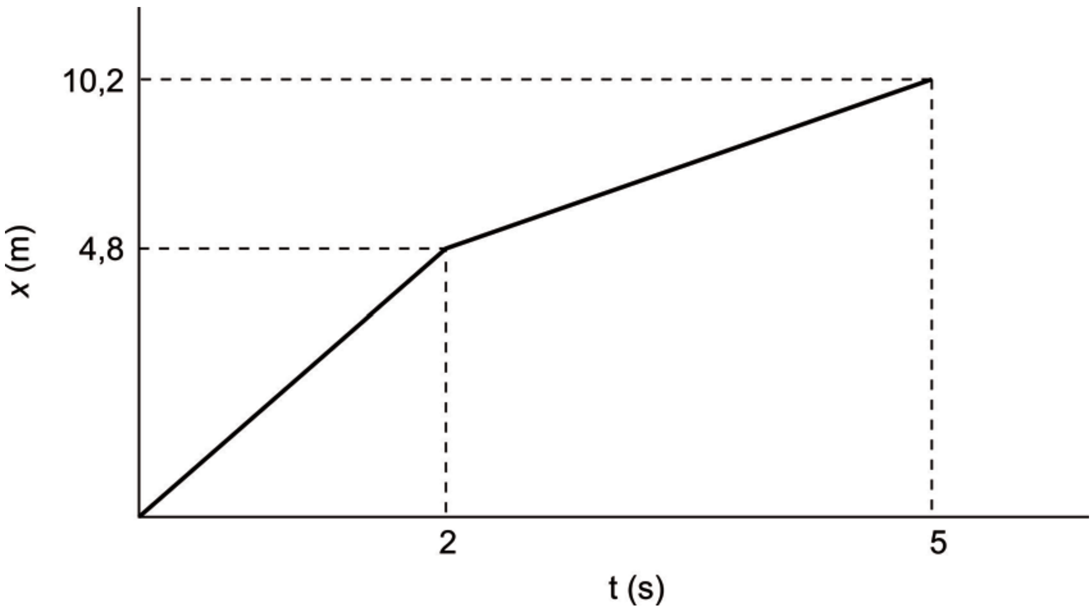
[25]

QUESTION 5 TROLLEYS & HAMMERS

5.1 Students are performing an experiment in the lab. A 0,9 kg trolley is travelling with a constant velocity of 2,4 $m \cdot s^{-1}$ on a long frictionless track when a metal cylinder of mass *m* is dropped vertically onto the trolley. The trolley with the metal cylinder continues to move with velocity *v* as shown in the diagram.



The students use video analysis to plot the following position vs time graph of the trolley.



5.1.1 Use the graph to determine the magnitude of the velocity (*v*) of the trolley **after** the metal cylinder is dropped on the trolley. (3)

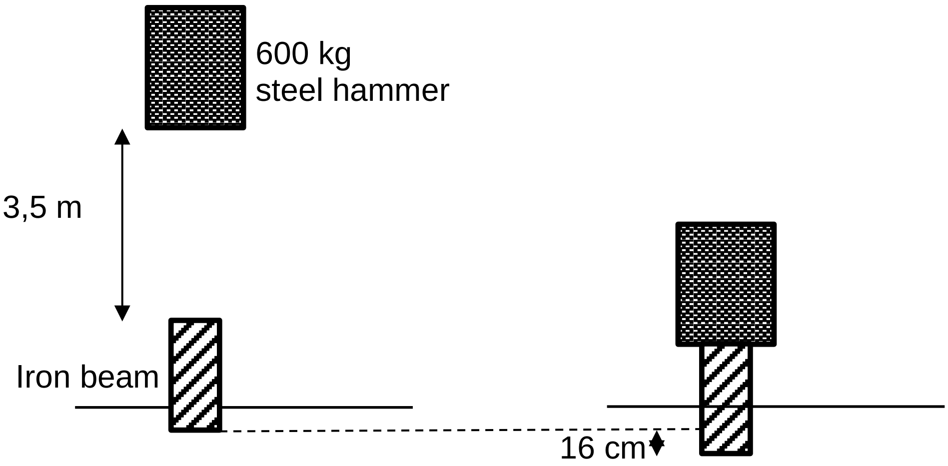
5.1.2 The law of conservation of momentum is a consequence of which of Newton's laws? (2)

5.1.3 Calculate the mass (*m*) of the metal cylinder. (4)

5.1.4 Why is the vertical velocity of the falling metal cylinder not taken into consideration? (2)

5.2 A steel hammer with a mass of 600 kg is used to drive an iron beam into the ground.

The steel hammer falls a distance of 3,5 m from rest under gravity before contacting the beam. The beam is driven a distance of 16 cm into the ground before coming to rest. Ignore air resistance.



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

5.2.2 Calculate the magnitude of the velocity of the steel hammer **as it strikes** the iron beam. (4)

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

5.2.4 Calculate the magnitude of the average net force the beam exerts on the hammer while the hammer is brought to rest on the beam. (4)

The machine that is used to raise the hammer, so that it can be used again, has a power output of 180 W.

5.2.5 Calculate the time the machine will take to lift the hammer through a height of 3,5 m. (4)

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QUESTION 6 ON ANOTHER PLANET

An astronaut on a planet wants to determine the acceleration due to gravity. The astronaut has a number of different masses available and determines the weight of each mass.

The following measurements were recorded by the astronaut:

Mass (kg)	**Weight (N)**
0,1	0,30
0,2	0,79
0,3	1,05
0,5	1,90
0,6	2,18
0,7	2,70

6.1 Distinguish between mass and weight. (4)

6.2 Plot a graph of weight (on the *y*-axis) vs mass (on the *x*-axis) on the graph paper provided **in the answer sheet**. (6)

6.3 Calculate the gradient of the graph. Show the values you used on your graph and include the appropriate unit in your answer. (4)

6.4 Hence, determine the acceleration due to gravity on the planet. (3)

Use the table of "g values" below to answer the questions that follow.

Planet	**g ($m \cdot s^{-2}$)**
Venus	8,87
Mars	3,71
Jupiter	23,12
Pluto	0,58

6.5 Which planet is the astronaut on? (2)

6.6 The radius of Pluto is $1,19 \times 10^6$ m. Determine the mass of Pluto. (4)

[23]

QUESTION 7 ELECTRIC CIRCUITS

7.1 A battery with emf 6 V and an internal resistance r is connected in series to two resistors, each of constant resistance R as shown in diagram 7a.

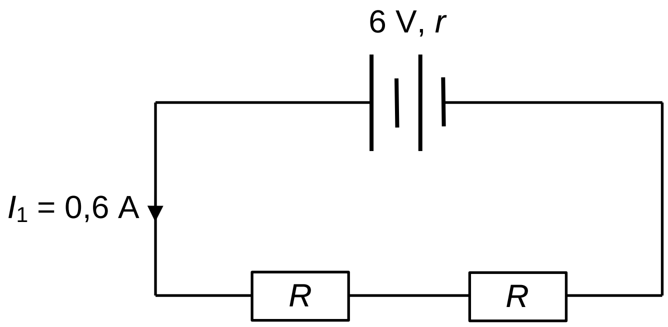


Diagram 7a

The current I_1 supplied by the battery is 0,6 A.

The same battery is now connected to two resistors, also of constant resistance R, connected in parallel as shown in diagram 7b.

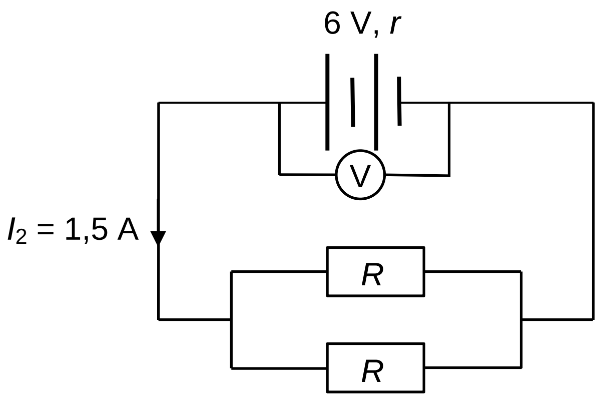


Diagram 7b

The current I_2 supplied by the battery is 1,5 A.

7.1.1 Define *resistance*. (2)

7.1.2 Define *emf*. (2)

7.1.3 Consider the circuit in diagram 7a and write an equation to express the *emf* in terms of I_1, r and R. (2)

7.1.4 Consider the circuit in diagram 7b and write an equation to express the *emf* in terms of I_2, r and R. (2)

7.1.5 Use your equations in Question 7.1.3 and Question 7.1.4 to calculate the resistance of R. (3)

7.1.6 Define *power*. (2)

7.1.7 Calculate the power dissipated by one resistor R in diagram 7b. (3)

A third resistor R is connected in parallel with the existing resistors in diagram 7b.

7.1.8 State whether the reading of the voltmeter would increase, decrease or stay the same. Use a suitable equation to help you explain your answer. (4)

7.2 Two different bulbs A and B are connected in parallel to a potential difference of 12 V. Bulb A glows more brightly than bulb B.

7.2.1 Define *potential difference*. (2)

For the following questions, answer bulb A, bulb B, or neither.

7.2.2 Which bulb has the greater potential difference across it? (2)

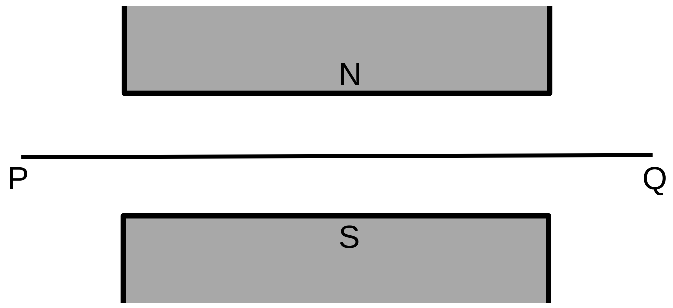
7.2.3 Which bulb carries the greater current? (2)

7.2.4 Which bulb has the greatest resistance? (2)

[28]

QUESTION 8 ELECTRODYNAMICS

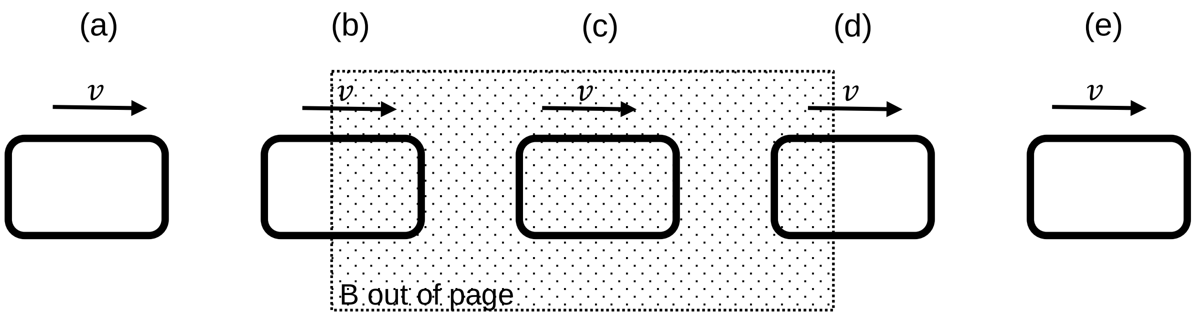
8.1 A current-carrying wire PQ is placed between the poles of two permanent magnets as shown in the diagram.



8.1.1 On the diagram **on the answer sheet**, sketch lines to show the direction of the magnetic field due to the permanent magnets. (2)

8.1.2 The force on the wire PQ is directed into the paper. Is the current direction in the wire from P to Q or from Q to P? (2)

8.2 A rectangular conducting loop travels from left to right at a constant velocity, v, through a magnetic field directed out of the page as shown in the diagrams (a)–(e).



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

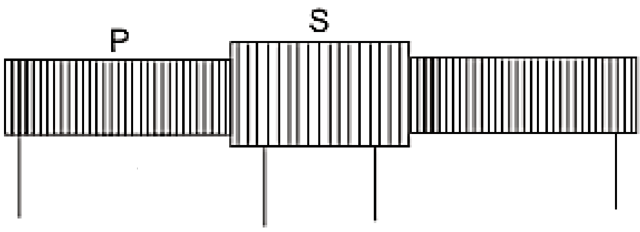
8.2.2 During the motion described:

(a) At what positions (a)–(e) is a current induced in the loop? (2)

(b) If there is a current induced in the loop, state the direction of the induced current as clockwise or anti-clockwise. (2)

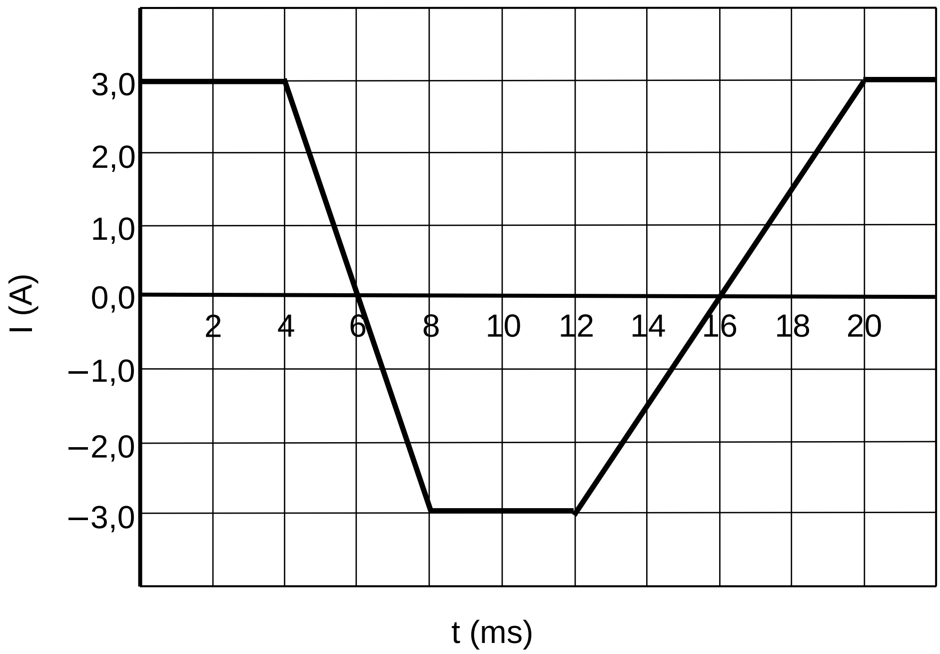
8.2.3 For diagram (c) briefly explain why there is, or why there is not, an induced current in the loop. (2)

8.3 A long primary solenoid (P) has a secondary coil (S) wound around the middle as shown in the diagram.



[Image available at <http://physicscatalyst.com>]

The current in the **primary solenoid** changes with time as shown on the graph below.



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

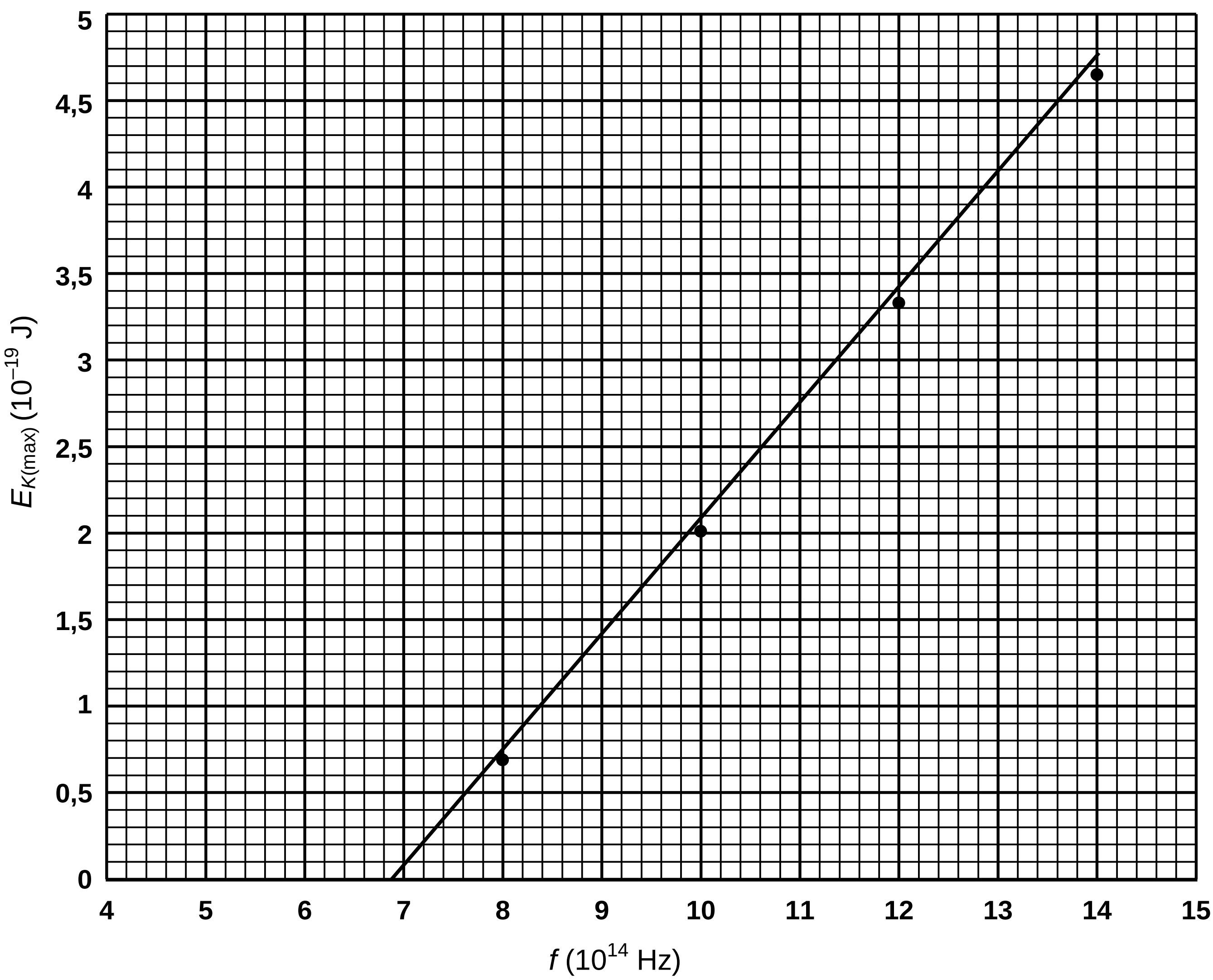
The **maximum emf** induced in the secondary solenoid is **4 mV**.

8.3.2 On the graph provided **on the answer sheet**, draw the corresponding induced emf vs time graph for the **secondary coil**. The relative sizes of the emf must be included on the graph. (4)

[18]

QUESTION 9 PHOTONS & ELECTRONS

9.1 The graph shows how the maximum kinetic energy $E_{K\,(max)}$ of electrons emitted from a surface of calcium metal varies with the frequency *f* of the incident radiation.

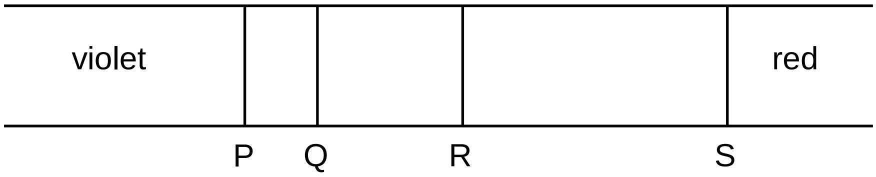


9.1.1 Define *work function*. (2)

9.1.2 Calculate the work function of calcium. (4)

9.1.3 The experiment is repeated using magnesium instead of calcium metal. The work function of magnesium is **1,3 times** the work function of calcium. Draw a second line on the graph **on the answer sheet** to illustrate the results of the experiment with magnesium. (2)

9.2 The four emission lines P, Q, R and S in the hydrogen spectrum are illustrated in the diagram.



The wavelengths of the four emission lines are provided in the table:

Emission Line	**Wavelength (10^{-7} m)**
P	4,10
Q	4,34
R	4,86
S	6,58

Frequencies associated with these wavelengths are emitted when electrons move from a higher energy level to the –3,4 eV energy level.

9.2.1 Calculate the value of the energy of the light associated with the emission line S. (4)

9.2.2 Which emission line is produced by the transition from the highest energy level to the –3,4 eV energy level? Briefly explain your answer. (3)

9.2.3 State why knowledge of the emission line wavelengths is useful to scientists to identify substances. (2)

[17]

Total: 200 marks