11.1 Electromagnetic Induction

Question Paper

Course	DP IB Physics
Section	11. Electromagnetic Induction (HL only)
Topic	11.1 Electromagnetic Induction
Difficulty	Medium

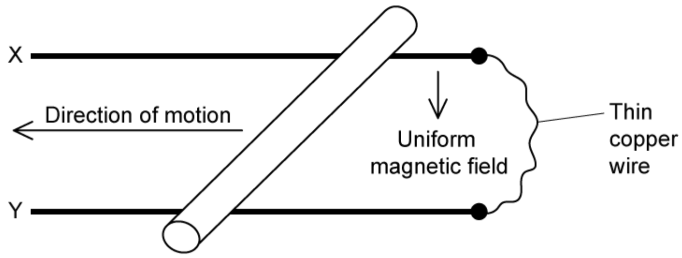
Time allowed: 70

Score: /58

Percentage: /100

Question 1a

A copper rod is placed in a region of uniform magnetic field. The rod is moved horizontally along two parallel conducting rails X and Y.



The rod lies at right angles to the direction of the uniform magnetic field. It moves at constant speed.

The rails are connected at one end by a thin copper wire.

(a)
Describe how an emf is induced in the rod. Refer to forces acting on the conduction electrons in the copper of the rod in your answer.

[2]

[2 marks]

Question 1b

(b)
State what is meant by rate of change of flux and apply it to this situation.

[2]

[2 marks]

Question 1c

The length of the rod is 0.8 m and it moves at a speed of 5.7 m s^{-1}. The induced emf is 9 mV.

(c)
Determine the magnitude of the magnetic field strength.

[2]

[2 marks]

Question 1d

(d)

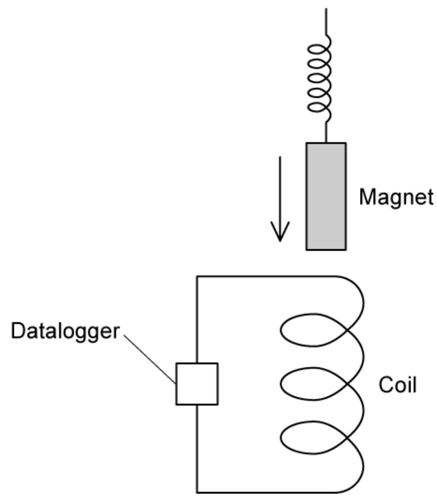
Explain how Lenz's law relates to the rod moving on the rails.

[3]

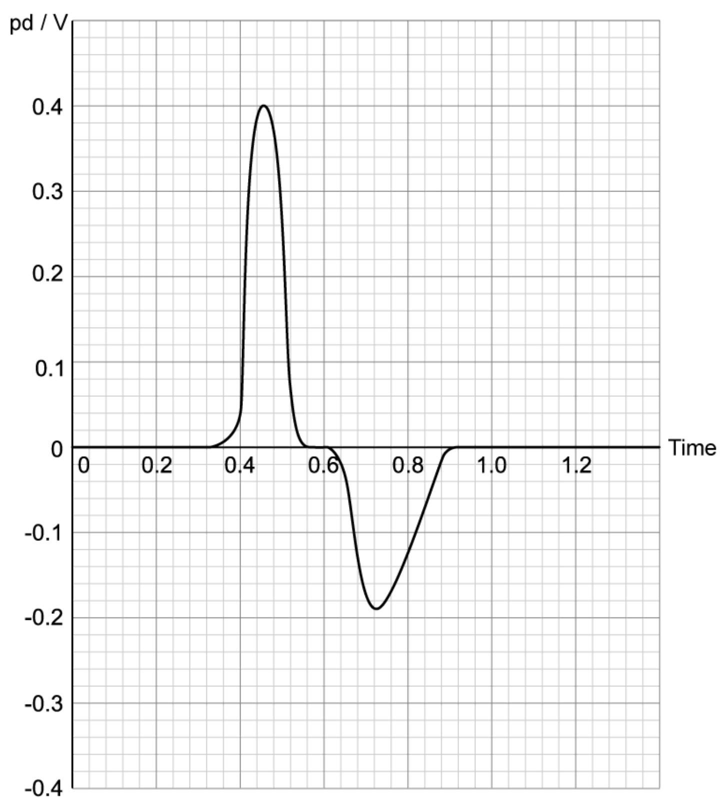
[3 marks]

Question 2a

A bar magnet attached to a spring is allowed to fall vertically from rest through a simple coil of conducting wire. The potential difference (pd) across the solenoid is measured using a datalogger.



The graph shows the variation of the pd across the coil with time.



(a)
Explain the shape of the graph by

(i)

Making reference to both Faraday's and Lenz's laws.

[2]

(ii)
Considering the mass-spring system.

[2]

[4 marks]

Question 2b

The coil has 2 200 turns.

(b)
Calculate the magnitude of the maximum rate of change of magnetic flux.

[2]

[2 marks]

Question 2c

(c)
The magnet is displaced vertically so that it initially oscillates with simple harmonic motion. Apply Lenz's law to this situation.

[3]

[3 marks]

Question 2d

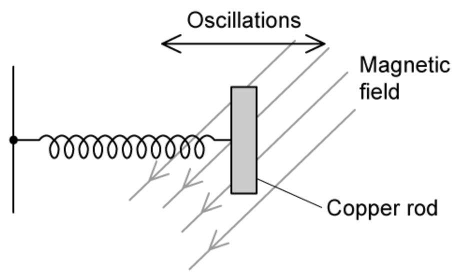
(d)
Outline how the simple harmonic motion of the oscillations would be affected by replacing the magnet with one of equal mass but with a greater magnetic field strength.

[3]

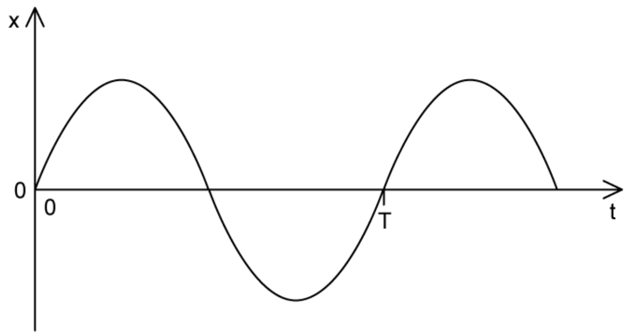
[3 marks]

Question 3a

A vertical copper rod is attached to the mass of a mass-spring system so that it can be made to oscillate with simple harmonic motion with a time period *T* at right angles to a uniform magnetic field.



The graph shows the variation with time *t* of the horizontal displacement *x* of the rod.



(a)
Sketch a graph to show

(i)
Variation with time *t* of the vertical velocity *v* of the rod.

[2]

(ii)
Variation with time *t* of the emf generated between the ends of the rod.

[2]

[4 marks]

Question 3b

The length of the rod is 25 cm and the magnitude of the magnetic field is 68 μT. At the equilibrium position the rod is moving at 5.1 m s^{-1}.

(b) Determine the magnitude of the maximum emf ε_{max} between the ends of the rod.

Explain your reasoning.

[3]

[3 marks]

Question 3c

The frequency of the motion is doubled without any change in the amplitude of the motion.

(c)
State and explain the changes this causes to the time, *t* and the induced emf.

[3]

[3 marks]

Question 3d

Conducting wire is wrapped around a circular disk of diameter 10 cm to create a loop with 145 turns. The loop is held in a constant magnetic field with field strength 0.36 T.

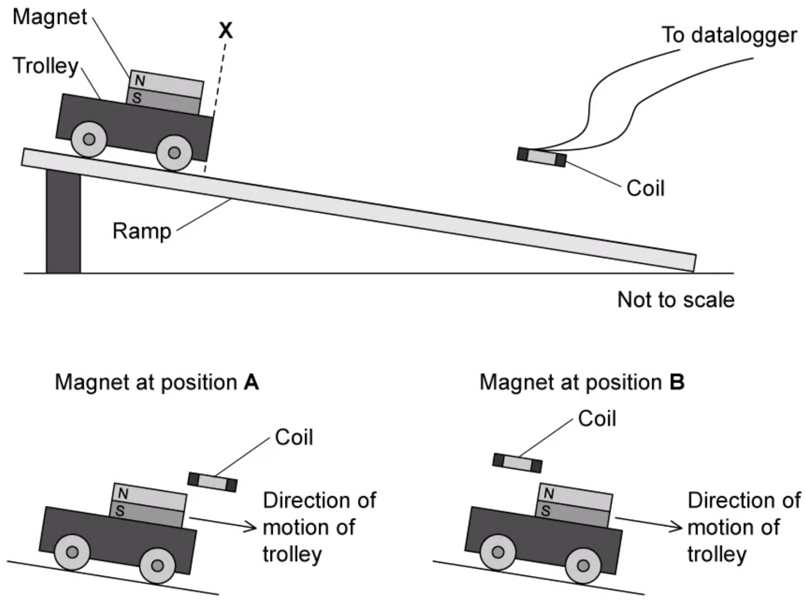
(d)
Determine the magnetic flux through the loop when the angle between the disk and the magnetic field is 10°.

[2]

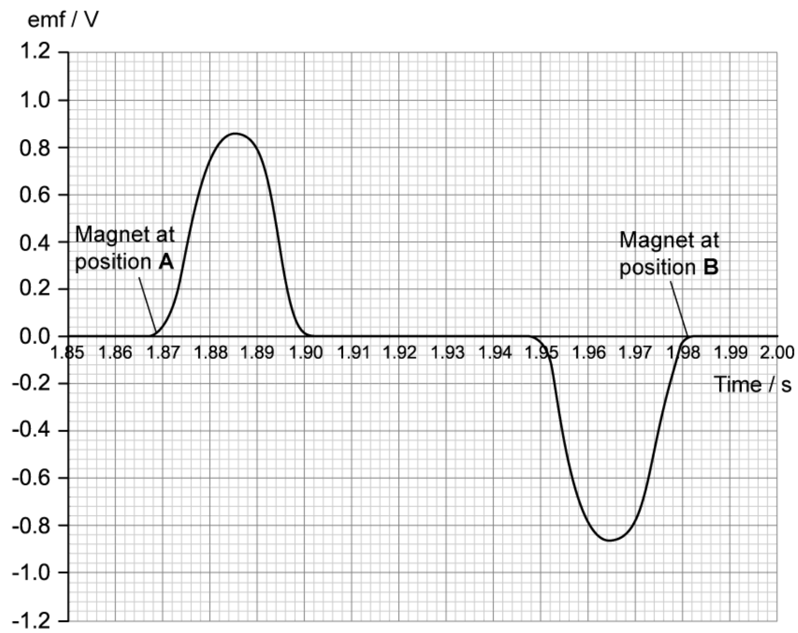
[2 marks]

Question 4a

A toy car with a magnet attached so that the North pole faces upwards is released from the top of a ramp. The car rolls down the ramp at constant speed. An emf is induced in a coil of wire as the toy and magnet pass underneath it.



The induced emf is recorded by a datalogger attached to the coil.



(a)
The graph shows the variation of induced emf.

(i)
Determine the maximum rate of change of flux linkage in the coil.

[1]

(ii)
Explain the shape of the graph between points A and B.

[3]

[4 marks]

Question 4b

The length of the magnet is 3.0 cm and the diameter of the coil is 1.5 cm.

(b)
Using the graph, determine the speed of the car between positions A and B.

[2]

[2 marks]

Question 4c

The slope of the ramp is increased, making the car accelerate when released. It reaches point A at 1.86 s.

(c)
Apply Faraday's Law to explain how this would affect the induced emf at points A and B.

[2]

[2 marks]

Question 4d

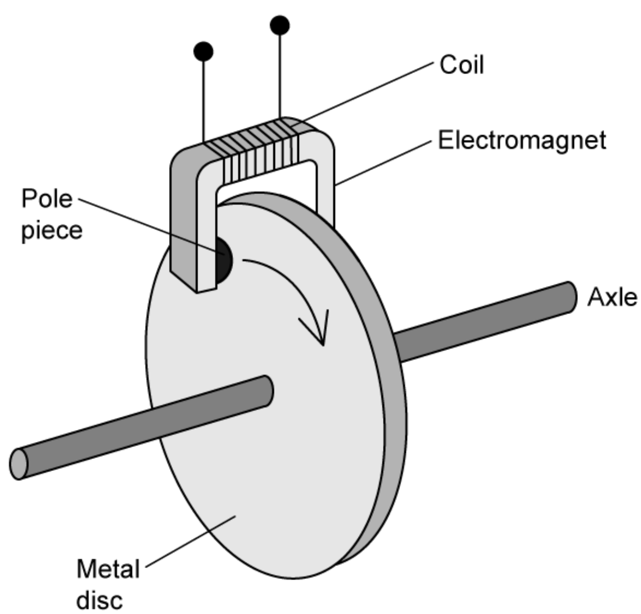
(d)
Sketch a graph to show the new induced emf as the magnet moves from point X to point B.

[4]

[4 marks]

Question 5a

An electromagnetic braking system uses a metal disk, attached to the wheel of the vehicle so that they rotate together. An electromagnet is placed such that the poles are on either side of the rotating disk, but do not touch it.



When the driver applies the brakes a direct current passes through the coil of the electromagnet.

(a)
Explain with reference to appropriate laws of electromagnetic induction how this design can produce a braking effect.

[3]

[3 marks]

Question 5b

Conventional braking systems use friction pads which are brought into contact with a rotating disk to slow down vehicles.

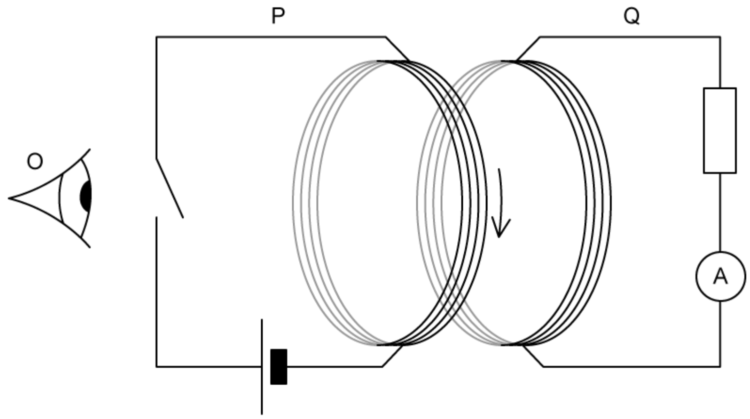
(b)
Distinguish between the electromagnetic and conventional braking systems, identifying at least two advantages and two disadvantage of the electromagnetic system.

[4]

[4 marks]

Question 5c

Induced current can be used in switching devices. A current in point P is made to flow in a clockwise direction when viewed from position O.



(c)
Outline how Lenz's law applies to the direction of the flow of induced current when the switch is opened and then closed.

[3]

[3 marks]

Question 5d

The coil at P has 50 turns and an area of 15.8 cm^2. It produces a constant magnetic field of 0.26 T. The two coils are identical.

(d)
For coil Q

(i)
Determine the magnetic flux when Q is positioned at 45° to the field produced by P.

[1]

(ii)
Calculate and explain the induced emf when the magnetic field is changing at a rate of 4.0 T s^{-1}.

[2]

[3 marks]