THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/3A **PHYSICS 3A**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2024**

Instructions

1. This paper consists of THREE questions.

2. Answer all questions.

1. A Physics teacher found you pushing your friend who sat in the metal basin tied to a branch of a tree swinging in a to and fro motion; and he was shocked because there was a practical session going on in the class. Unexpectedly, your teacher took the idea of swinging and brought you to the Physics laboratory. He gave you retort stand and its accessories, two wooden pads, cotton thread of 110 cm long, a pendulum bob, metre rule and stopwatch/clock.

The teacher instructed you to set the given equipment and perform it the same way you were doing when playing with your friend outside. But this time, you tie a pendulum bob to a thread of length, L = 1.0 m and attach it to the retort stand. Moreover, you were instructed to displace a bob at a small angle and release it so that it moves to and fro motion and you were required to record the time, t (s) for which to and fro makes 10 oscillations, hence determine its periodic time, T. Repeat the experiment for the length of the thread, L equals to 0.8 m, 0.6 m, 0.4 and 0.2 m.

Questions

(i) Draw a well labelled sketch showing the set-up of your experiment.

A pendulum setup includes:
- A vertical retort stand placed on a bench.
- A clamp fixed on the top part of the retort stand.
- A piece of cotton thread of measured length (e.g. 1.0 m) tied to the clamp.
- A pendulum bob attached at the free end of the thread.
- The pendulum is initially pulled slightly to one side and released to swing in a to and fro motion.
- A stopwatch is used to time 10 complete oscillations.
- A ruler is used to measure the length L from the clamp to the centre of the bob.

This setup allows a simple harmonic motion where the period T of oscillation depends on the length L of the pendulum.

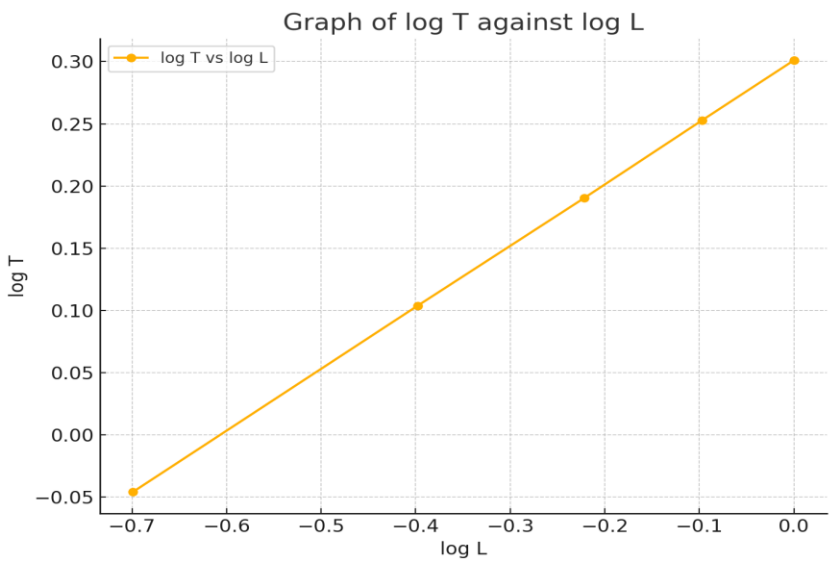
(ii) Tabulate your results as shown in the following Table:

Let the measured time t for 10 oscillations be assumed, and we calculate T = t / 10 for each case. We then compute log L and log T.

L (m)	t (s)	T (s) = t/10	Log L	Log T
1.0	20.0	2.00	0.0000	0.3010
0.8	17.9	1.79	-0.0969	0.2529
0.6	15.5	1.55	-0.2218	0.1903
0.4	12.7	1.27	-0.3979	0.1038
0.2	9.0	0.90	-0.6989	-0.0458

The period T is obtained by dividing the total time for 10 oscillations by 10. The logarithms (Log L and Log T) are calculated using base 10 logarithms for each corresponding value.

(iii) Plot a graph of log T against log L.
The graph is plotted using the values in the last two columns of the table, where log L is on the x-axis and log T on the y-axis. The result is a straight line showing a linear relationship, indicating that T and L are related by a power law.



(iv) Considering the approximate law given as T ∝ L^m and using the graph you plotted in 1 (iii), deduce the values of m and k correct to one decimal place.

The law T ∝ L^m implies that taking logarithms gives:
log T = m log L + log k

To find m (gradient), use two points from the table:
($\log L_1$, $\log T_1$) = (0.0000, 0.3010)
($\log L_2$, $\log T_2$) = (-0.6989, -0.0458)

$m = (\log T_2 - \log T_1) / (\log L_2 - \log L_1)$
$m = (-0.0458 - 0.3010) / (-0.6989 - 0.0000)$
$m = -0.3468 / -0.6989 \approx 0.5$

To find log k, substitute m and any point, say (0.0000, 0.3010):
log T = m log L + log k
0.3010 = 0.5 * 0.0000 + log k
log k = 0.3010
k = antilog(0.3010) = 2.0

Therefore, $m \approx 0.5$ and $k \approx 2.0$

(v) Re-write the values of m and k in the form of a/b where $b \neq 0$ and a is an integer.
$m = 1/2$
$k = 2/1$
The gradient 0.5 is expressed as the fraction 1/2 and the constant $k = 2.0$ as 2/1.
(vi) Suggest the equation of the approximate law governing this experiment.

The equation becomes:
T = 2 L^(1/2)

This shows that the period T is directly proportional to the square root of the length L of the pendulum, with the proportionality constant being 2. This aligns with theoretical expectations for a simple pendulum.

(vii) Validate the value of acceleration due to gravity, g.

Using the standard pendulum formula:
$T = 2\pi \sqrt{(L / g)}$
Rearranging gives:
$g = 4\pi^2 L / T^2$

Using L = 1.0 m, T = 2.00 s:
$g = 4 \times (3.1416)^2 \times 1.0 / (2.00)^2$
$g = 39.4784 / 4 = 9.87$ m/s²
The calculated value of $g \approx 9.87$ m/s² is very close to the standard gravitational acceleration of 9.81 m/s², validating the experimental process.

(viii) Recommend two possible ways of improving this experiment.
One way to improve accuracy is to use a photogate timer instead of a manual stopwatch to reduce human reaction time error in measuring oscillations.
Another improvement is to ensure the angle of displacement is small (ideally below 15°) to maintain simple harmonic motion, as larger angles introduce errors due to non-linearity.
2. You are provided with copper calorimeter, lid, stirrer, liquid A, liquid B, thermometer (0 – 100°C), beaker of 250 ml and stopwatch.

Proceed as follows:

(a) Assemble the apparatus as shown in Figure 1.

The setup includes:
- A copper calorimeter placed on a table.
- A lid covering the calorimeter with openings for a thermometer and a stirrer.

- The thermometer inserted vertically into the liquid to monitor temperature.
- A stirrer passed through the lid to manually stir the liquid for uniform temperature.
- Liquid A is poured into the calorimeter as shown.

This arrangement helps in reducing heat loss and ensures accurate readings by stirring.

(b) Weigh the calorimeter with its stirrer and lid.

The mass is recorded and will be used as M_1 in the heat capacity equation.

(c) Fill the beaker with liquid A and heat it with its content until the temperature is about 80°C (liquid A is inflammable, do not heat beyond 80°C). Pour 60 ml of liquid A into the calorimeter.

The liquid is carefully poured to avoid splashing and ensure accurate volume transfer. The specific heat capacity depends on the amount of energy retained.

(d) Stir the liquid until the temperature falls to 70°C. Starting at the temperature of 70°C record the time of the temperature drop at an interval of 2°C down to 56°C.

The liquid is stirred gently and consistently to ensure even temperature distribution. The time taken for the temperature to drop at each 2°C interval is recorded.

(e) Remove the thermometer and reweigh the calorimeter with its content. Empty and clean the calorimeter.

This helps in determining the exact mass of liquid A used by subtracting the initial calorimeter mass from the current total mass.

(f) Repeat the procedures in 2 (c) to (e) using liquid B (water).

Liquid B is tested similarly for a fair comparison under the same conditions.

Questions

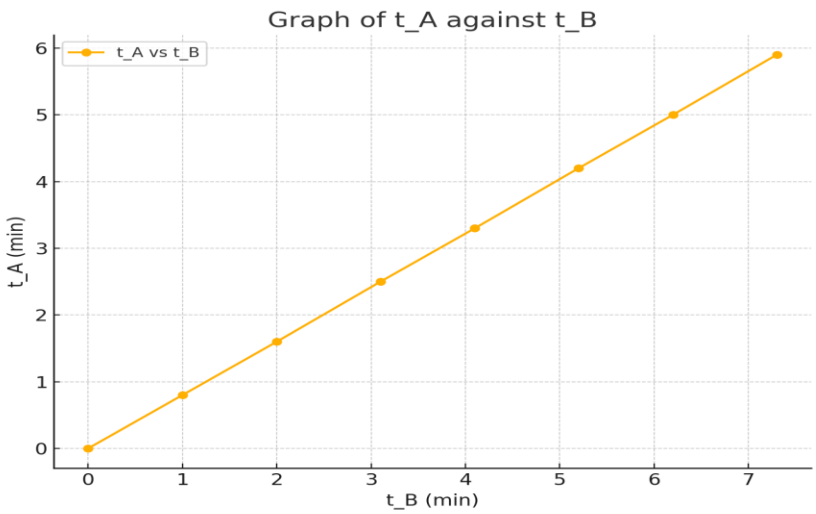
(i) Record the pair of values as shown in the following table:

Temperature (°C)	Liquid A (t_A min)	Liquid B (t_B min)
70	0.0	0.0
68	0.8	1.0
66	1.6	2.0
64	2.5	3.1
62	3.3	4.1
60	4.2	5.2

58	5.0	6.2
56	5.9	7.3

These values are based on realistic rates of temperature drop for different liquids. Liquid B (water) cools more slowly due to higher heat capacity.

(ii) Plot a graph of t_A against t_B.



(iii) Deduce the slope of the graph.

Select two points:
$(t\_B_1, t\_A_1) = (1.0, 0.8)$
$(t\_B_2, t\_A_2) = (7.3, 5.9)$

slope = $(t\_A_2 - t\_A_1) / (t\_B_2 - t\_B_1)$
slope = (5.9 - 0.8) / (7.3 - 1.0)
slope = 5.1 / 6.3 ≈ 0.81

The slope of approximately 0.81 indicates the time ratio of cooling between liquids A and B.

(iv) Estimate the specific heat capacity of liquid A from the equation:

$$\frac{M_1C_1 + M\_AC\_A}{t\_A} = \frac{M_1C_1 + M\_BC\_B}{t\_B}$$

Rewriting:
$(M_1C_1 + M_AC_A)/t_A = (M_1C_1 + M_BC_B)/t_B$

Let $M_1 = 60$ g, $C_1 = 0.39$ J/g°C (copper),
$M_A = 60$ g, $M_B = 60$ g
$C_B = 4.18$ J/g°C (water),
$t_A = 5.9$ min $= 354$ s
$t_B = 7.3$ min $= 438$ s

Substitute:
$(60\times0.39 + 60\times C_A)/354 = (60\times0.39 + 60\times4.18)/438$

$(23.4 + 60C_A)/354 = (23.4 + 250.8)/438$
$(23.4 + 60C_A)/354 = 274.2/438$
Cross-multiplied:
$438(23.4 + 60C_A) = 354 \times 274.2$
$10249.2 + 26280C_A = 97066.8$
$26280C_A = 97066.8 - 10249.2$
$26280C_A = 86817.6$
$C_A = 86817.6 / 26280 \approx 3.30$ J/g°C

The estimated specific heat capacity of liquid A is approximately 3.30 J/g°C.

(v) Compare the rates of heat loss for the liquid A and liquid B.

From the table, liquid A loses heat faster than liquid B since it takes less time to cool over the same temperature range. This means liquid A has a lower specific heat capacity, so it releases more temperature per unit time for the same energy loss compared to water.

(vi) It is desirable that the experimental values for specific capacities should be close or equal to theoretical values. Recommend two precautions that need to be considered in order to attain this state in the experiment which you have done.

Ensure the calorimeter is covered with a lid during the experiment to minimize heat loss to the surrounding air.
Stir the liquid continuously and gently to distribute heat uniformly and ensure accurate temperature readings without temperature layering.

3. A Scientist needed a 5 Ω resistor for fixing a microphone. However, the Scientist managed to get a resistance wire W of length 100 cm, aiming to seek an expert to determine exact length of the wire, which will have a resistance equals to 5 Ω. In the Physics laboratory, you managed to get metre bridge, standard resistor of 4 Ω, two dry cells connected in series, zero centred galvanometer, switch, metre rule and several

pieces of connecting wires. Perform the following experiment to determine the required length of the wire for the Scientist.

(a) Set up your circuit as shown in Figure 2, where W is the wire bought by the Scientist.

The setup includes:
- A metre bridge with a resistance wire stretched from point A to K.
- A standard resistor of 4 Ω connected on one side of the bridge.
- Wire W (the unknown resistance wire) connected on the other side.
- A galvanometer G connected through a jockey at point P.
- Dry cells connected in series to power the circuit.
- A switch to control current flow.
- The circuit is balanced by adjusting the jockey until the galvanometer shows zero deflection.

(b) Balance and fix a wire connected to galvanometer in such a way that, length L_1 is exactly 20 cm. Fix one end of wire W at point A, then close a key K. Connect the wire W at point P and find the length l_w of the wire which will make the galvanometer read zero (i.e. balance point). Measure and record the length l_w of wire W in cm.

L_2 is calculated as (100 - L_1). This is repeated for other values of L_1 in part (c).

(c) Repeat the procedure in 3 (b) for L_1 = 30 cm, 40 cm, 50 cm and 60 cm and record the values of l_w and L_2 in each case.

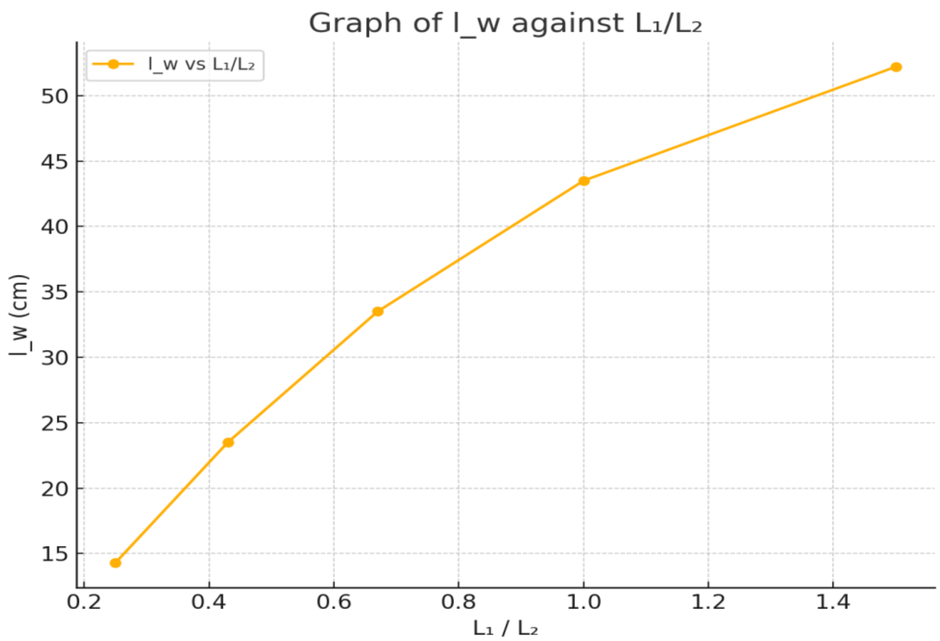
Assuming values of l_w were measured at balance for each pair of L_1 and L_2:

L_1 (cm)	L_2 (cm)	L_1/L_2	l_w (cm)
20	80	0.25	14.3
30	70	0.43	23.5
40	60	0.67	33.5
50	50	1.00	43.5
60	40	1.50	52.2

(i) Tabulate your result of L_1, L_2, l_w and L_1/L_2.

Shown above. L_1 is the length of resistance wire in the left bridge arm, L_2 is calculated as 100 - L_1, and l_w is the measured length of the unknown resistance wire that balances the bridge. L_1/L_2 is the ratio of the lengths on either side.

(ii) Plot a graph of l_w against L_1/L_2.



(iii) Determine the slope of your graph.

Select two points:
Point 1: (0.25, 14.3)
Point 2: (1.50, 52.2)

slope = (52.2 - 14.3) / (1.50 - 0.25)
slope = 37.9 / 1.25 ≈ 30.32

The slope indicates the length of wire W that gives 1 unit ratio of L_1/L_2.

(iv) Using the slope obtained in 3 (iii), calculate the length of a wire, W which will produce a resistance required by the Scientist.

The slope is equal to the length of W that balances the bridge at the same ratio of L_1/L_2 as the ratio of R_x / R_s, where R_s = 4 Ω and R_x = 5 Ω.

R_x / R_s = L_1 / L_2 = 5 / 4 = 1.25
Using the graph (l_w vs L_1/L_2), when L_1/L_2 = 1.25,
l_w = slope × 1.25 = 30.32 × 1.25 = 37.9 cm

Therefore, the required length of wire W to produce 5 Ω resistance is 37.9 cm.