MINISTRY OF EDUCATION

M 102

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Solutions and Markscheme in Physics

I. Numerical Problems

Problem 1 (5. 27.)
A model train is travelling around a circular track of radius 1m at a speed of 0.4 m/s. Find the period of revolution and its angular speed.

Data: $R = 1\text{m}$, $v_{\text{tangential}} = 0.4\ \frac{\text{m}}{\text{s}}$

The angular speed is $\omega = \frac{v_{\text{tangential}}}{R} = 0.4\ \frac{1}{\text{s}}$. **5 marks**

The period of revolution is $T = \frac{2\pi}{\omega} = 15.7\frac{\text{m}}{\text{s}}$. **5 marks**

Subtotal: 10 marks

Problem 2 (3.25.)
A railway freight wagon with a mass of 30 tonnes travelling at a velocity of 12 m/s catches up with another freight wagon with a mass of 20 tonnes travelling at a velocity of 7 m/s and collides into it. The two wagons move on coupled together.

a) What will be the momenta and velocities of the two wagons after the collision?
b) How much will the kinetic energy of the system change?

Data: $m_1 = 30\text{ t} = 3\cdot10^4\text{ kg}$; $v_1 = 12\frac{\text{m}}{\text{s}}$; $m_2 = 20\text{ t} = 2\cdot10^4\text{ kg}$; $v_2 = 7\text{ m/s}$.

a) If the forces retarding the motion are neglected, the sum of the momenta after the collision equals the initial sum of momenta:

$$\Sigma p = (m_1 + m_2)\, v = m_1v_1 + m_2v_2. = 5\cdot10^5\text{ kg}\cdot\frac{\text{m}}{\text{s}},$$ **5 marks**

where v is the common velocity of the coupled wagon. Hence

$$v = \frac{\Sigma p}{m_1 + m_2} = 10\frac{\text{m}}{\text{s}}.$$ **5 marks**

b) The kinetic energy before the collision is $E_1 = ½(m_1v_1^2 + m_2v_2^2)$.
The kinetic energy after the collision is $E_2 = ½(m_1 + m_2)\, v^2$.
The change in kinetic energy is $\Delta E = E_2 - E_1 = -\ 150\text{ kJ}$ **5 marks**

Subtotal: 15 marks

Problem 3 (15.43.)
An immersion heater is connected to a voltage of 230V. Determine its resistance, given that it takes 10 minutes to raise the temperature of 1kg of water by 20°C.

(The specific heat of water is $4.2\cdot10^3\ \frac{\text{J}}{\text{kg K}}$. Ignore all losses of energy.)

Data: $U = 230\text{V}$; $m = 1\text{kg}$; $t = 10\text{ min} = 600\text{s}$; $\Delta T = 20°\text{C}$; $c_{water} = 4.2 \cdot 10^3 \dfrac{\text{J}}{\text{kg K}}$.

The heat supplied by the immersion heater during the 10 minutes is

$$W = \frac{U^2}{R}t.$$ **5 marks**

That work is used for heating the water by 20°C. **5 marks**

$$\frac{U^2}{R}t = c_{water} m \Delta T.$$

Hence

$$R = \frac{U^2 t}{c_{water} m \Delta T} = 378\Omega.$$ **5 marks**

Subtotal: 15 marks

Problem 4 (10.82.)

A cylinder in a workshop contains gas at a pressure of 6 MPa and a temperature of 27 °C.

a) What will be the pressure of the remaining gas in the cylinder if 20% of the gas is used up, and the temperature stays constant?

b) What will be the pressure if the used cylinder is transferred from the workshop to a storeroom where the temperature is 7 °C?

Data: $p_1 = 6$ MPa; $T_1 = (273 + 27)$ K $= 300$ K; $T_2 = T_1$;
$T_3 = (273 + 7)$ K $= 280$ K; $\text{R} = 8.31 \dfrac{\text{J}}{\text{K} \cdot \text{mol}}$.

a) Consider the form $p \cdot V = \dfrac{m}{M} \cdot R \cdot T$ of the universal gas equation. The variables V, T and M are constant during the process, therefore

$$\frac{p}{m} = \frac{R \cdot T}{V \cdot M} = \text{constant, that is}$$

$$\frac{p_1}{m_1} = \frac{p_2}{m_2}.$$ **10 marks**

Hence

$$p_2 = \frac{m_2}{m_1} \cdot p_1$$

The mass of the gas remaining is $m_2 = 0.8 \cdot m_1$,
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$$p_2 = 0.8\, p_1 = 4.8 \text{ MPa}.$$ **5 marks**

b) Now the mass and volume of the enclosed gas are constant. In a process of this kind, pressure is proportional to temperature:

$$p_3 = \frac{T_3}{T_2} \cdot p_2 = 4.48 \text{ MPa}.$$ **5 marks**

Subtotal: 20 marks

II. Analysis of an Experiment

Problem 5 (8. 28.)

An object hanging from a helical spring is oscillating harmonically.

a) We want to determine the angular frequency of the oscillation.. The materials available are a stopwatch, and a ruler with a millimetre scale on it. Explain how the measurement is carried out and how the measured quantities are used to determine the angular frequency.

b) How can the measured oscillation period be checked, given the mass of the oscillating object used int he experiment?

a) The total time of several oscillations is measured. The period of one oscillation is calculated, and the average of the data obtained is used for calculating the angular speed from $\omega = \frac{2\pi}{T}$. **10 marks**

b) The period is determined by using the formula $T = 2\pi\sqrt{\frac{m}{D}}$. The only unknown quantity here is D but that can also be determined by measurement: the object of known mass m is hung on the unstretched spring, and the elongation of the spring is measured in the new equilibrium position. Let that be x_0. Hence the spring constant can be calculated: $D = \frac{mg}{x_o}$.

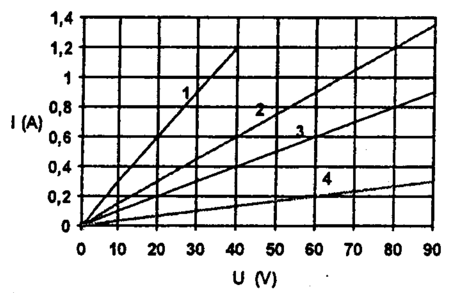
The measured value of the period is checked by substituting the values of m and D.

10 marks.

Subtotal: 20 marks

Problem 6 (15.19.)

The graph below shows the currents flowing in four different pieces of wire against the voltage applied d between the ends.



a) Explain the theoretical law that can be used to determine the resistances of the wires from the data of the graphs.

b) Using the data of the graphs, list the resistances of the wires in increasing order.

a) Ohm's law states that the voltage between two points of a metallic conductor is directly proportional to the current flowing through the conductor. Their ratio is constant. That constant is called the resistance of the conductor, denoted by R. By definition, $R = \frac{U}{I}$, and its unit is $1\ \Omega = 1\frac{\text{V}}{\text{A}}$. **10 marks**

b) The graph shows, for example, that for $U = 40$ V

$I_1 > I_2 > I_3 > I_4$, that is $R_1 < R_2 < R_3 < R_4$ **10 marks**

Subtotal: 20 marks

EVALUATION

A total of 100 marks can be received on this paper.
From 0 to 19 inclusive: fail (1); 70 and above: excellent (5).

If there is a very good reason, the teacher may depart from the lower boundary of the excellent grade (70 marks) and the upper boundary of the fail grade (19 marks) by at most ±3 marks.
The setting of the other grade boundaries is left to the teacher's professional judgment.

In the case of calculation errors, deduct marks only where the error occurs. If the error is carried forward in calculations, the candidate should receive the indicated number of marks for all the following steps that are principally correct.

A correct solution different from the one given in the markscheme should receive full marks. The individual steps should be marked proportionately.

Evaluate only one correct solution of each problem.