福建中學

FUKIEN SECONDARY SCHOOL

S6 Mock Examination (2021-2022)
Physics Paper 1
(2 hours 30 minutes)
Section B: Question-Answer Book

Date: 25th January 2022 Name: ____________________

Time: 8:30a.m. – 11:00a.m. Class: __________ No.: ________

Instructions to students:

1. Write your name, class and class number in this Question-Answer Book.

2. Refer to the general instructions on the cover of the Question Paper for Section A.

3. Hand in this Question-Answer Book at the end of the examination.

4. This section carries 84 marks. **Answer ALL questions**.

5. Write your answers in the spaces provided in this Question-Answer Book.

6. The diagrams in this section are **NOT** necessarily drawn to scale.

Section B: Answer **ALL** questions. Parts marked with * involve knowledge of the extension component. Write your answers in the spaces provided.

1. Iced milk tea (Figure 1) is a special drink in Hong Kong. It consists of a cup of milk tea immersed into a bowl of ice cubes. Many people think it tastes better than the traditional milk tea because the milk tea is not diluted with the melted ice.

Figure 1

(a) To produce a cup of good milk tea, hot water at 96 °C is used to prepare the tea. Water at such temperature cools down rapidly due to evaporation. Briefly explain why evaporation cools down the water in terms of molecular energy. (2 marks)

(b) When the tea is ready, 200 g of 70 °C tea is added to 100 g of 25 °C milk. Find the equilibrium temperature of the mixture.

Given: specific heat capacity of tea = 4200 J kg^{-1} °C^{-1}

specific heat capacity of milk = 3930 J kg^{-1} °C^{-1} (2 marks)

(c) Finally, the milk tea is immersed into a large bowl of −4 °C ice cubes. Some ice cubes are melted while the milk tea is cooled down. Find the total mass of ice cubes melted. Assume that there is no heat loss to the surroundings, and the heat capacities of the cup and the bowl are negligible.

Given: specific heat capacities of milk tea and water = 4200 J kg^{-1} $°C^{-1}$

specific heat capacity of ice = 2100 J kg^{-1} $°C^{-1}$

specific latent heat of fusion of ice = 3.34×10^5 J kg^{-1} (2 marks)

(d) If crushed ice is used instead of ice cubes, the milk tea will cool down in a shorter time. Briefly explain why. (1 mark)

*2. In Figure 2, an ideal gas is contained in a cylinder fitted with a piston which can move smoothly. The volume V of the gas is 400 cm^3 when the pressure p is 1×10^5 Pa and temperature T is 27 °C. Then the piston is pushed until V becomes 300 cm^3 and p becomes 1.4×10^5 Pa. Assume the container is well insulated.

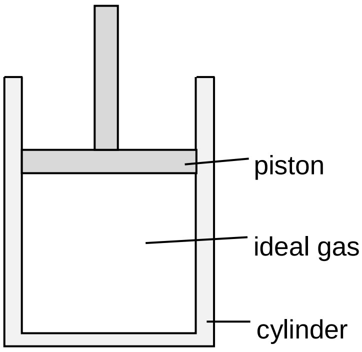


Figure 2

(a) Find the number of moles of the gas molecules in the cylinder. (2 marks)

(b) Find the ratio of the root-mean-square speed of the gas molecules before and after the piston is pushed. (2 marks)

(c) By considering the change in internal energy, find the total energy gained by the gas during the compression. (2 marks)

3. Read the following passage about helicopters and answer the questions that follow.

Stable lift of a helicopter

Typical helicopters consist of two rotors. The bigger one mounted horizontally at the top of the aircraft is called the main rotor, while the smaller one mounted vertically at the tail is called the tail rotor (Figure 3.1). Both rotors are operated by powerful engines mounted on the helicopter body, and contribute the forces needed for a stable lift.

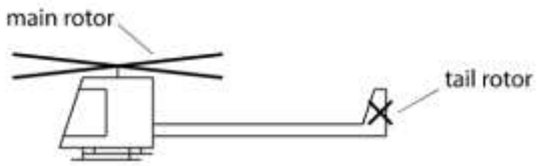


Figure 3.1

Using a powerful motor, the main rotor turns in a high rotational speed and thus provides lifting force to lift up the helicopter. However, when the motor provides a torque to turn the main rotor, at the same time, the rotor exerts a torque of equal magnitude but opposite directions, on the engine, and thus on the helicopter body. This results in a self-rotation of the helicopter body!

To avoid the helicopter body from self-rotating, an additional horizontal force and hence horizontal torque is needed to exert on the helicopter that the 'reaction' torque exerted by the main rotor can be cancelled out. The tail rotor is designed to provide a suitable torque to stop the helicopter from self-rotating when the helicopter lifts up.

(a) A helicopter is lifting up vertically without self-rotation. Figure 3.2 shows the top view of a helicopter. The main rotor is rotating in anticlockwise direction with rotational axis at *O* The tail rotor is mounted vertically at *A*.

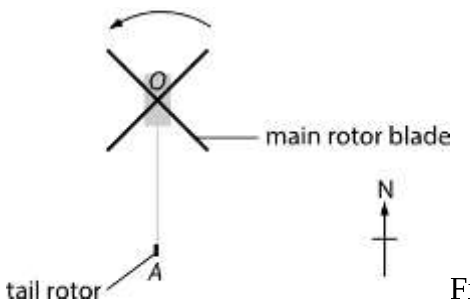


Figure 3.2

(i) In Figure 3.2, draw an arrow at *A* to indicate the direction of *F*, the force exerted on the helicopter by the tail rotor. (1 mark)

(ii) The information of the helicopter in Figure 3.2 is listed below:

Length between the axis of main rotor to the tail *OA* = 14.0 m

Torque exerted on the main rotor by the motor = 132 000 N m

Assume no horizontal torque exerts on the helicopter body due to air resistance.

Estimate the value of *F*. (2 marks)

(iii) Explain why *F* does zero work on the helicopter body. (1 mark)

(b) In a firefighting mission, a bucket with water of mass 900 kg is connected to the helicopter by a cable to fill sea water. The helicopter moves with constant horizontal acceleration, *a*, as shown in Figure 3.3.

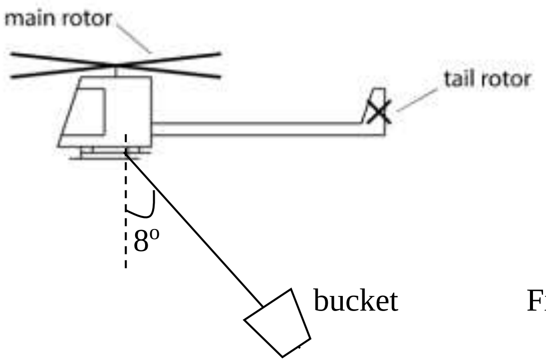
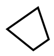


Figure 3.3

(i) Draw a free body diagram of the bucket. (2 marks)



(ii) Find the acceleration of the helicopter. (3 marks)

4. A metal ball P of mass 2 kg moves with speed u on a smooth horizontal surface. It collides with another metal ball Q of mass 4 kg, which is initially at rest as shown in Figure 4.1.

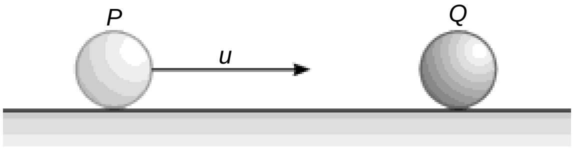


Figure 4.1

Figure 4.2 below shows the variation of the momentum of P with time. Direction to the right is taken as positive.

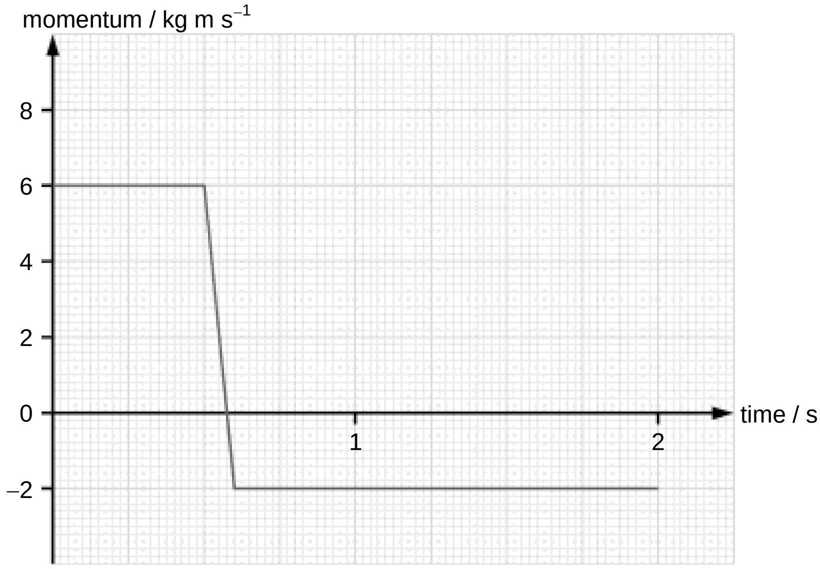


Figure 4.2

(a) Find u. (1 mark)

(b) (i) In Figure 4.2, draw the variation of the momentum of Q with time. (1 mark)

(ii) Find the speed of Q after the collision. (1 mark)

(iii) Find the average forces acting on P by Q during the collision. (3 marks)

5. Peter of mass 65 kg slides from rest at *P* on a snowy ramp as shown in Figure 5. He gains a speed of 25 m s^{-1} when he reaches *Q*, where he jumps and leaves the ramp. He finally lands on the ramp at *R*. Neglect air resistance.

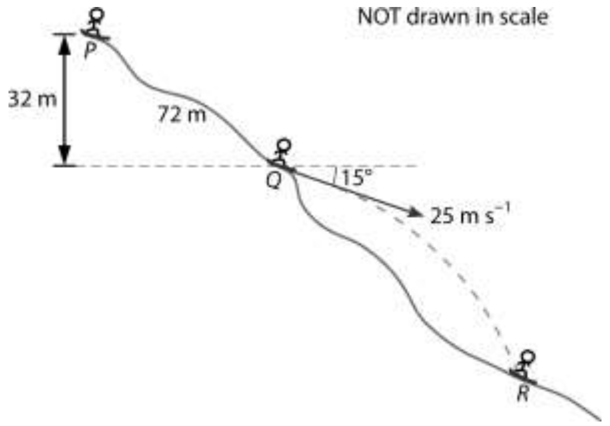


Figure 5

(a) The length of path *PQ* is 72 m. Find the average friction acting on Peter when he slides down from *P* to *Q*. (2 marks)

*(b) Peter makes a jump at an angle 15° below the horizontal at *Q*. It takes 3 s for him to move from *Q* to *R*. Find the speed of Peter at the moment when he lands. (3 marks)

(c) Peter bends his knees when he lands. Explain why he does so. (2 marks)

6. In the Figure 6.1, a light ray passes from air into water. The angle of incidence is 45°. A plane mirror is placed under water. The refractive index of water is 1.33.

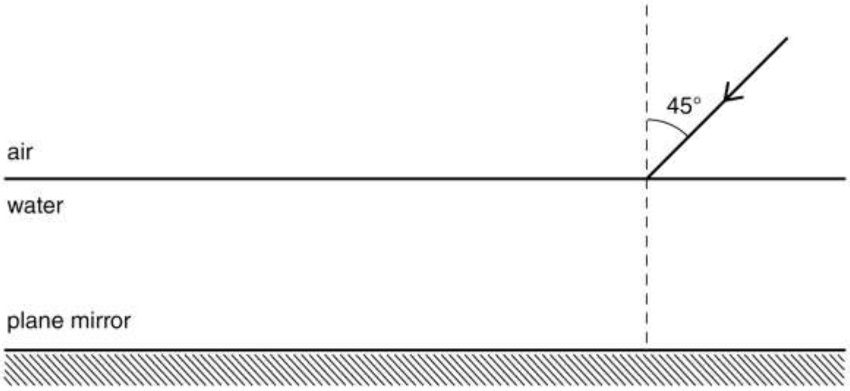


Figure 6.1

(a) (i) Find the angle of refraction in the water. (2 marks)

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(ii) Complete the ray diagram to show the light emerges in the air again. Mark all the angles made by each ray with the normal. (2 marks)

(iii) Find the critical angle for the water-air interface. (2 marks)

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(d) Figure 6.2 shows a sound wave entering the air-water boundary. It is known that the sound of sound in water is about 1000 ms^{-1}.

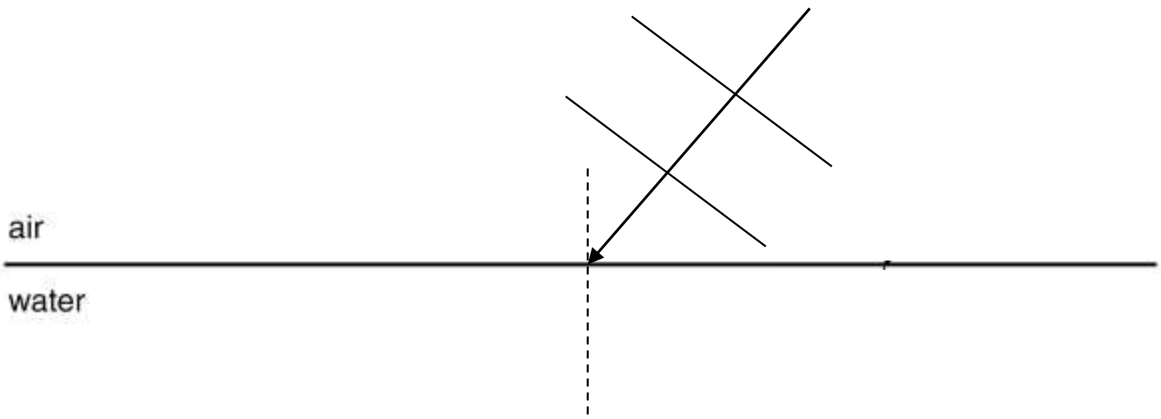

Figure 6.2

(i) How do the frequency and wavelength of the sound change after entering water? (2 marks)

(ii) In Figure 6.2, sketch the sound wave after entering water. (2 marks)

7. A compact disc (CD) is a plastic plate covered with a reflective coating (Figure 7.1). The surface of the plastic plate has many closely and evenly spaced tracks that carry information. With the reflective coating removed, the tracks can behave like the lines of a plane transmission grating. Bright dots can be produced when a beam of monochromatic light passes through the plastic plate (Figure 7.2).

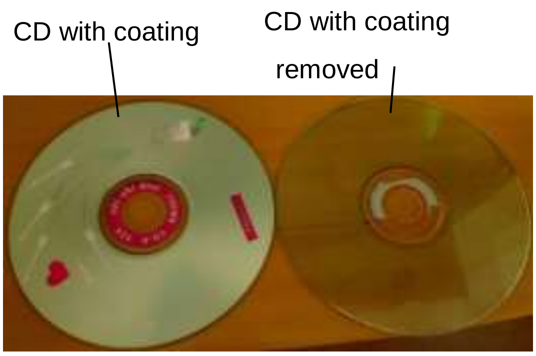

Figure 7.1

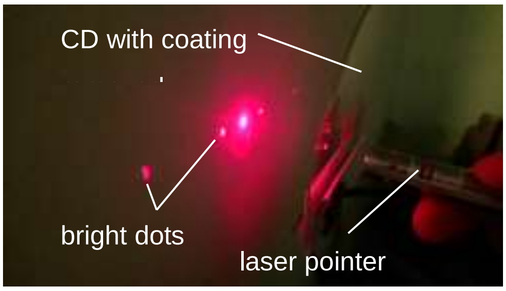

Figure 7.2

(a) Name the two wave phenomena that explain how a plane transmission grating works. (2 marks) *(b) A student studies the spacing of CD tracks using the setup shown in Figure 7.3. Monochromatic light of wavelength 650 nm is directed normally onto a CD with the reflective coating removed. A screen is 5.5 cm behind the CD. Some bright dots are formed on the screen. The distance between the second-order bright dots is 18.5 cm.

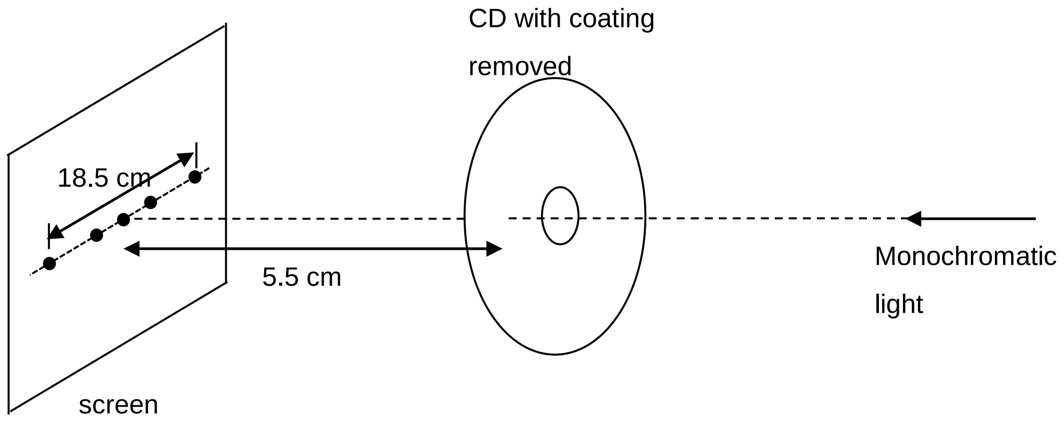

Figure 7.3

(i) Estimate the distance between two adjacent tracks on the CD. (3 marks)

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(ii) Find the maximum number of bright dots that is formed. (2 marks)

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(iii) Suggest a method that can improve the accuracy of the result in (b)(i). (1 mark)

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8. Figure 8 shows the structure of a hand-dryer, which produces hot air for drying wet hands.

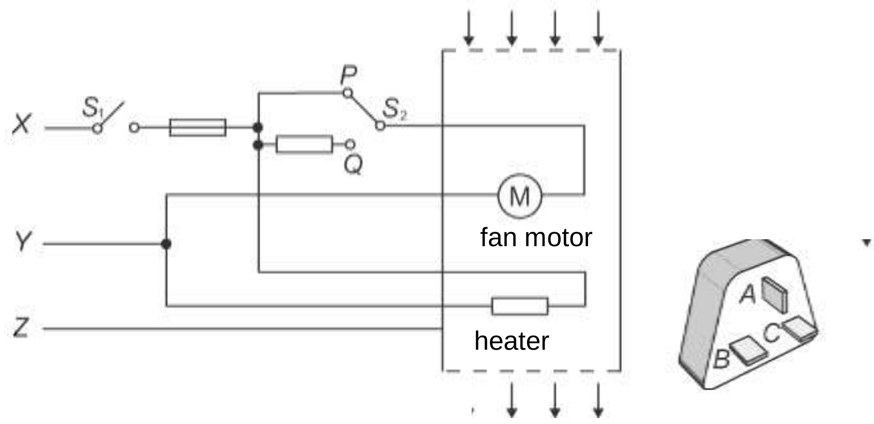

Figure 8

(a) To which of the pins *A*, *B*, *C* of the plug should each of the wires *X*, *Y* and *Z* of the hand-dryer be connected? (2 marks)

X: ________________ *Y:*________________ *Z:*_________________

(b) Explain why S_1 of the hand-dryer is placed in wire *X* instead of wire *Y*. (1 mark)

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(c) The hand-dryer operates at 220 V and its heating element has a resistance of 50 Ω.

(i) Calculate the current passing through the heating element. (2 marks)

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(ii) Find the power of the heating element. (2 marks)

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(iii) The power of the fan motor is 200 W. If 1 kW h of electrical energy costs $0.90, calculate the cost to switch on the hand-dryer for 5 hours. (2 marks)

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(d) The S_2 is now switched to Q. How would the amount of air passing over the heating element be affected? Briefly explain your answer. (2 marks)

9. A charged particle of mass m=1.5kg and charge q=+0.1C, as shown in Figure 9, rest at point A initially. Now it slides down a smooth circular ramp with radius r=0.5m.The particle leaves the ramp at C. The directions of the magnetic field and the electric field are indicated in Figure 9. It is given that B=1.2 T and E=100 NC^{-1}.

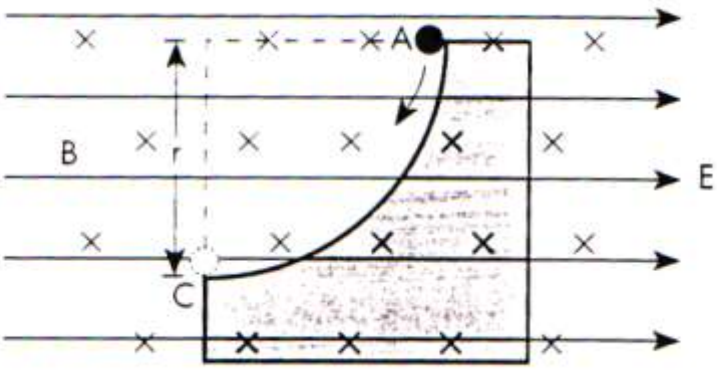
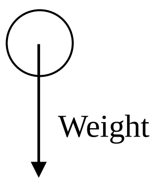


Figure 9

(a) Complete the free body diagram to show all forces acting on the charged particle when it reaches point C. (2 marks)



(b) (i) The magnetic force does not work in the whole process. Why? (1 mark)

(ii) By the principle of conservation of energy, calculate the kinetic energy gained by the charged particle at point *C*. (2 marks)

(c) From *A* to *C*, which force(s) provide(s) the centripetal force? (1 mark)

10. In Figure 10.1, a bar magnet with its N-pole pointing downwards is dropped through a 30-turn coil mounted on a vertical plastic tube. The induced e.m.f. in the coil is recorded by a data-logger. Figure 10.2 shows how the induced e.m.f. in the coil changes with time.

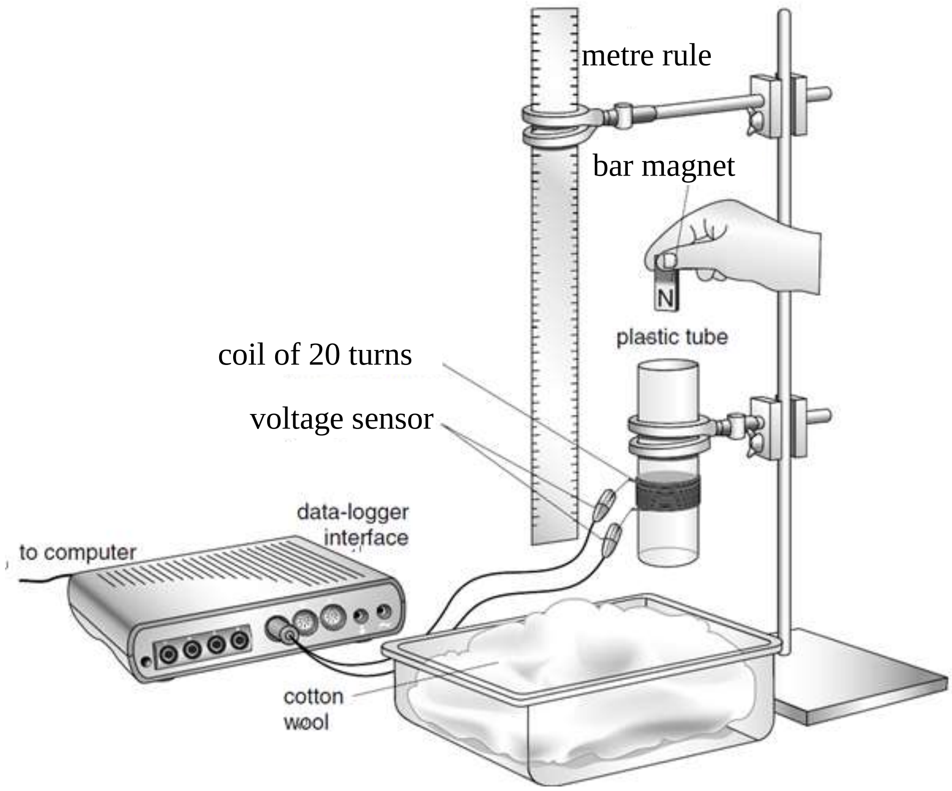


Figure 10.1

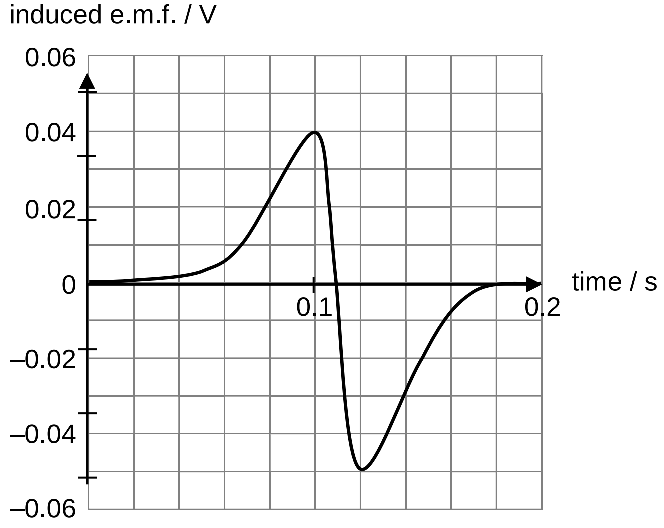
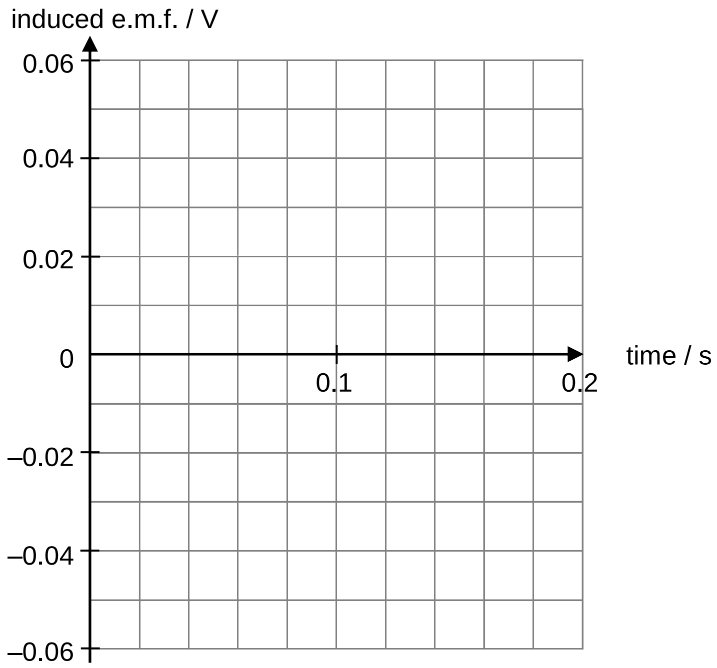


Figure 10.2

(a) What is the direction of the induced current in the coil as seen from the top of the tube when the magnet approaches the coil? Explain your answer. (2 marks)

(b) Explain why the two peaks in Figure 10.2 are different in magnitude. (1 mark)

(c) Now, the magnet is dropped from the same height with its S-pole pointing downwards. Sketch a graph to show how the induced e.m.f. in the coil changes with time. (1 mark)



*(d) Find the maximum magnitude of the induced e.m.f. in the coil if a 150-turn coil is used.

(2 marks)

11. As shown in Figure 11, a nuclear reactor is generating energy by nuclear fission of uranium-235.

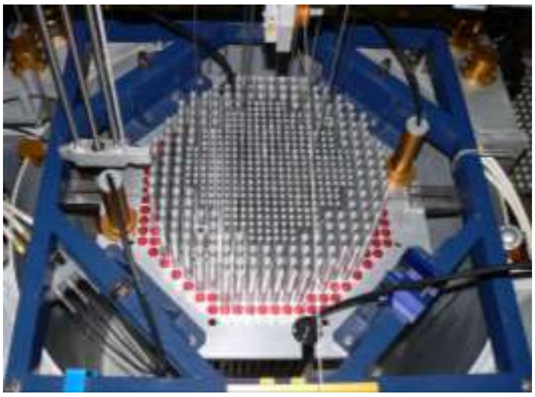


Figure 11

(a) A uranium-235 nucleus is hit by a neutron and splits according to the following equation.

$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{144}_{56}\mathrm{Ba} + ^{x}_{36}\mathrm{Kr} + 2^{1}_{0}\mathrm{n}$

Find x. (2 marks)

(b) On average, 3.24×10^{-11} J of energy is produced when a uranium-235 atom undergoes nuclear fission. If the useful power output of the nuclear reactor is 2.7×10^{8} W and the efficiency is 30%, find the number of uranium-235 atoms splitting in the reactor in one second. (3 marks)

*(c) A barium-144 nucleus may undergo β-decay or α-decay. It is known that the half-life of barium-144 is 0.530 s and 0.37% of the decays are α-decays. A radiation source initially contains 5×10^{20} barium-144 atoms. How many α particles are released by the source after 3 seconds? (3 marks)

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