INSTRUCTIONS

1. Write your STUDENT ENROLMENT NUMBER (SEN) on the top right hand corner of this booklet.

2. Answer ALL QUESTIONS. Write your answers in the spaces provided in this booklet.

3. If you need more space for answers, ask the Supervisor for extra paper. Write your SEN on all extra sheets used and clearly number the questions. Attach the extra sheets at the appropriate places in this booklet.

4. The questions are organized under the headings below, with allocations of marks and suggested times indicated. The total skill level assigned to the questions is 75.

5. Some useful formulae are given on Sheet 1 provided.

Check that this booklet contains pages 2-23 in the correct order and that pages 22-23 has been deliberately left blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.
 QUESTION ONE: TRANSLATIONAL MOTION

1. **Figure 1** shows an aircraft and the horizontal forces acting on it as it moves along a runway. The *resultant force* on the aircraft is zero.

   **Figure 1:**

   ![Diagram of an aircraft with forces](image)

   a. Describe the movement of the aircraft when the resultant force is zero.

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   b. As the aircraft moves along the runway to take off, its acceleration decreases even though the force from the engines is constant. Explain why.

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A football of mass 0.42 kg is moving horizontally at 10 m.s\(^{-1}\) towards a footballer’s boot, which then kicks it. The graph of force versus time in **Figure 2** shows how the force between the boot and the ball varies with time while they are in contact.

**Figure 2:**

![Graph of force versus time](image)

a. Use the graph above to estimate the impulse that acts on the ball, stating an appropriate unit.

b. Calculate the speed of the ball after it has been kicked, assuming that it returns along the same horizontal line it followed when approaching the boot.
QUESTION TWO: ROTATIONAL MOTION

1. A student uses two methods to calculate the moment of inertia of a solid cylinder about its central axis.
   a. In the first method the student measures the mass of the cylinder to be 0.115 kg and the diameter to be 0.030 m.
      Calculate the moment of inertia of the cylinder.

   moment of inertia

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   Skill level 3
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   Moment of Inertia

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   Skill level 3
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   Moment of Inertia :

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   Skill level 3
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   b. In a second method the student allows the cylinder to roll down a slope and measures the final speed at the bottom of the slope to be 1.60 m.s\(^{-1}\). The cylinder has a diameter of 0.03 m and the slope has a height of 0.25 m, as shown in Figure 3.

   Using the conservation of energy, calculate the moment of inertia.

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   Moment of Inertia :
c. Explain why the moment of inertia found in part b. is greater than in part a.

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2. An ideal conical pendulum consists of a mass moving with constant speed in a circular path, as shown in Figure 4.

Acceleration due to gravity = 9.8 m. s\(^{-2}\)

**Figure 4:**

a. State the direction of the acceleration by an arrow on the mass in Figure 4 and explain why the mass is accelerating despite moving with constant speed.

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b. Swing-ball is a garden game in which a ball is attached to a light string connected to a vertical pole as shown in **Figure 5**. The motion of the ball can be modeled as a conical pendulum. The ball has a mass of 0.059 kg.

**Figure 5:**

The ball is hit such that it moves with constant speed in a horizontal circle of radius 0.48 m. The ball completes 1.5 revolutions in 2.69 s.

i. Show that the angular velocity of the ball is $3.5\, \text{rad.s}^{-1}$.

ii. Calculate the magnitude of the tension in the string.

The horizontal component of the tension in the string provides the centripetal force acting on the ball and the vertical component balances the weight of the ball.

Tensions : ____________________________
QUESTION THREE: SIMPLE HARMONIC MOTION

A metal ball is suspended from a fixed point by means of a string, as illustrated in Figure 6.

Figure 6:

The ball is given a small displacement and then released. The variation with time $t$ of the displacement $x$ of the ball is shown in Figure 7.

Figure 7:
a. i. State **TWO** (2) times at which the speed of the ball is a maximum.

1: ________________________________________________
2: ________________________________________________

ii. Show that the maximum speed of the ball is approximately 0.08 m.s\(^{-1}\).

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b. The variation with displacement \(x\) of the potential energy \(E_p\) of the oscillations of the ball is shown in **Figure 8**.

**Figure 8:**

i. On the axes of **Figure 8**, sketch a graph to show the variation with displacement \(x\) of the kinetic energy \(E_K\) of the ball.
ii. The amplitude of the oscillations reduces over a long period of time. After many oscillations, the amplitude of the oscillations is 0.60 cm.

Use the graph to determine the total energy of the oscillations of the ball for oscillations of amplitude 0.60 cm. Explain your working.
QUESTION FOUR: WAVES

1. **Figure 9** represents a stationary wave formed on a steel string fixed at P and Q when it is plucked at its Centre. It has a frequency of 150 Hz. The string PQ has a length of 1.2 m.

**Figure 9:**

![Stationary wave diagram](image)

a. Explain why a stationary wave is formed on the string.

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b. On **Figure 10**, draw the stationary wave that would be formed on the string at the same tension if it was made to vibrate at a frequency of 450 Hz.

**Figure 10:**

![Stationary wave diagram](image)
2. Figure 11 shows a ray of monochromatic light passes through grating.

Figure 11:

The angle between the central maximum and the second order maximum for red light is 19.0°. The frequency of this red light is $4.57 \times 10^{14}$ Hz.

a. Calculate the distance between the slits on this grating

b. Explain why the angle to the second order maximum for blue light is different to that for red light.
3. **Figure 12** shows a model helicopter flying in a straight horizontal path from student **A** to student **B**.

Speed of Sound in air = 340 m. s\(^{-1}\).

**Figure 12:**

The helicopter has a siren that emits sound of frequency 595 Hz. The velocity of the helicopter is described by the equation

\[ v = 8.2t \]

a. Suggest what happens to the frequency of the sound heard by student **B** as the helicopter accelerates towards her.

b. After 2.0 s the helicopter continues towards student **B** with a constant velocity. Calculate the frequency of the sound heard by student **B**.

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**Frequency:** __________________________
QUESTION FIVE: DC CIRCUITS AND CAPACITANCE

1. A battery is connected to a 10 Ω resistor as shown in Figure 13. The e.m.f (electromotive force) of the battery is 6.0 V.

**Figure 13:**

![DC Circuit Diagram](image)

a. When the switch is open the voltmeter reads 6.0 V and when it is closed it reads 5.8 V. Explain why the readings are different.

b. Calculate the internal resistance of the battery.

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2. A student sets up the circuit shown in Figure 14 to investigate the charging of a capacitor.

**Figure 14:**

The battery has an *e.m.f.* of 9·0 V and negligible internal resistance. Initially the capacitor is uncharged and the variable resistor $R_V$ is set to 12 Ω.

a. Switch S is now closed and the capacitor charges. Sketch a graph of the current in the circuit against time from the moment the switch is closed until the capacitor is fully charged. Numerical values are only required on the current axis.
b. Switch S is now opened and the capacitor is fully discharged. The variable resistor is adjusted to a greater resistance.

Switch S is closed and the capacitor charges again.

Explain what effect, if any, this increase in resistance has on the maximum current in the circuit.

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QUESTION SIX: ELECTROMAGNETIC INDUCTION

A small coil is positioned so that its axis lies along the axis of a large bar magnet, as shown in Figure 15.

Figure 15:

The coil has a cross-sectional area of 0.040 cm$^2$ and contains 150 turns of wire. The average magnetic flux density $B$ through the coil varies with the distance $x$ between the face of the magnet and the plane of the coil, as shown in Figure 16.

Figure 16:

a. i. The coil is 5.0 cm from the face of the magnet. Use the graph above to determine the magnetic flux density in the coil.

\[
\text{Magnetic Flux Density: } \boxed{\quad \text{mT} \quad \text{NR}}
\]
ii. Hence show that the magnetic flux linkage of the coil is $3.0 \times 10^{-4}$ Wb.

Magnetic Flux Density: 

b. The coil is moved along the axis of the magnet so that the distance $x$ changes from $x = 5.0$ cm to $x = 15.0$ cm in a time of 0.30 s. Calculate:

i. the change in flux linkage of the coil,

Change in flux linkage:

iii. the average $e.m.f.$ induced in the coil.

Average $e.m.f.$:

c. State and explain the variation, if any, of the speed of the coil so that the induced $e.m.f.$ remains constant during the movement in part b.
QUESTION SEVEN: AC CIRCUIT

Figure 17 shows AC supply with a rms voltage of 6.00 V at a frequency of 100 Hz, connected in series with an ammeter, resistor, capacitor and inductor (all voltages are in rms values).

Figure 17:

a. Explain why the numerical values of $V_R$, $V_C$ and $V_L$ in the diagram do not add up to the numerical value of the supply voltage.

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b. State the mathematical condition for resonance, and use it to show that the resonant frequency of this circuit is 105 Hz if the reading on the ammeter is 324 mA.

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**QUESTION EIGHT: ATOMIC AND NUCLEAR PHYSICS**

1. **Figure 18** shows part of an energy level diagram for a hydrogen atom.

   Plank’s Constant = $6.63 \times 10^{-34} \, J \cdot s$
   Speed of Light = $3.00 \times 10^8 \, m/s$
   Charge on the electron = $1.60 \times 10^{-19} \, C$

   **Figure 18:**
   
   
   - $n = 4$ ———— $-0.85 \, eV$
   - $n = 3$ ———— $-1.50 \, eV$
   - $n = 2$ ———— $-3.40 \, eV$
   - $n = 1$ ———— $-13.60 \, eV$

   a. The level, $n = 1$, is the ground state of the atom. State the ionization energy of the atom in $eV$.

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   b. When an electron of energy $12.1 \, eV$ collides with the atom, photons of three different energies are emitted.

   i. On **Figure 18**, show with arrows any two of the transitions responsible for these photons.

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   ii. Calculate the wavelength of the photon with the smallest energy.

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2. The following apparatus is set up in a physics laboratory to investigate the photoelectric effect.

Plank's Constant = $6.63 \times 10^{-34} \, J.s$
Speed of Light = $3.00 \times 10^8 \, m.s^{-1}$

Figure 19:

The work function of sodium is $3.78 \times 10^{-19} \, J$.

a. Light of frequency $6.74 \times 10^{14} \, Hz$ is incident on the sodium plate and photoelectrons are emitted.

Calculate the maximum kinetic energy of a photoelectron just as it is emitted from the sodium plate.

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b. The irradiance of this incident light is now decreased.

Explain how this affects the maximum velocity of a photoelectron just as it is emitted from the sodium plate.

3. The following statement represents a nuclear reaction.

\[ \frac{A}{Z}X + \frac{1}{2}H \rightarrow 2 \frac{4}{2}He + 1 \frac{1}{0}n + \text{energy} \]

The masses of some of the particles involved in this reaction are shown in the table.

<table>
<thead>
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<th>Particle</th>
<th>Mass/kg</th>
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<td>( \frac{1}{2}H )</td>
<td>6.642 \times 10^{-27}</td>
</tr>
<tr>
<td>( \frac{4}{2}He )</td>
<td>6.642 \times 10^{-27}</td>
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<tr>
<td>( \frac{1}{0}n )</td>
<td>1.675 \times 10^{-27}</td>
</tr>
</tbody>
</table>

The energy released in this reaction is 2.97 \times 10^{-12} \, J.

Speed of Light = 3.00 \times 10^8 \, m.s^{-1}

Calculate the mass of the nucleus \( \frac{A}{Z}X \).