The University of Nottingham Ningbo China

Centre for English Language Education

AUTUMN SEMESTER EXAMINATION 2022 – 2023

Foundation Science A – Physics

Time allowed: **TWO HOURS**

There are 6 Questions. Answer any FOUR Questions.
All questions are worth 25 marks.

Only silent, self-contained calculators with a Single-Line Display or Dual-Line Display are permitted in this examination.

Dictionaries are not allowed with one exception: those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination.
Subject-specific translation dictionaries are not permitted.

ADDITIONAL MATERIALS: Science A Formula Sheet

continued

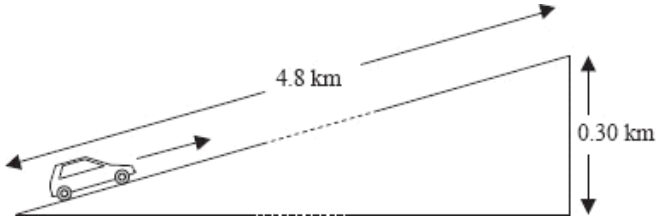
Q.1 (25 Marks)

Answer each of the following questions.

(a) Define power. **[1 mark]**

(b) A car is travelling with constant speed, v, along a horizontal straight road. There is a total resistive force, F, acting on the car.
Deduce that the power, P, to overcome the force F is $P = Fv$. **[2 marks]**

(c) Consider the following situation of a car drives up a straight incline, which is 4.8 km long. The total height of the incline is 0.30 km.



The car moves up the incline at a steady speed of 16 $m.s^{-1}$. During the climb, the average friction force acting on the car is 5.0×10^2 N. The total weight of the car and the driver is 1.2×10^4 N.

i) Determine the time it takes the car to travel to the top of the incline. **[2 marks]**

ii) Determine the work done against the gravitational force in travelling from the bottom to the top of the incline. **[1 mark]**

iii) Using your answers to (c)(i) and (c)(ii), calculate a value for the minimum power output of the car engine needed to move the car from the bottom to the top of the incline. **[4 marks]**

d) From the top of the incline, the road continues downwards in a straight line. Going downhill, the driver decides to save fuel. He switches off the engine and allows the car to move freely down the hill. The car descends to a height of 0.30 km in a distance of 6.4 km before leveling out.

i) Calculate the acceleration of the car down the incline. **[5 marks]**

ii) Calculate the speed of the car at the bottom of the incline. **[3 marks]**

iii) In fact, for the last few hundred metres of its journey down the hill, the car travels at constant speed. State the value of the frictional force acting on the car whilst it is moving at constant speed. **[2 marks]**

continued

e) A small lump of ice (a hailstone) at 0°C falls to the Earth's surface. When the hailstone hits the surface, all of the kinetic energy of the hailstone is transferred to thermal energy in the ice.

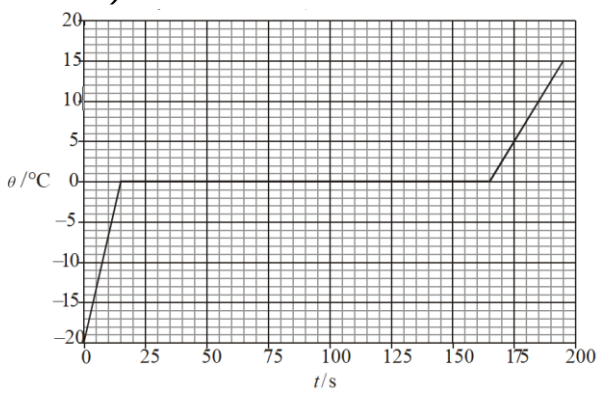
i) Calculate the minimum speed of the hailstone so that it just melts when it hits the surface. The specific latent heat of fusion of ice is 340 kJ kg^{-1}.
[3 marks]

(ii) By reference to your answer in (i), suggest whether hailstones are likely to melt on hitting the Earth's surface. **[2 marks]**

Q.2 (25 Marks)

Answer each of the following questions.

a) Consider the situation of ice inside a calorimeter. Thermal energy is supplied to the ice at a constant rate. To ensure that all the ice is at the same temperature, it is continually stirred. The temperature of the contents of the calorimeter is recorded every 15 seconds. *(Uncertainties in the measured quantities are not shown.)*



i) On the graph above, which data point on the graph indicates all the ice has just melted. **[1 mark]**

ii) Explain, with reference to the energy of the molecules, the constant temperature region of the graph. **[3 marks]**

Given that the mass of ice was 0.25 kg, the specific heat capacity of water is 4200 J. kg^{-1} K^{-1} and data from the graph:

iii) Deduce that energy is supplied to the ice at the rate of about 530 W.
[3 marks]

iv) Calculate the specific heat capacity of ice. **[3 marks]**

v) Calculate the specific latent heat of fusion of ice. **[2 marks]**

continued

b) Outline how a temperature scale is constructed. **[2 marks]**

c) Discuss why even an accurate thermometer may affect the reliability of a temperature reading. **[2 marks]**

d) Define specific heat capacity. **[2 marks]**

e) A surveyor uses a steel measuring tape that is exactly 50.000 m at a temperature of 20 °C.

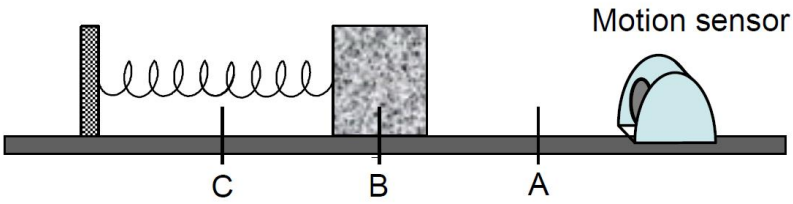
i) What is the length on a hot summer day when the temperature is 35 °C? ($\alpha_{steel} = 1.2\times10^{-5}\ K^{-1}$) **[4 mark]**

ii) On this day, when the tape reads 35.794 m, what is the true distance? **[3 marks]**

Q.3 (25 Marks)

Answer each of the following questions.

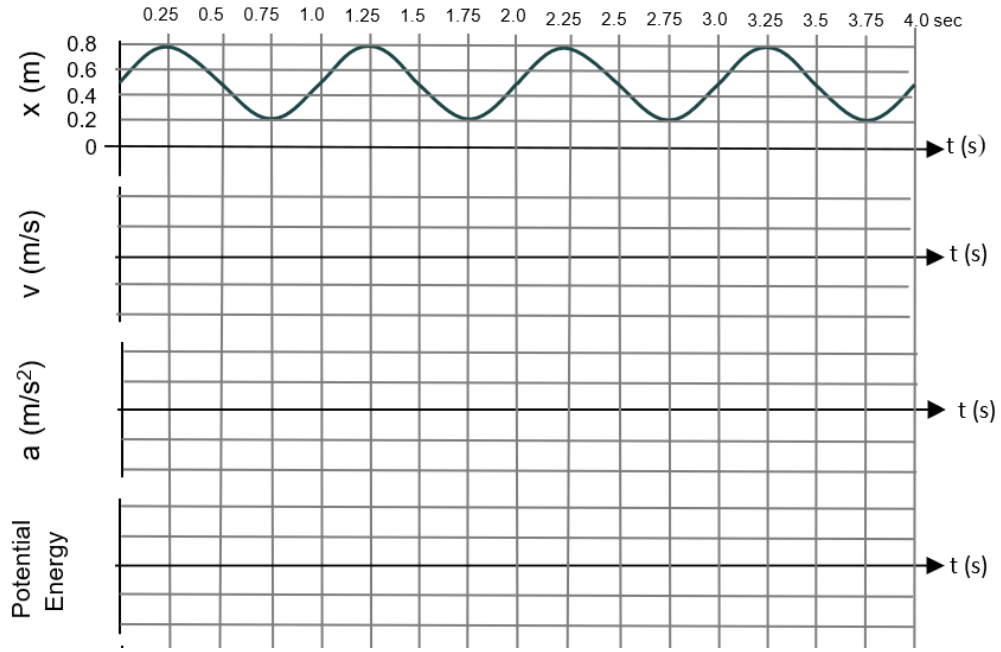
a) Consider the following situation



The diagram above shows a 2 kg block attached to a Hookean spring on a frictionless surface. The block experiences no net force when it is at position B. When the block is to the left of point B the spring pushes it to the right. When the block is to the right of point B, the spring pulls it to the left.

The mass is pulled to the left from point B to point A and released. The block then oscillates between positions A and C. A motion sensor placed to the right of position A gathers position-time data for the oscillating block. The position vs. time graph below describes the motion of this system for four cycles.

continued



i) What is the period of oscillation for this system? **[1 mark]**

ii) What is the frequency of this oscillating system? **[1 mark]**

iii) What is the amplitude of vibration of this system? **[1 mark]**

iv) Determine the spring constant of the spring. **[2 marks]**

v) Complete sketches for the other graphs shown based on the position vs. time graph on your answer sheet. Label maxima and minima with numerical values on the axes.
Show all the necessary calculations to label the graphs. **[11 marks]**

b) A particle oscillates with SHM according to the equation

$$x = 5\cos\left(2\pi t + {}^{\pi}/_{4}\right)\ meter.$$

At t = 1.5 s, calculate the:

i) Displacement of the particle. **[1 mark]**

ii) Velocity of the particle. **[2 marks]**

iii) Acceleration of the particle. **[2 marks]**

continued

c) A block of mass weighing 1 kg is fastened to a spring. The spring has a string constant of 50 N/m. The block is pulled to a distance of x =10 cm from its equilibrium position at x =0 cm on a frictionless surface from rest at t =0 s.
Calculate:

i) The velocity of the block at the distance of 5 cm. **[2 marks]**

ii) The kinetic energy of the block. **[2 marks]**

iii) The potential energy. **[2 marks]**

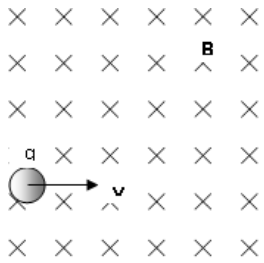
Q.4 (25 Marks)

Answer each of the following questions.

a) Two identical conducting spheres, fixed in place, attract each other with an electrostatic force of 0.108 N when separated by 50.0 cm, center-to-center. The spheres are then connected by a thin conducting wire. When the wire is removed, the spheres repel each other with an electrostatic force of 0.36 N.

Calculate the initial charges on the spheres. **[11 marks]**

b) A proton enters a magnetic field **B** which is directed into the page. The proton has a charge $+q$ and a velocity, v, which is directed to the right, and enters the magnetic field perpendicularly.



Calculate:

i) The magnitude and direction of the initial force acting on the proton. **[2 marks]**

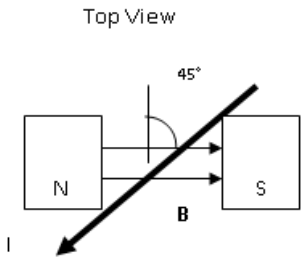
ii) The subsequent path of the proton in the magnetic field. **[2 marks]**

iii) The radius of the path of the proton. **[2 marks]**

continued

iv) The magnitude and direction of an electric field that would cause the proton to continue moving in a straight line. **[4 marks]**

c) A wire carrying a 20 A current and having a length L = 0.10 m is placed between the poles of a magnet at an angle of 45°, as shown. The magnetic field is uniform and has a value of 0.8 T.



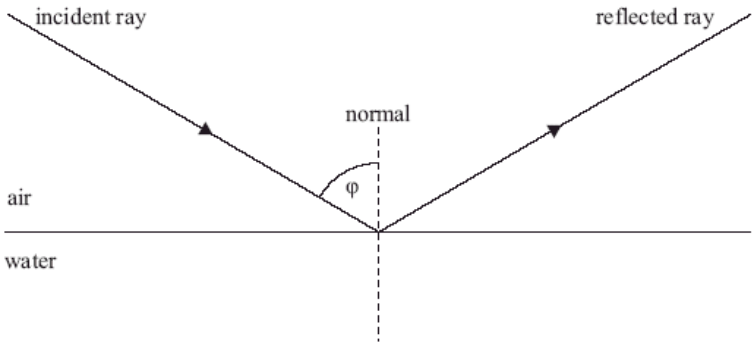
Determine the magnitude and direction of the magnetic force acting on the wire. **[4 marks]**

Q.5 (25 Marks)

Answer each of the following questions.

a) State what is meant by polarized light. **[1 mark]**

b) A ray of light is incident on a lake's surface. The angle of incidence is φ.



The reflected light is completely polarized horizontally. The refractive index of water is *n*.

i) On your answer sheet, sketch the diagram above and indicate the direction of the refracted ray. **[1 mark]**

ii) Use the diagram to deduce the relationship between φ and n. **[3 marks]**

continued

iii) If the refractive index of the water, n = is 1.3, calculate the value of φ.

[1 mark]

c) State one way in which a standing wave differs from a travelling wave. **[1 mark]**

d) An organ pipe of length, L is closed at one end.

Using diagrams, draw a representation of the displacement of the air in the pipe when the frequency of the note emitted by the pipe is the

i) fundamental (first harmonic) frequency f_1. **[1 mark]**

ii) second harmonic frequency f_2. **[1 mark]**

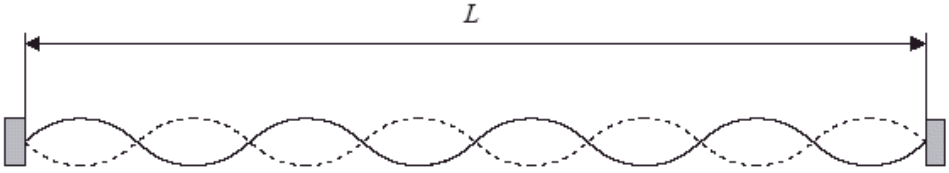
iii) Use your answer to (ii) to deduce an expression for the ratio $\frac{f_1}{f_2}$. **[3 marks]**

iv) State, in terms of the boundary conditions of the standing waves that can be formed in the pipe, the reason why the ratio of the higher frequencies of the harmonics to that of the fundamental must always be an integer number.

[1 mark]

v) An organ pipe that is open at one end has the same fundamental frequency as the string in part (i). The speed of sound in air is 330 m/s. Determine the length of the pipe. **[2 marks]**

e) The diagram, below, represents a standing wave of wavelength λ set up on a string of length L. The string is fixed at both ends.



i) For the standing wave state the relationship between λ and L.

[1 mark]

ii) On your answer sheet, sketch the standing wave and label, on the diagram, two antinodes where the string is vibrating in phase. Label the antinodes with the letter A. **[2 marks]**

f) The standing wave has wavelength λ and frequency f. State and explain, with respect to a standing wave, what is represented by the product $f\lambda$.

[3 marks]

continued

g) A string is attached between two rigid supports and is made to vibrate at its fundamental frequency (first harmonic) *f*.

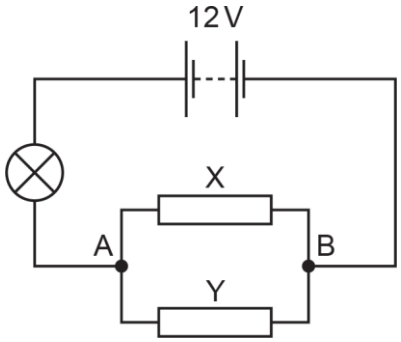
The diagram shows the displacement of the string at t = 0.

i) On your answer sheet sketch the displacement of the string at time $t = \frac{1}{4f}$ and $t = \frac{1}{2f}$ **[2 marks]**

ii) The distance between the supports is 1.0 m. A wave in the string travels at a speed of 240 m/s. Calculate the frequency of the vibration of the string. **[2 marks]**

Q.6 (25 Marks)
Answer each of the following questions.

(a) A 12V battery is connected in series to a 24 W lamp and to a parallel pair of identical resistors X and Y. The diagram shows the circuit.



The 24 W lamp lights at normal brightness when the potential difference (p.d.) across it is 6.0 V. The lamp is at normal brightness.

i) Calculate resistance of the lamp. **[3 marks]**

ii) Determine the p.d. between A and B. **[1 mark]**

iii) The combined resistance of the parallel pair of identical resistors X and Y, **[1 mark]**

(iii) The resistance of X. **[2 marks]**

(iv) Resistor X is removed from the circuit in the diagram.
Explain why the lamp becomes dimmer. **[2 marks]**

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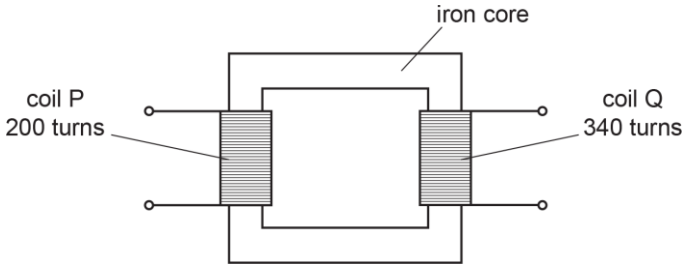
(b) The diagram shows a transformer that consists of two coils P and Q, and an iron core.

There are 200 turns on coil P and 340 turns on coil Q. A 4.0 V a.c. power



supply is connected to coil P.

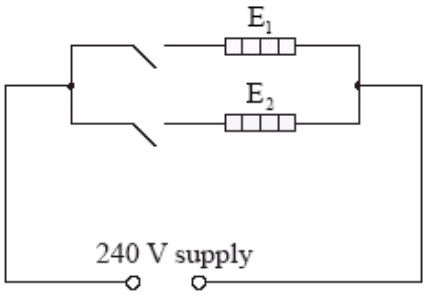
i) Explain why there is a voltage between the two terminals of coil Q. **[3 marks]**

ii) Explain why the core of the transformer is made of soft iron. **[1 mark]**

iii) Calculate the voltage between the two terminals of coil Q. **[2 marks]**

iv) A heater is connected to coil Q. The current in the heater is 3.5 A. The transformer is 100% efficient. Calculate the current in coil P. **[2 marks]**

(c) The diagram shows a horizontal wire PQ placed in the gap between the N pole and the S pole of a magnet.



Element E_1 is made from wire that has a cross-sectional area of 6.8×10^{-8} m^2. The resistivity of the wire at the operating temperature of the element is 1.1×10^{-6} Ωm.

i) The total length of wire is 4.5 m. Show that the resistance of E_1 is 73 Ω. **[1 mark]**

ii) Calculate the power output of E_1 with only this element connected to the supply. **[2 marks]**

iii) Element E_2 is made of wire of the same cross-section and material as E_1. The length of wire used to make E_2 is 1.5 m. Determine the total power

continued

output when both E_1 and E_2 are connected to the supply. **[3 marks]**

iv) With reference to the power output, explain why it would be inappropriate to connect the heating elements in series. **[2 marks]**

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