L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2026 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	I
DATE:	16th May 2026
TIME:	9:00 a.m. to 12:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81$ m s^{-2} unless otherwise stated.

SECTION A

Attempt all EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1. When a thin capillary tube is inserted into a liquid, the liquid either climbs above or dips below the surrounding fluid level. This phenomenon is known as *capillarity*. The height h to which the liquid rises (or falls) in a tube of radius r is given by

$$h = \frac{2\gamma cos\theta}{\rho g r}$$

where γ is the surface tension of the liquid, ρ is the density of the liquid, θ is the angle between the liquid and the surface, and g is the acceleration due to gravity.

a. Express the unit of surface tension γ in terms of its base units. (5)

b. Classify each of the quantities h, ρ and r as a scalar or vector. (2)

c. Explain how an equation can be said to be homogeneous but physically incorrect. Using the equation above, give an example of a homogeneous, physically incorrect equation. (2,1)

(Total: 10 marks)

2. a. Circuit A has two bulbs in series and Circuit B has two bulbs in parallel.

i. Which circuit will have brighter bulbs if they are powered by identical power sources? Explain your answer. (2)

ii. Explain what happens when one bulb burns out in both circuits. (2)

b. A greenhouse is equipped with a thermistor to monitor the internal temperature. The thermistor is connected in series with a fixed resistor across a power supply. When low temperatures are reached, a heater in the greenhouse is switched on to obtain the optimal temperature for plants to grow.

i. Describe how the total resistance changes with temperature for a negative temperature coefficient thermistor. (1)

ii. Explain how the voltage drop across the thermistor changes as the greenhouse temperature decreases. (2)

iii. Derive an equation for the voltage drop across the thermistor in terms of the supply voltage V_s, the resistance of the thermistor R_t, and the fixed resistance in the circuit R_f. (3)

(Total: 10 marks)

Please turn the page.

3. Consider Rutherford's alpha scattering experiment:
   a. i. Explain what alpha particles are. (1)
      ii. Sketch a basic diagram of the experimental apparatus, labelling each element clearly. (2)
      iii. Describe how the observations made in the experiment can be utilised for providing a model of the structure of atoms. (2)
   b. The two most abundant stable isotopes of Calcium are $^{40}_{20}\mathrm{Ca}$ and $^{44}_{20}\mathrm{Ca}$.
      i. What is the difference between these two isotopes? (1)
      ii. Given the radius of a nucleon to be $R_0 = 1.05 \times 10^{-15}$ m, what is the radius of the nucleus of $^{40}_{20}\mathrm{Ca}$? (2)
      iii. Assuming that alpha particles with kinetic energy of 5 MeV are incident at a scattering angle of $\theta = 0$ on a thin foil of $^{40}_{20}\mathrm{Ca}$ atoms, what is the distance of the closest approach of the alpha particles to the nucleus of the atoms? (2)

(Total: 10 marks)

4. Three different materials were tested under applied stress, and their responses to increasing strain were measured. The resulting stress–strain is given in Figure 1.

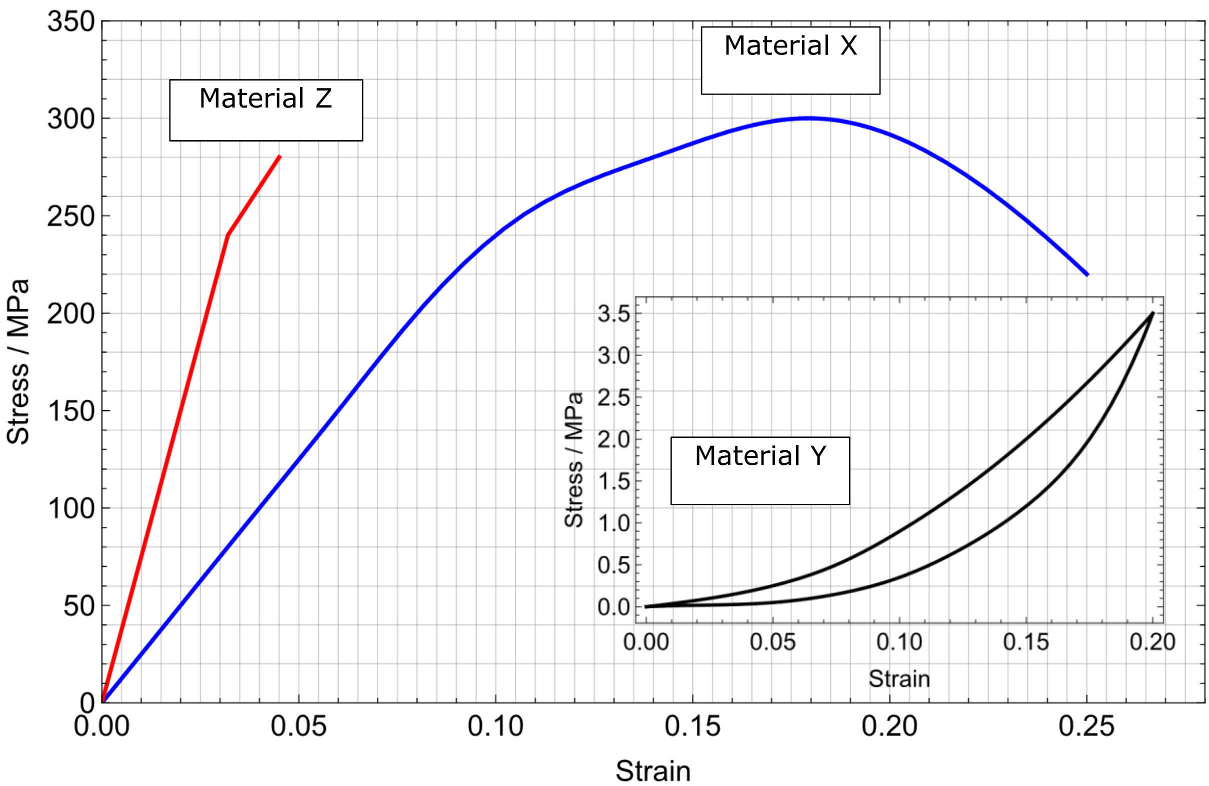

Figure 1

   a. Determine which material is brittle, ductile, and a rubber band. (3)
   b. Material Y exhibits a certain property when subjected to loading and unloading. State the name of this property and what it represents. (2)
   c. State the coordinates where the ultimate tensile stress occurs for the ductile material. (1)
   d. Calculate the Young's modulus of Material X. (2)
   e. Explain the difference between elastic behaviour and plastic behaviour. (2)

(Total: 10 marks)

5. An object of mass $m = 10$ kg is launched with initial velocity $v_0 = 50$ m s^{-1} at an angle of $\theta = 45°$ with respect to the ground and lands on a hill at height $h = 20$ m. Neglect the effects of air resistance.
   a. Calculate the mechanical work done by the gravitational force. (2)
   b. State the principle of conservation of energy. (2)
   c. Calculate the speed at which the object hits the hill. (2)
   d. Assuming that the object hits the hill after 3.6 s, what is the rate at which work has been done by the gravitational force? (2)
   e. If the object were to land on a spring with elastic constant $k = 150$ kN m^{-1}, what would be the maximum possible compression of the spring? You may assume that the object's final velocity is parallel to the spring. (2)

(Total: 10 marks)

6. A car battery with e.m.f. E supplies current to a starter motor of resistance R. When the starter motor is switched on, it draws a current I. Due to internal resistance r, the battery's terminal p.d. V_T drops. The following values were recorded.

E	V_T	I
12.7 V	12 V	140 A

   a. Define terminal p.d. (1)
   b. Calculate the internal resistance of the car battery. (2)
   c. Calculate the power dissipated inside the internal resistance. (2)
   d. The battery is replaced with one with a higher internal resistance, and the car is struggling to start. Explain why this happens. (2)
   e. Calculate the current drawn by the starter motor to start if the internal resistance is given the maximum value of $r_{\text{max}} = 6$ mΩ. Assume that R and E remain the same. (3)

(Total: 10 marks)

7. Consider a disc of radius $R = 50$ cm and mass $m = 12$ kg rotating around its central axis, which is perpendicular to the plane of the disc.
   a. Which of the following distributions of mass of the disc has the highest moment of inertia? (i) the mass is uniformly distributed throughout the disc; (ii) the mass is mainly concentrated around the centre of the disc; or (iii) the mass is mainly concentrated around the border of the disc. Justify your answer. (2)
   b. Assuming that the disc rotates with an angular velocity of 4 rad s^{-1}, calculate
      i. the angular momentum of a disc having moment of inertia 1.5 kg m^2; (1)
      ii. the tangential velocity of a point of the disc on the rim; and (1)
      iii. the work that needs to be performed to bring the rotating disc to rest. (2)
   c. i. Define what is meant by rolling without slipping. (1)
      ii. In the case of a rolling wheel of radius R, what is the relation between the speed of the center of mass of the wheel and the angular velocity of the wheel's rotation around its center? (1)
      iii. How is the relation found in part (c)(ii) related to the fact that the frictional force does not perform any work? (2)

(Total: 10 marks)

Please turn the page.

8. a. Using the principles of conservation of charge and energy, explain how currents and potential differences behave at junctions and around loops in an electrical circuit. (2)
   b. State the magnitude and direction of the current through each resistor in Figure 2. (8)

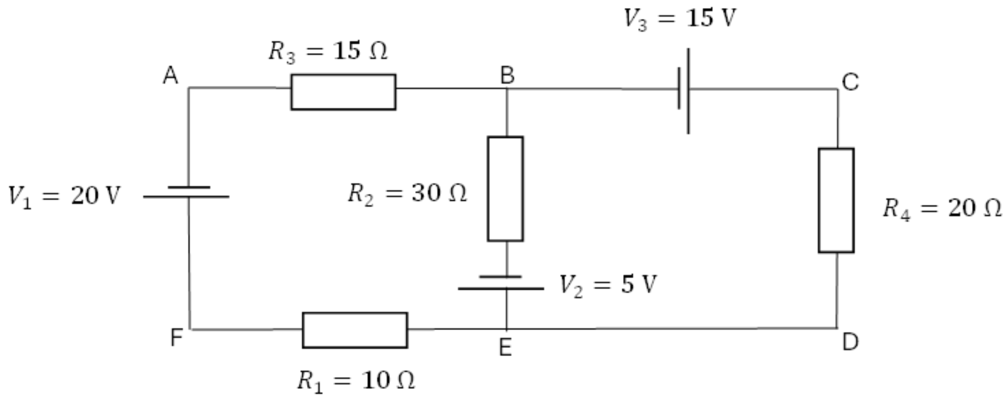

Figure 2

(Total: 10 marks)

SECTION B

Attempt any FOUR questions from this section. Each question carries 20 marks. This section carries 50% of the total marks for this paper.

9. This question is about electric circuits.
   a. A lab technician is presented with a set of wires made of different unknown materials. By determining the temperature coefficient of each wire, she can label them correctly.
      i. Define the temperature coefficient of resistance α. Provide an appropriate equation. (2)
      ii. Draw an experimental setup to determine α. Clearly label the apparatus. (4)
      iii. Outline a procedure to determine α. (3)
      iv. She determines that one of the wires must be some type of semiconductor. How can this be determined from the value of α. (1)
      v. Draw an I-V characteristic plot of a semiconductor. (2)
   b. Two identical wires have a length of 0.5 m and a cross-sectional area of 1 mm^2. The temperature coefficient of each wire is $\alpha = 0.004$ °C^{-1} and their resistivity is 2.4×10^{-3} Ω m at 20°C.
      i. Calculate the resistance of a single wire at 20°C. (2)
      ii. The two wires are connected in parallel across a p.d. of 12 V. The temperature of the wires rises to 35°C. Calculate the total resistance at this temperature. (4)
      iii. Suggest **TWO** possible changes to the apparatus and/or setup in part (b)(ii) to increase the total resistance from that obtained in (b)(ii). (2)

(Total: 20 marks)

10. As shown in Figure 3, a firefighter of mass $M = 80$ kg stands in equilibrium in the middle of a ladder of mass $m = 20$ kg. The centre of gravity of the ladder is at point O, that is, at $1/3$ of the length, L, of the ladder from the pavement. The ladder rests on the pavement at point A and leans against a wall at point B. The distance between A and the vertical wall is $a = 5$ m and between B and the floor $h = 12$ m. There is a frictional force between the ladder and the pavement, whereas the vertical wall is frictionless.

a. i. Define the centre of gravity. (2)

ii. State two conditions that have to be fulfilled for a body to be in equilibrium. (2)

iii. Draw a free body diagram of the forces acting on the system composed of the firefighter and ladder. (5)

iv. Calculate:
- the force exerted by the wall on the ladder;
- the force exerted by the pavement on the ladder;
- the magnitude of the frictional force. (7)

b. Assume now that the maximum frictional force between the ladder and the pavement is 300 N. What is the maximum height to which the firefighter can climb along the ladder before the ladder slips? (4)

(Total: 20 marks)

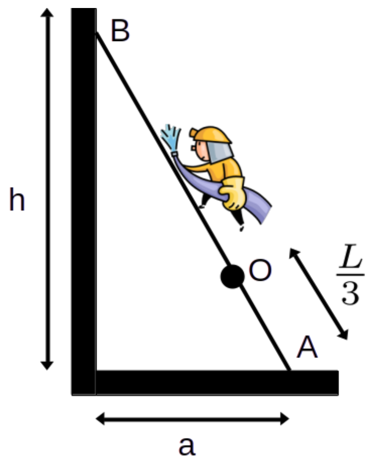

Figure 3

11. a. Consider a copper wire of length $L = 5$ m and uniform radius $r = 1.2$ mm. The wire conducts a current of $I = 5$ A. The electron number density is 8.5×10^{28} m^{-3} for copper. The electron charge is $e = 1.6 \times 10^{-19}$ C. When the copper wire is connected to a battery, free electrons acquire a small net velocity along the wire called *drift velocity.*

i. Derive the equation

$$v = \frac{I}{n\,A\,e}.$$

Clearly describe **each** step and define any quantities introduced. (4)

ii. Calculate the drift velocity. (1)

iii. Estimate the average time taken for a single electron to travel from one end of the wire to another. (1)

iv. By referring to your answers in parts (a)(ii) and (a)(iii), explain why the current is observed to flow as soon as the circuit is closed. (2)

v. The end of the wire is now slightly pinched (the radius is made smaller). Assuming there is no change in current, would the drift velocity at the end be the same, faster or slower? Give a reason for your answer. (2)

vi. Use the equation in part (a)(i) to illustrate the difference between conductors, insulators and semiconductors. (3)

b. A pure silicon sample undergoes a *compensation doping* where it is first doped with phosphorus (donor) atoms and later doped with boron (acceptor) atoms at room temperature.

i. State the definition of donor and acceptor. (2)

ii. Draw a labelled band level diagram showing both contributions from phosphorus and boron. (3)

iii. The sample is heated from room temperature to a higher temperature. Explain what happens to the number of charge carriers for both doping atoms. (2)

(Total: 20 marks)

Please turn the page.

12. In Figure 4, two particles of mass $m_1 = 4$ kg and $m_2 = 10$ kg are initially stationary at the origin and at $d = 20.5$ m, respectively, along the x-axis. At time $t = 0$ s, a constant force, parallel to the x-axis, is applied to each particle as shown in Figure 4. The magnitudes of the two forces are: $F_1 = 12$ N on m_1, acting for 2 s, and $F_2 = 10$ N on m_2, acting for 3 s.

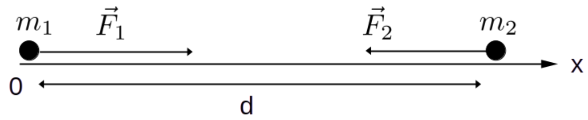

Figure 4

a. i. Define the term impulse and specify the meaning of each symbol used. (2)
ii. Calculate the velocity along the x-axis of the two masses when the respective forces cease to act on the masses. (2)
iii. Determine the position along the x-axis of the two masses when the respective forces cease to act on the masses. (2)
iv. Calculate the position along the x-axes where the two masses collide. (4)
v. Draw a distance (displacement)-time graph for the mass m_1 from $t = 0$ s until the time of collision, clearly reporting the numerical values on both axes. (2)

b. Assume now that the two masses undergo a perfectly elastic collision.
i. Which quantities, if any, are conserved in a perfectly elastic collision and which ones, if any, in an inelastic collision? (2)
ii. Calculate the velocities of the two masses after the collision. (6)

(Total: 20 marks)

13. a. State Hooke's law. (1)

b. A student is asked to determine the energy stored in a long, thin steel wire which has been stretched to a known length.
i. Draw a diagram to show the apparatus used to carry out this investigation. (3)
ii. List the procedure to carry out this experiment. (2)
iii. Provide a labelled graph of the results. (2)
iv. State the physical quantities represented by the gradient and the area under the graph. (2)
v. Write down the equation that is used to determine the energy stored. (1)
vi. This experiment assumes Hooke's law. State **ONE** precaution that should be taken during the experiment to ensure this assumption can be made. (1)

c. The student is now provided with two springs connected in series, with spring constants of $k_1 = 150$ N m^{-1} and $k_2 = 275$ N m^{-1}. The spring system is laid on a smooth horizontal table and one end is fixed. A mass of 1 kg is attached to the free end of the spring system. The mass is then displaced 5 cm to the right and projected with a velocity $v_0 = 0.4$ m s^{-1} to the right. Assume no energy is lost to friction or air resistance.
i. Calculate the total spring constant. (1)
ii. Determine the total energy of the system. (2)
iii. Calculate the maximum extension of the combined springs during the ensuing oscillations. (3)
iv. Determine the maximum extension experienced by the spring whose spring constant is k_1. (2)

(Total: 20 marks)

14. A hockey puck of mass $m = 5.0$ kg moves on a frictionless, circular track of radius $R = 120$ m with constant speed $v = 80$ km h^{-1}.
    a. Derive the expression $a = \frac{v^2}{R}$ for the centripetal acceleration. (2)
    b. How long does it take for the puck to complete one full circle? (2)
    c. Draw a diagram showing the velocity and the acceleration vectors $\vec{v}$ and $\vec{a}$, respectively, on the circular path. (2)
    d. Figure 5 shows a cross section of the circular path, with θ denoting the banking angle.
        i. Draw **all** the forces acting on the hockey puck when it performs the uniform circular motion. (2)
        ii. What is the value of the banking angle such that the hockey puck moves with uniform circular motion? (3)

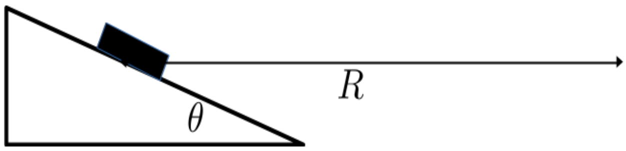

Figure 5

        iii. What is the moment of inertia of the hockey puck evaluated with respect to the centre of the circular track? (3)
    e. Assume now that a braking mechanism is activated. The brake exerts a force of $F_f = 40$ N, acting in the opposite direction of the tangential velocity vector. Neglect that the hockey puck slides on the track, that is, assume that it performs a circular motion with the same radius $R = 120$ m until it comes to a complete halt.
        i. Derive the time after which the hockey puck will stop once the braking mechanism is activated. (4)
        ii. Derive the linear distance, that is, the total length travelled along the circular track, and the angular distance, that is, the total angle travelled along the circular track, that the hockey puck travels before coming to a complete halt once the braking mechanism is activated. (1,1)

(Total: 20 marks)

15. A lithium (Li) atom has atomic number $Z = 3$. The two electrons located in the inner energy shells of an atom are called core electrons. The outermost, valence, electron has the energy level diagram shown in Figure 6.
    a. i. Define the terms ground state energy, excited energy state, and electron ionisation energy for an atom. (3)
        ii. What are the values of the ground state energy, of the first excited state energy and of the ionisation energy for the valence electron? (3)
        iii. Explain why the energy levels are assigned a negative value. (3)
        iv. A valence electron, initially in its ground state level, absorbs light and jumps to the third excited level. Calculate the wavelength of the incident light. (3)

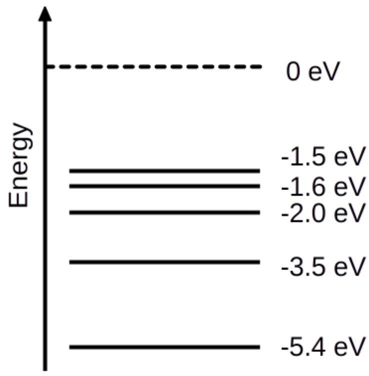

Figure 6

    b. i. Describe the Rutherford model of the atom and explain why this model is unstable. (3)
        ii. State the de Broglie equation, clearly specifying the meaning of each symbol used and how it is related to the wave-like behaviour of electrons. (3)
        iii. Using the de Broglie equation, discuss how an electron in an atom can be described as a standing wave. (2)

(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2026 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	II
DATE:	16th May 2026
TIME:	4:00 p.m. to 7:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity g = 9.81 m s^{-2} **unless otherwise stated.**

SECTION A
Attempt all EIGHT questions in this section. This section carries 50% of the total marks for this paper.

1. Astronomers have discovered an exoplanet of mass 6.0×10^{24} kg orbiting a star in the Andromeda galaxy having a rotational period of 18 hours about its own axis. The radial distance measured from the exoplanet's centre to the pole is 5.5×10^6 m while that to the equator is 5.73×10^6 m.
   a. Define what is meant by gravitational field strength. (1)
   b. State **ONE** other factor which influences the value of the gravitational field strength at the surface of a planet. (1)
   c. Calculate the force acting on a mass of 1 kg on the surface of the exoplanet at:
      i. the poles of the exoplanet; (2)
      ii. the equator of the exoplanet. (4)
   d. Describe briefly what the effect on the values obtained in part (c) would be if the planet had a shorter rotational period. (1,1)

[Newton's Gravitational Constant = 6.67×10^{-11} m^3 kg^{-1} s^{-2}]

(Total: 10 marks)

2. A well-insulated calorimeter contains 150 g of warm water at some initial temperature, θ_1. An 18 g ice cube at 0 °C was added and left to melt completely. During this process, the water's temperature was measured using a thermocouple, which uses electrical resistance as a thermometric property. The initial and final thermocouple readings were 112.5 Ω and 107.0 Ω respectively. The thermocouple had been previously calibrated at the ice and steam points having resistance readings X_0 = 90.0 Ω and X_{100} = 126.0 Ω respectively.
   a. Define what is meant by thermometric property. (1)
   b. Calculate the initial and final water temperatures. (2)
   c. Define what is meant by latent heat of fusion. (1)
   d. Determine the latent heat of fusion of ice. (4)
   e. State **TWO** reasons why the value obtained in (d) may **not** be accurate. (2)

[Specific Heat Capacity of Water = 4200 J kg^{-1} K^{-1}]

(Total: 10 marks)

Please turn the page.

3. A solar water heater system uses solar radiation to heat water as it is being passed through black-painted copper pipes. The water is then stored in an insulated tank for later use. The pipes can be treated as a blackbody.
   a. Define what is a blackbody. (1)
   b. On the same axes, sketch a graph of radiation intensity against wavelength for the radiation emitted by the copper pipes at temperatures (i) 300 K, (ii) 400 K. (3)
   c. What is the method of heat transfer that causes the water to heat up due to the copper pipes? Explain in detail how it arises. (3)
   d. The pipes are replaced by another black-painted material which has a lower thermal conductivity.
      i. Explain what thermal conductivity of a material describes. (1)
      ii. Explain how this physical change influences the efficiency of the solar water heater. (2)

(Total: 10 marks)

4. Astronomers can determine the composition and the distance of a star relative to Earth by observing its emitted spectral lines. Hydrogen, which is a gas mainly present in stars, has a set of prominent spectral lines in the visible region as shown in Figure 1. Consider two stars, Star A and Star B, whose observed spectral lines are also shown in Figure 1.

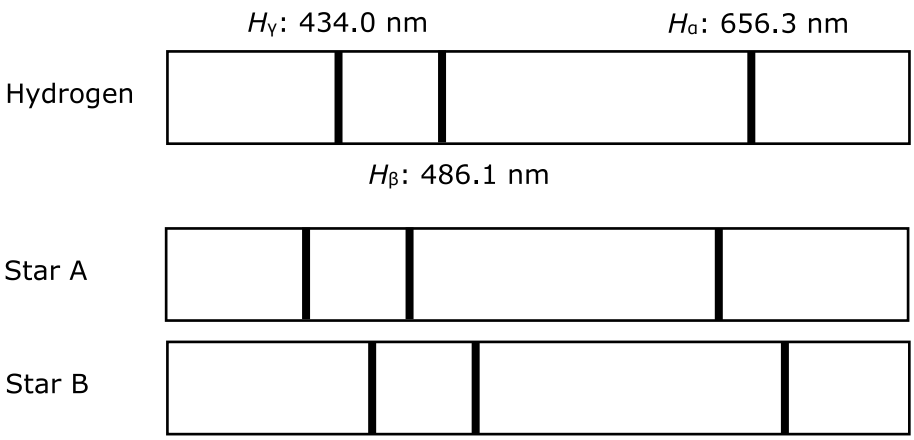

Figure 1

   a. Define and distinguish between a star and a galaxy. (2)
   b. Identify whether each of Star A and Star B is receding from or approaching Earth. Give a reason for your answer. (3)

A third star, Star C, has an observed H_α-line at 662 nm.

   c. Calculate the velocity of Star C relative to Earth. (3)
   d. Explain, referring to relevant laws, what this observation tells us about the behaviour of the Universe. (2)

(Total: 10 marks)

5. A physicist places a small conductive sphere, referred to as charge *A,* in an ideal vacuum chamber. The sphere carries a negative charge of exactly -5×10^{-6} C. For calculation purposes, all spheres are to be considered point charges. Take the permittivity of free space to be $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}.

   a. Sketch the electric field due to charge *A*. (1)

   b. A second sphere, referred to as charge *B,* has a positive charge of $+2\times10^{-6}$ C, and is fixed at some distance x away from charge *A*. Using an ideal electrostatic fieldmeter, the physicist determines that the electric field strength at charge *B* is $|E| \approx 4.5\times10^{6}$ V m^{-1}. Calculate the distance x. (3)

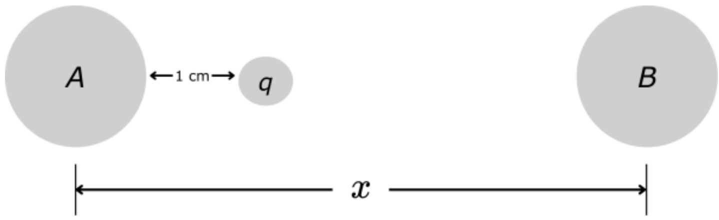

Figure 2

   c. A small test charge *q* with charge $q=1\times10^{-6}$ C is added on the line joining charges *A* and *B*, 1 cm away from charge *A* as shown in Figure 2.

      i. State Coulomb's law of electrostatics mathematically, defining **all** terms. (2)

      ii. The physicist now embeds all spheres in silicone oil with a dielectric constant of $\varepsilon_r = 2.7$, while retaining the same setup shown in Figure 2. Calculate the magnitude of the resultant force on charge *q,* indicating its direction. (4)

(Total: 10 marks)

6. A long straight copper wire, *A,* carries a current I_1 = 18.0 A into the paper plane.

   a. State the expression for the magnetic flux density *B* at some distance *r* from the wire. Hence, calculate the magnetic flux density 10 cm away from the wire. Assume that $\mu_0 = 4\pi\times10^{-7}$ H m^{-1}. (2)

   b. Another long straight wire, *B,* is placed parallel to wire A at a distance *r* = 9 mm, and carrying a current I_2 = 10 A in the same direction as I_1. Using the equation for the force per unit length between two wires, calculate the force per metre between the two wires. (3)

   c. Assume the two parallel wires now carry an equal current. On a copy of Figure 3 (planar view of the two wires), sketch the magnetic field pattern around the wires, clearly indicating its direction. (3)

Figure 3

   d. Define the ampere in terms of the force between two long parallel conductors. (2)

(Total: 10 marks)

Please turn the page.

7. a. Describe an experiment used to determine the speed of sound in air using progressive waves. The description should include:
   i. a labelled diagram; (3)
   ii. methodology and analysis, including a description of any calculations used. (3)

   b. Define longitudinal and transverse waves, providing **ONE** example of each. (4)

(Total: 10 marks)

8. a. A 1 m long string with a mass of 50 g is stretched with a tension of 125 N.
   i. What is the velocity of a wave on this string? (2)
   ii. What are the **TWO** lowest frequencies that can form standing waves on the string? (2)

   b. Two lasers, S_1 and S_2, are ideal coherent point sources of monochromatic light. Both sources emit green light of wavelength λ = 530 nm, and are placed 0.3 mm apart.
   i. Explain what is meant by two coherent sources. (1)
   ii. A screen is placed at some distance D away, and an interference pattern was recorded. If the separation between the first and third fringe was found to be d = 7 mm, find the distance D. (3)
   iii. The two green lasers are replaced with two identical infrared lasers. Explain how the fringe spacing changes and give a reason for this change. (2)

(Total: 10 marks)

Section B

Attempt any FOUR questions from this section. Each question carries 20 marks. This section carries 50% of the total marks for this paper.

9. Guitar strings are designed to vibrate at their fundamental frequency to play various musical notes. Consider a guitar string, fixed at both ends, which is plucked at its midpoint. When the string is plucked, the displacement at the plucking point causes a vibrational motion which can be modelled as simple harmonic motion (SHM). The displacement-time graph for the plucking point is shown in Figure 4.

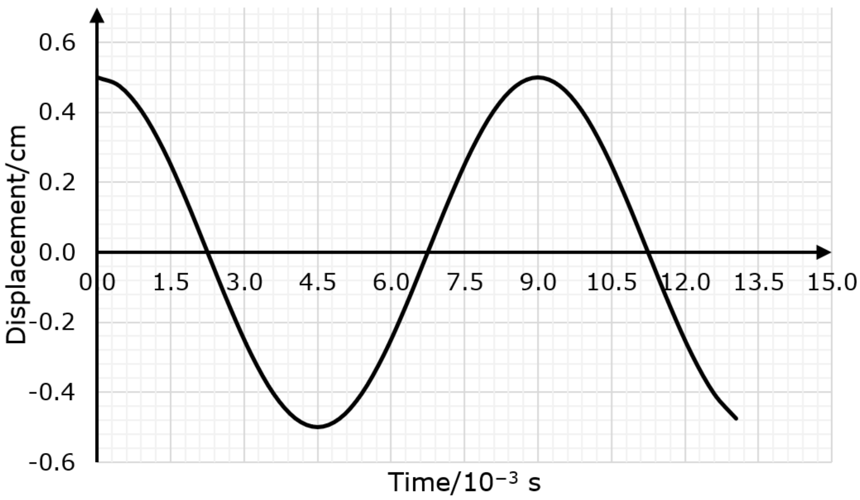

Figure 4

   a. State the conditions required for a system to undergo SHM. (2)

   b. For the small string element at the plucking point, determine the:
   i. amplitude; (1)
   ii. angular frequency; (2)
   iii. maximum instantaneous speed; (2)
   iv. instantaneous speed when the element reaches half its amplitude; (2)
   v. maximum instantaneous acceleration. (2)

c. Sketch a velocity-time graph representing one full oscillation. Include any known values. (2)

d. Sketch an acceleration-time graph representing one full oscillation. Include any known values. (2)

After the guitar string is plucked, the sound slowly dissipates until the musical note is no longer heard.

e. Identify the type of damping which causes this effect, giving reasons for your answer. (3)

f. Sketch a displacement-time graph illustrating the damping stated in part (e). (2)

(Total: 20 marks)

10. The piston-flywheel setup shown in Figure 5 can be used to demonstrate the basic function of an engine. It consists of an ideal gas enclosed in an insulated cylinder which is heated to allow it to expand and contract. This allows a vertically free moving piston to move, causing the connected flywheel to rotate. The gas undergoes a cyclic process ABCDA shown in Figure 6. The gas has an index $\gamma = 1.4$.

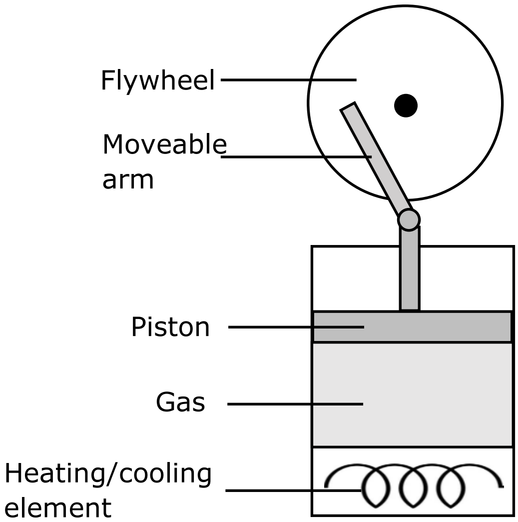

Figure 5

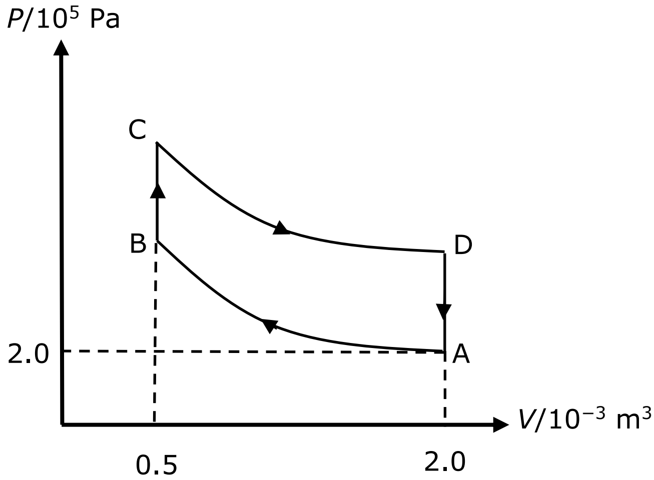

Figure 6

a. State **TWO** conditions for the gas to behave ideally. (2)

b. Describe the thermodynamic process occurring through each part of the cycle given that the processes AB and CD occur under no heat transfer. (4)

c. Determine the gas pressure when it reaches B. (3)

d. Given $P = \frac{1}{3}\rho\langle c^2\rangle$, where ρ is the gas density and $\langle c^2\rangle$ is the mean square speed of the gas particles, show that $\langle c^2\rangle = \frac{3kT}{m}$, where m is the mass of a gas particle, T is the gas temperature, and k is Boltzmann's constant. (3)

e. Hence, discuss the changes to the mean square speed throughout the processes BC and CD. (2, 2)

f. What does the area enclosed in the PV graph represent and how does it relate to the motion of the flywheel? (2)

g. Discuss why this engine cannot operate at 100% efficiency. (2)

(Total: 20 marks)

Please turn the page.

11. A student wishes to carry out an experiment to investigate the thermal properties of air.
    a. Describe in detail an experiment that the student can perform to investigate how the volume of air changes with pressure under constant temperature conditions. Your description should include:
        i. a labelled diagram of the experimental setup; (3)
        ii. the procedure to carry out the experiment. (2)
    b. State the first law of thermodynamics, naming **each** variable appearing in the equation. (2)
    c. Discuss the changes, if any, for **each** of the listed variables when the gas:
        i. heats up isovolumetrically; (2)
        ii. compresses isothermally; (2)
        iii. expands adiabatically. (2)
    d. Sketch the *PV/T* against *P* graph for 1 mole of gas assuming the gas behaves ideally. Label any notable values in the graph. (3)

    The student then decides to investigate the thermal properties of a metal wire. At first, the wire is clamped at one end and pulled from the other end causing it to stretch within its elastic region. During stretching, 20 J of work is done on the wire, while 8 J is lost to the surroundings.

    e. Calculate the change in internal energy of the wire. Clearly state the convention used in deriving the result. (3)
    f. Hence, explain whether the wire experienced any changes to its temperature. (1)

(Total: 20 marks)

12. A homeowner decides to buy an induction hob for their kitchen. The hob makes use of a tightly wound coil of self-inductance 220 μH connected to a high-frequency 25 kHz 230 V RMS AC supply installed beneath a ceramic–glass surface as shown in Figure 7. When the electricity supply is on and a ferromagnetic pan is placed on the hob, it quickly heats up. The base of the ferromagnetic pan can be modelled as a conducting loop. The base of the pan and the inductive coil have a mutual inductance of 35 μH.

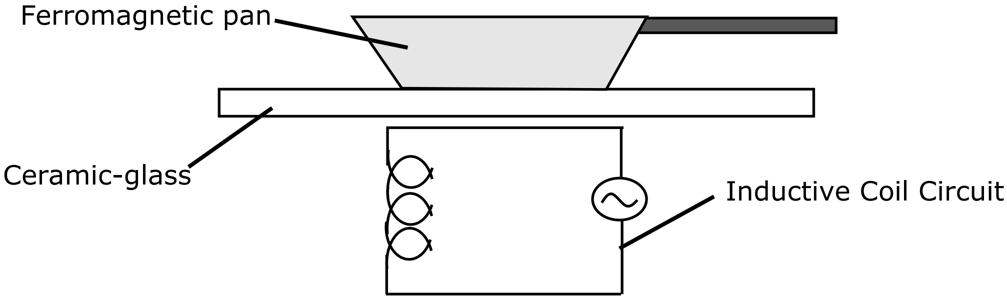

Figure 7

    a. Explain, by stating the relevant law, how an induction hob heats up the pan. (3)
    b. Explain why a copper pan does **not** heat up over an induction hob. (1)
    c. State **TWO** reasons why the ceramic-glass kitchen surface remains cold to touch. (2)
    d. The homeowner is undecided whether they should install a drawer containing metal cutlery just underneath the hob. Discuss, giving reasons, whether the metal cutlery would heat up. (2)
    e. Define and distinguish between self-inductance and mutual inductance. (2)

f. Calculate the coil's reactance. (2)

g. Hence, calculate the peak current, I_0, passing through the hob's coil. (3)

h. Given that the rate of change of current at a given instant is $\frac{dI}{dt} = I_0 \omega \cos(\omega t)$, calculate the peak emf induced in the hob's coil. (3)

i. Hence, calculate the peak emf induced in the ferromagnetic pan. (2)

(Total: 20 marks)

13. A student uses two perfectly circular metal plates to construct a parallel-plate capacitor with the aim of carrying out some measurements. Using a multimeter, the student finds that the capacitor has a capacitance of 194 nF.

a. List **all** factors that affect the capacitance of the parallel-plate capacitor. Write down the expression for the capacitance of a parallel-plate capacitor in terms of these factors. (4)

b. The student then proceeds to charge the same capacitor using a variable direct current (DC) power supply. As the potential difference *V* is slowly increased from 0 V to 18 V, the student takes readings of the charge *Q* stored on the capacitor through an electrometer, producing the graph shown in Figure 8. Determine the final energy stored in the capacitor. (3)

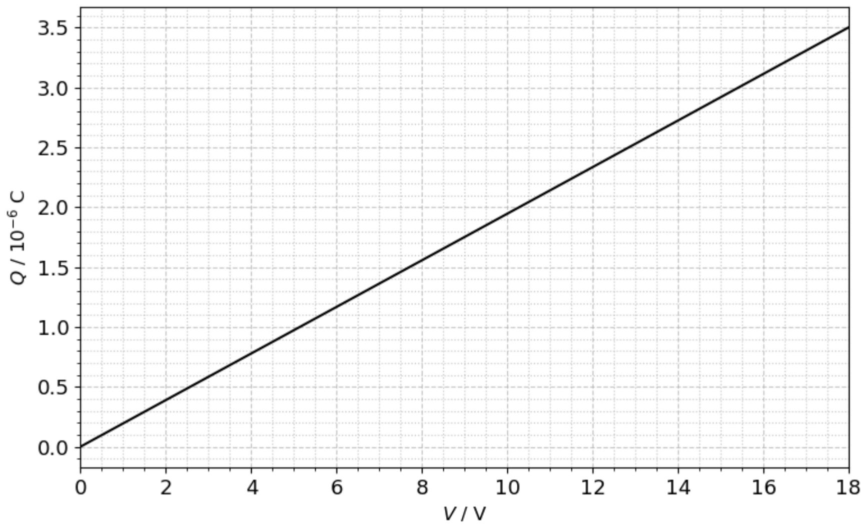

Figure 8

c. The capacitor is now fully charged to 18 V. The student connects the capacitor in series with a 100 kΩ resistor, and allows the capacitor to discharge through it.

i. Calculate the time taken for the potential difference across the capacitor to fall to 10% of its value. (4)

ii. Determine the charge remaining on the capacitor at this time. (2)

iii. Sketch a graph of charge stored in the capacitor against time during discharging, marking any notable values. (2)

d. The student is now wondering whether an electrolytic capacitor should be used instead of a parallel-plate capacitor.

i. Write down **ONE** advantage and **ONE** disadvantage of the electrolytic capacitor. (2)

ii. Describe in words how an electrolytic capacitor is constructed. (3)

(Total: 20 marks)

Please turn the page.

14. The lobby of a luxurious hotel has large glass panels and a prism-shaped crystal hanging from the ceiling. During the day, sunlight passes through the crystal, producing a spectrum of colours on the walls of the lobby.

a. Explain the process through which the prism produces the observed spectrum and name the physical phenomenon that is taking place. (4)

b. A person walks near a glass panel of refractive index $n = 1.55$. A light ray from the person strikes the plane glass surface at an angle of incidence of 40º.

i. Before travelling into the glass panel, the light ray was travelling through the air with a velocity of 3.0×10^8 m s^{-1}. Calculate the speed of light in the glass panel. (1)

ii. Calculate the angle of refraction as the light ray enters the glass panel. (2)

iii. Assuming the glass is 0.30 m thick, calculate the vertical distance difference d between the straight path the ray would have followed in air A, and its actual refracted path B, as it emerges from the glass, as shown in Figure 9. (4)

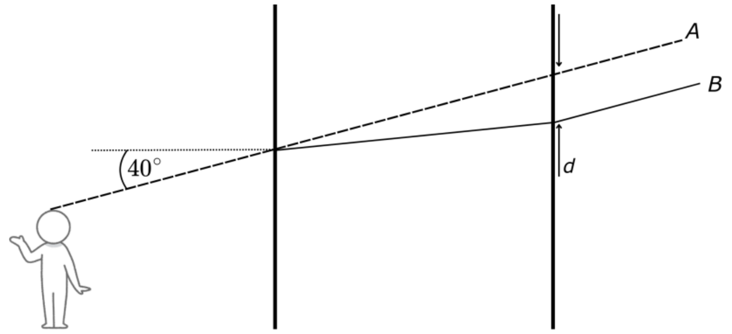

Figure 9

c. A technician is installing a security camera in the lobby. The security camera uses a thin converging lens, but the focal length f is not known to the technician. To calibrate the camera, the installer places a test photograph 2.8 m away from the lens. The camera forms a perfect sharp image of the photograph on its sensor, positioned 13 mm behind the lens.

i. Calculate the focal length of the lens. (2)

ii. Calculate the linear magnification, and state whether the image formed on the sensor is real or virtual, and upright or inverted. (2)

iii. Draw a ray diagram to show how the image is formed, clearly marking **all** notable values. (2)

d. A light source is located underwater in the koi pond outside the hotel lobby, where the water has a refractive index $n = 1.33$. A ray of light travels upwards and strikes the water-air surface. If the ray strikes the surface 47º to the normal, determine whether it undergoes total internal reflection or emerges into the air. Justify your answer. (3)

(Total: 20 marks)

15. A new security scanner at a biotech research facility uses a long solenoid of length 0.8 m to create a magnetic region for security verification tests. The solenoid has 2400 turns and carries a steady current of 2 A. Treat the interior of the solenoid as having a uniform horizontal magnetic field. Take $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}.

a. Define the magnetic flux density *B*, and the magnetic flux *φ,* clearly indicating what each term means. Calculate the magnetic flux density for the solenoid above. (4)

b. An ID card chip contains **ONE** small rectangular current loop, situated in the magnetic field as illustrated in Figure 10. The current loop has length *L* = *PS* = *QR* and width *d* = *PQ* = *SR.* Figure 11 shows a view of the setup from the top. The normal of the loop, N, is situated such that it makes an angle of θ with the direction of the magnetic field. The loop carries a steady current of I_l. (*Hint: The + symbol in figure 11 represents the current flowing into the paper, and the • symbol represents the current flowing out of the paper.*)

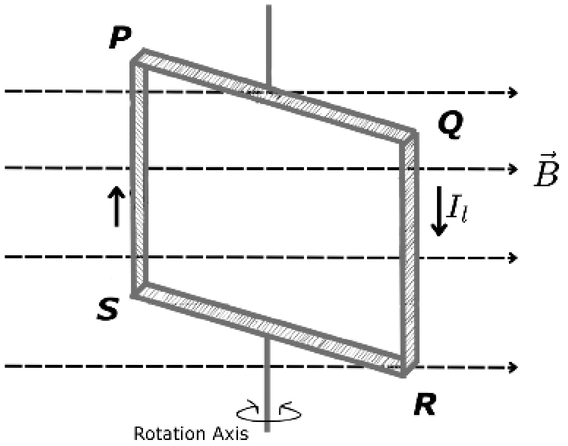

Figure 10

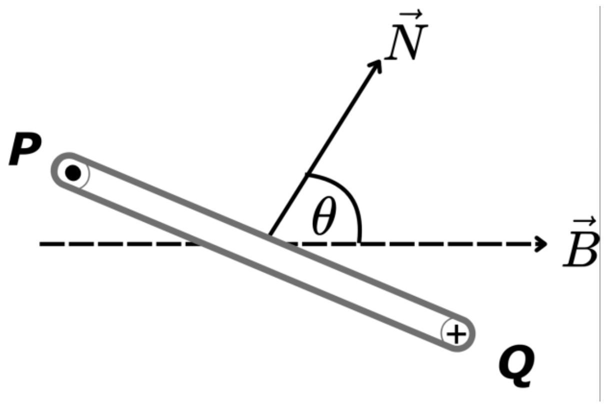

Figure 11

i. State the value of the angle between the normal to the loop and the direction of the magnetic field, *θ,* for which sides *PQ* and *SR* would experience zero magnetic force. (1)
ii. Determine whether the loop rotates clockwise or counterclockwise around the rotation axis (when viewed from the top of the setup, as shown in Figure 11). Explain how you arrived at your answer. (2)
iii. Show that the torque on the rectangular coil can be written as $T = B\,A\,I_l \sin\theta$. (5)

c. The current loop has dimensions *L* = 3.0 cm and *d* = 1.0 cm, and carries a steady current I_l = 12 mA. The card is held at a fixed orientation such that the normal to the loop makes an angle *θ* = 35º with the direction of the magnetic field inside the solenoid, as calculated in part (a). The scanner only triggers if the torque in this position reaches a threshold $T_{thresh} = 5.0 \times 10^{-5}$ N m. Determine whether the tag will trigger the scanner. (3)

d. A narrow beam of singly charged ions is shot through the centre of the solenoid perpendicular to the magnetic field with speed $v = 2.4\times10^{5}$ m s^{-1}. Each ion has a charge 1.60×10^{-19} C and a mass of 3.2×10^{-26} kg.
i. Calculate the radius of the circular path followed by the ions in the magnetic field calculated in part (a). (3)
ii. It is required to set the radius of the circular path to 0.05 m. To what value should the solenoid current *I be* changed to? (2)

(Total: 20 marks)

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2026 FIRST SESSION

SUBJECT:	**Physics**
PAPER NUMBER:	III - Practical
DATE:	2nd June 2026
TIME:	2 hours 5 minutes

Experiment: Static Deflection and Oscillations of a Wooden Beam

Apparatus: Wooden beam, metre ruler, small ruler, G-clamp, mass hanger, several masses and stopwatch.

Diagram:

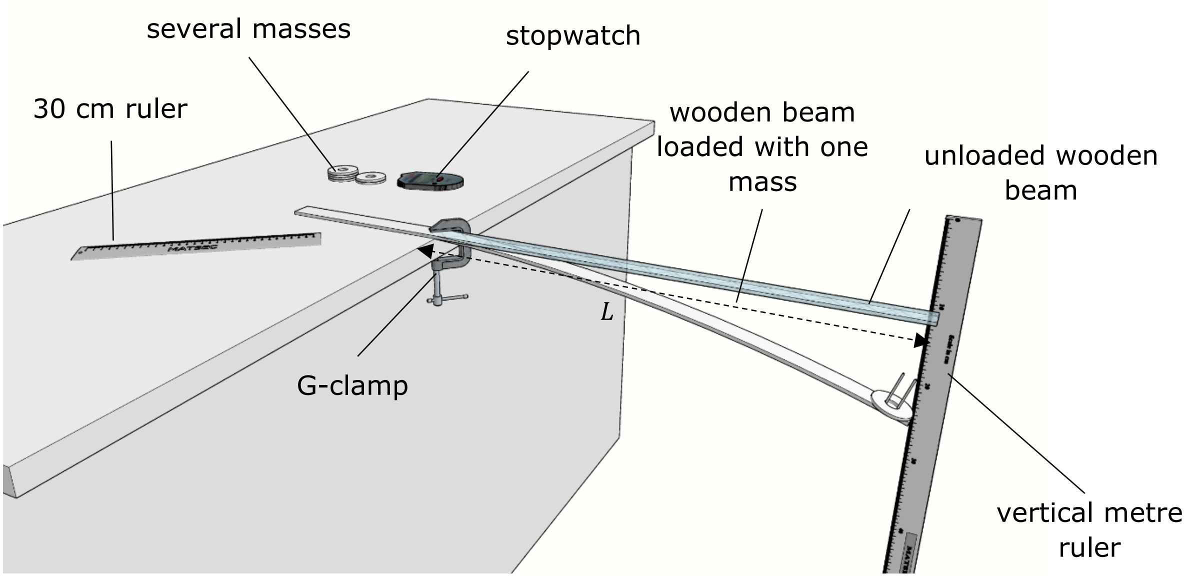

Figure 1: The experimental setup

Method – Part A:

1. A thin wooden beam is secured to the edge of the bench so that it acts as a cantilever as shown in Figure 1.

2. Using the metre ruler, measure the free length L of the wooden beam from the edge of the bench to the edge of the free end of the beam. $L =$ ___________m (1)

3. Using the small ruler, measure the width B and the thickness T of the beam at three different positions along the free length. Record the readings in Table 1 and calculate the average values. (7)

Table 1

Quantity	1st reading / m	2nd reading / m	3rd reading / m	Average / m
Width, B				
Thickness, T				

Please turn the page.

4. The free end of the wooden beam deflects downwards due to its own weight and any additional force applied to it, such as the force exerted by added masses.

5. With no masses attached to the wooden beam $(n = 0)$, place the metre ruler upright beside the free end of the beam, making sure that the 100 cm end of the ruler is touching the ground. Read the value on the ruler that is level with the bottom edge of the free end of the beam and record this initial reading as r_0. Record this value in the row corresponding to $n = 0$ in Table 2. (1)

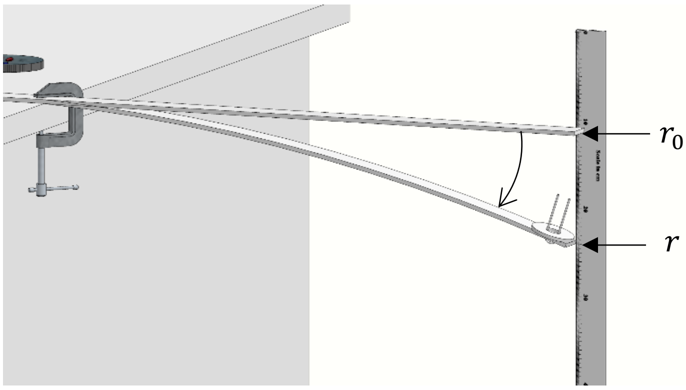

Figure 2

6. Attach **ONE** mass to the free end of the wooden beam and wait until the beam comes to rest. Keeping the metre ruler in the same upright position, with the $100\,\mathrm{cm}$ end touching the ground, read the value on the ruler that is level with the bottom edge of the free end of the beam. Record this new reading as r in the row corresponding to $n = 1$ in Table 2. (1)

7. Repeat step 6 for **all** the remaining seven masses. (7)

Table 2

n	r /m	m_L /kg	d/m
0	$r_0 =$ ________	0.0000	0.000
1			
2			
3			
4			
5			
6			
7			
8			

8. Each attached mass has a mass of $0.0236\,\mathrm{kg}$. Calculate the total attached mass m_L, and the deflection d of the free end of the beam using $d = r - r_0$. Complete Table 2 by filling in the missing values. (2)

9. Plot a graph of deflection d on the y-axis against mass m_L on the x-axis and draw the best straight line through the plotted points. (8)

10. Let S be the gradient of the graph obtained in Step 9. If the force creating the deflection d is given by $F = m_L g$, by comparing the system to a linear spring show that the stiffness constant k of the beam is given by $k = g/S$.

(2)

11. Use the gradient of your graph to determine the stiffness constant k of the beam. State the unit of k.

(3)

12. For a rectangular cantilever beam loaded at its free end,

$$k = \frac{YBT^3}{4L^3}$$

Use your values of B, T, L and k to calculate the Young modulus Y of the wooden beam.

(3)

13. State **ONE** precaution that should be taken when measuring the static deflection of the beam.

(1)

Method – Part B:

14. In this stage of the experiment, the value of k found in Part A is used to analyse the oscillations of the loaded beam.

15. Attach **TWO** masses to the free end of the beam. Slightly displace the free end downwards and release it so that it oscillates vertically with small amplitude.

16. Using the stopwatch, measure the time t_1 for 20 complete oscillations. Repeat the timing twice more for the same attached mass and record these readings as t_1, t_2 and t_3 in Table 3. (3)

17. Increase the attached mass by **ONE** mass and repeat the timing procedure. Continue until readings have been recorded for $n = 2$ to $n = 8$. (18)

Table 3

n	m_L /kg	t_1 /s	t_2 /s	t_3 /s	t_{avg} /s	τ /s	τ^2 /s^2
2							
3							
4							
5							
6							
7							
8							

18. Complete Table 3 by working out the missing values for m_L, t_{avg}, τ and τ^2, where t_{avg} is the average time for 20 oscillations and τ is the periodic time. (3)

19. The period τ of the oscillating beam is related to the attached mass m_L by

$$\tau = 2\pi\sqrt{\frac{m_L + m_E}{k}}$$

where m_E is the effective oscillating mass of the beam. Square this equation and express it in the form $y = mx + c$ for a graph of τ^2 against m_L.

____

____ (2)

20. Plot a graph of τ^2 on the y-axis against m_L on the x-axis and draw the best straight line through the plotted points. (8)

21. Use the gradient of the graph to obtain a second value of the stiffness constant using k. Compare this value with the value of k obtained in Part A.

____

____

____ (4)

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22. Use the y-intercept of the graph and the value of k obtained in Part A to calculate the effective oscillating mass m_E of the beam.

(4)

23. State **ONE** possible source of error and **ONE** corresponding precaution that could be taken to improve the setup or the procedure.

(2)

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