MJSO

Malta Junior Science Olympiad

2021 Physics

SCIENCE CENTRE
PEMBROKE MALTA

MINISTRY FOR EDUCATION
Directorate for Learning and Assessment Programmes

Acknowledgements

The examination questions included in this Malta Junior Science Olympiad set of booklets are the result of a team effort and reflect the contributions by Ms Penelope Fitzgerald (EO Biology), Mr Michael Mercieca (EO Chemistry) and Ms Audrey Vella Bondin (EO Physics).

Much appreciation to Mr Gaetano Calleja (Head of School) for hosting the event at Giovanni Curmi Higher Secondary School.

Special thanks are due to Mr Michael Mercieca for his technical support, design and compilation of the final version of the booklets.

Table of Contents

Instructions

- You are asked to attempt all questions within the four sections and write your answers clearly in the spaces provided. Whenever necessary indicate the question number to your answer.
- Show all steps in your working including any equations used.
- The use of a calculator is permitted.
- You are also reminded of the necessity of good English and orderly presentation of your answers.
- No extra foolscaps will be provided.

Equations

Density	$m = \rho V$
Waves	$v = f \lambda$
Electricity	$E = Pt$

Section A: Short answer questions (20 marks)

1. The first modern tidal power station was built in 1966 in La Rance in France.

   Water flows into the barrage when the sea is at a higher level than the water behind the barrage. The water flows out again when the sea level is lower than the water behind the barrage (Figure 1).

   Tidal turbines work like wind turbines, except that it is ocean currents, not wind, that turn them. The spinning turbine is connected to another device that produces electricity.

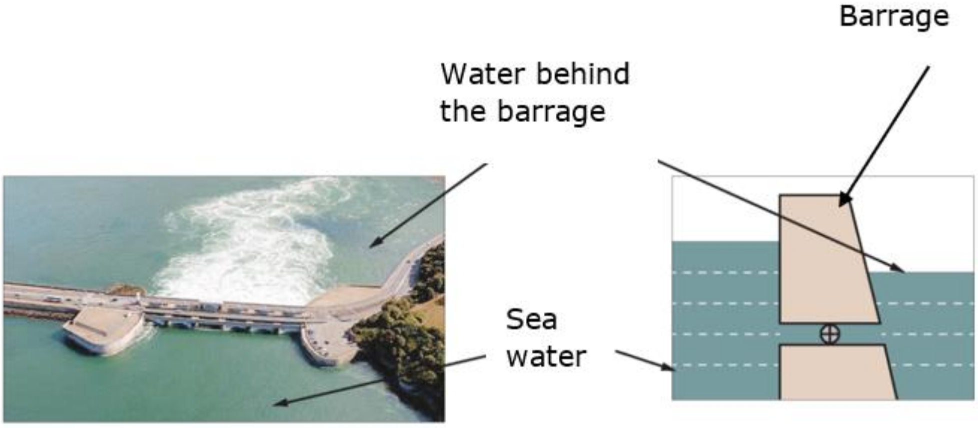
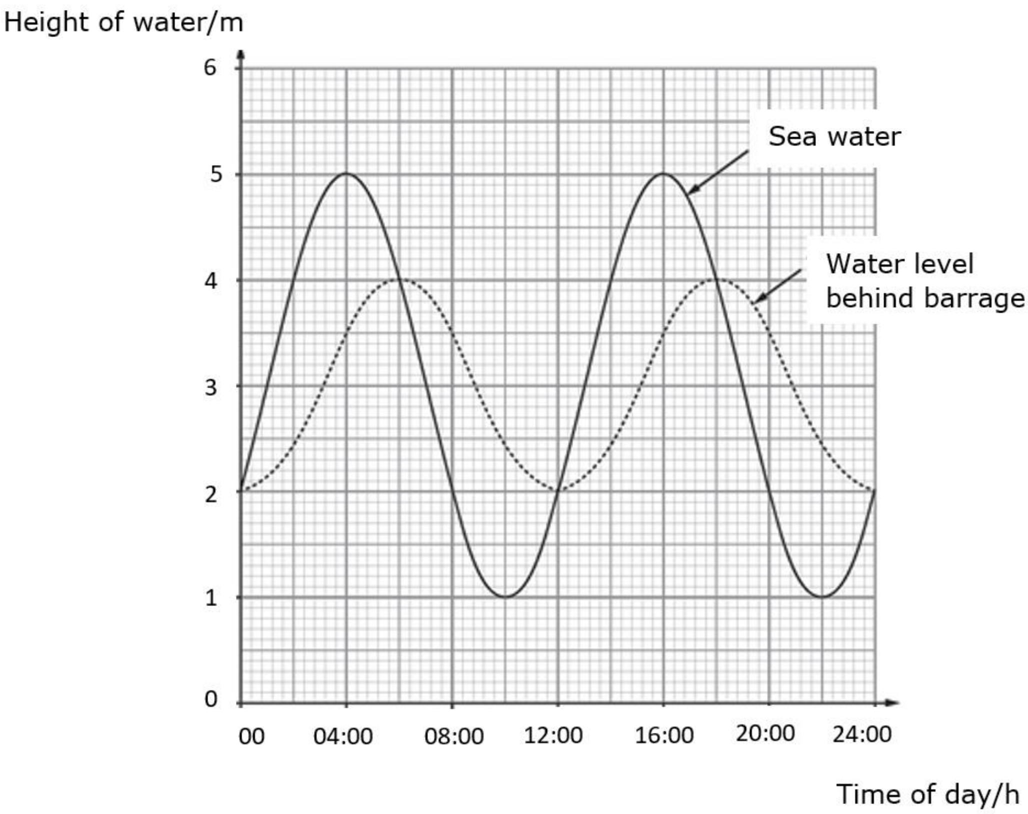


Figure 1

One day in June 2020 the sea water levels on each side of the barrage changed as shown in the graph below.



The first tide occurred at 04:00.

a. Using the graph on page 3, find:

i. the height of the sea water at high tide

____ (1)

ii. the time of the second high tide of the day

____ (1)

iii. the time lapse between two high tides

____ (1)

iv. ONE specific time when both sea and water levels are the same

____ (1)

v. ONE specific time when no power is generated.

____ (1)

b. The table below gives information about a turbine in the barrage at La Rance.

Power (MW)	
Power output	10
Power input	16

Calculate the efficiency of this turbine.

____

____ (2)

c.

i. State TWO environmental advantages of generating electricity from tidal power.

____

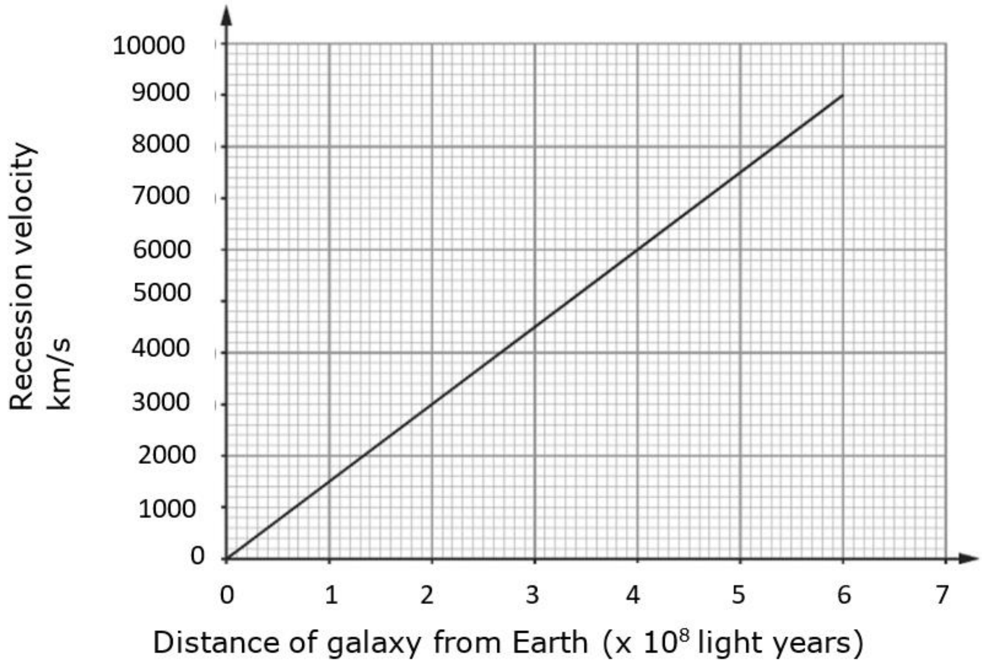
____ (2)

ii. State ONE environmental disadvantage of generating electricity from tidal power.

____ (1)

Total: 10 marks

2. The graph below shows how the velocities of galaxies moving away from the Earth (known as the recession velocity) depends on the galaxies' distance away from the Earth (in light years).



The American astronomer, Sir Edwin Hubble, put forward this theory:

"The recession velocity of a galaxy is directly proportional to its distance from Earth."

a. State how the graph supports Hubble's theory.

____

____ (2)

b. The gradient of the graph is called the 'Hubble constant'. Its value is given by the equation:

$$\text{Hubble constant} = \frac{1}{\text{Age of Universe}}$$

Explain how the gradient of this line will change in the future.

____

____ (2)

c. The speed of recession of a distant galaxy is measured as 6000 km/s. Use the graph to calculate the distance of this galaxy from Earth. Give your answer in km. (A light year is equivalent to 9.5×10^{12} km).

____

____ (2)

d. Cosmic Microwave Background (CMB) radiation is thought to be leftover heat from the Big Bang. Explain how this radiation provides evidence that supports the Big Bang Theory.

____

____ (2)

e. Space has a temperature of about -270 °C and is filled with CMB radiation. Explain why the temperature of space will decrease as the Universe continues to expand. (Note that the energy of the wave is directly proportional to its frequency).

____

____ (2)

Total: 10 marks

Section B: Comprehension (20 marks)

3. Read the following article adapted from The Physics of Music and Musical Instruments by David R. Lapp, Fellow Wright Centre For Innovative Science Education, Tufts University Medford, Massachusetts (2003). Then answer the questions that follow.

The guitar is the most common and popular instrument of the string family and is still prominent in modern day music.

It has been around for 4000 years and evolved from an instrument called a Vihuela. It was later made into what we now call the guitar by Antonio Torres Jurado (1827-1892).

If a string is removed from any stringed instrument (guitar, violin, piano) and held taut outside the window of a moving car, there would be very little resistance from the air, even if the car was moving very fast.

If a string is stretched in between two large concrete blocks and plucked, very little sound would be heard. This is mostly due to the huge acoustic impedance difference between the string and the concrete blocks such that the string's vibrations would transmit very little wave energy to the blocks. With so little of its energy transmitted, the string would simply vibrate for a long time, producing very little sound.

For the non-electric stringed instrument to efficiently produce music, its strings must couple to some object (with similar impedance) that will vibrate at the same frequency and move a lot of air. To accomplish this, the strings of guitars, violins, pianos, and other stringed acoustic instruments all attach in some fashion to a soundboard.

Figure 2 shows the strings of a guitar stretched between the nut and the bridge.

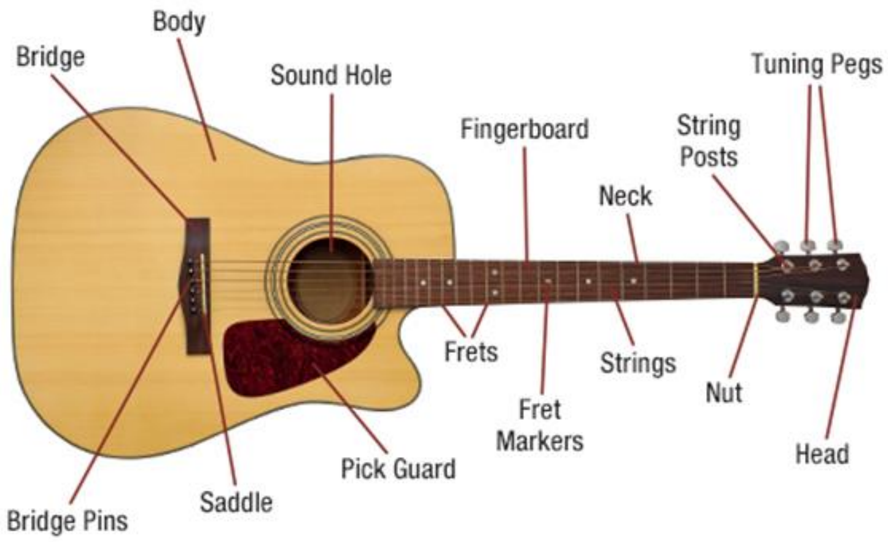


Figure 2: https://musicpartnership.com.au

Figure 3 shows a magnified image of the bridge attachment of strings which stretch to the top of the guitar. As a string vibrates it applies a force to the top of the guitar, which varies with the frequency of the string. The string forces the bridge and guitar top to begin vibrating at the same frequency as the string. The frequency at which the surrounding air molecules vibrate is equal to the frequency of vibration of the string. This is known as resonance. When all the molecules are vibrating at the certain frequency, then the sound is produced.

Figure 3 https://www.alamy.com/stock-photo

It's easier to understand how musical instruments can be set into resonance by thinking about standing waves. Standing waves occur whenever two waves with equal frequency and wavelength move through a medium so that the two perfectly reinforce each other. Usually, one of the two waves is the reflection of the other. When they reinforce each other, it looks like the energy is standing in specific locations on the wave medium, hence the name standing waves.

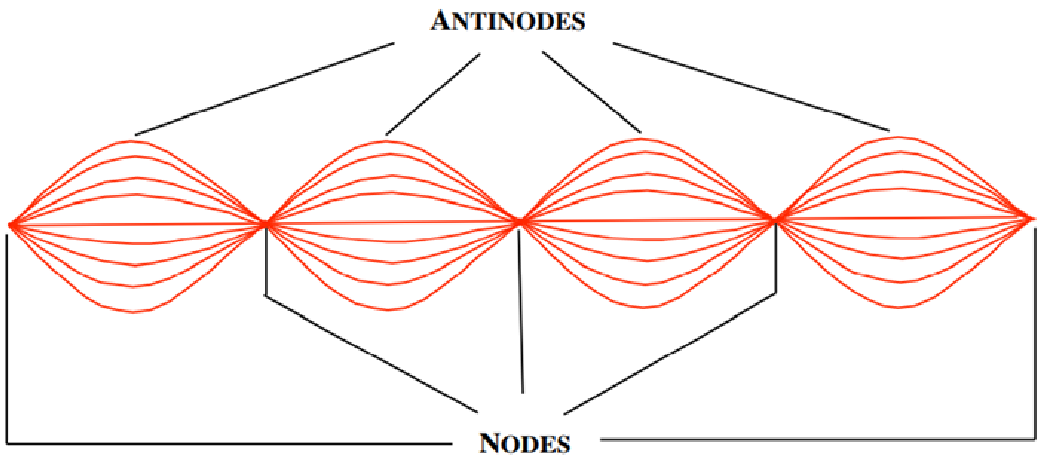


Figure 4

In standing waves, there are parts of the wave medium that remain motionless and parts where the wave medium move back and forth between maximum positive and maximum negative amplitude as seen in Figure 4. Standing waves can occur in all wave mediums and may be present during any resonance.

Guitar strings can be made of either nylon or steel, nickel or bronze. The type used depends on the type of chords and music being played. Strings stretch from the bridge of the guitar, all the way over the body and sound hole. They reach up the neck, across the finger board, where they then go past the nut and into the tuning pegs. The mass, length, and tension of the strings create the frequency of sound which the guitar makes.

Although the guitar is not the most complex musical instrument, a deeper understanding of its composition, clearly indicates that a range of physics concepts are involved in making sound from a string.

a. Explain why a guitar string that is held outside a window of a fast-moving car experiences little air resistance.

____ (1)

b. What do you understand by the term 'acoustic impedance'?

____

____ (2)

c. List the condition necessary for resonance to occur such that the sound produced by the string becomes audible.

____

____ (2)

d. Referring to lines (31-40), explain how a standing wave is formed.

____

____

____

____ (4)

e. Name:

   i. the parts of the wave medium that remain motionless in a standing wave

____ (1)

   ii. the parts where the wave medium moves back and forth between maximum positive and maximum negative amplitude in a standing wave.

____ (1)

f. Explain how the tension of the guitar strings can be changed.

____

____ (2)

g. The length of the string is changed when playing the guitar. Describe how this is achieved.

___

___ (2)

h. A note of Middle D (294 Hz) is sounded out by a guitar string. The length of the guitar string is 70 cm. For the first harmonic, the wavelength is twice the length of the string. Calculate the speed of the standing wave (first harmonic) in the guitar string.

___

___

___ (3)

i. A student calculated the volume of a nylon guitar string and found it to be 0.398 cm^3. If the density of nylon is 1.14 g/cm^3, calculate the mass of the string.

___

___ (2)

Total: 20 marks

Section C: Data Analysis (30 marks)

4. The resistance (R) of a wire is measured in ohms (Ω) and is given by the equation:

$$R = \frac{\rho L}{A}$$

The symbol, ρ, stands for resistivity.
Resistivity is a property of the material and is constant over a wide range of temperatures. Good conductors have a low resistivity.
L is the length of the wire and A is the cross-sectional area.
In one experiment, the resistance of a number of wires, of different cross-sectional area, was determined and the results were tabulated as shown in the table below. All wires were made of the same material and were 8.0 cm long.

$R/10^{-5}$ (Ω)	**$A/10^{-5}$ (m^2)**	**$1/A$ $/10^4$ (m^{-2})**
2.1	7.01	1.40
5.3	2.64	
8.4	1.56	
11.0	1.22	
13.2	1.00	
21.0	0.63	

a. Fill in the table by calculating values of $1/A$ $/10^4$ (m^{-2}). (5)

b. Plot a graph of R(Ω) on y axis against $1/A$ (m^{-2}) on x axis on page 11. (6)

c. Use your graph to determine a value for the resistivity, ρ, of the material.

____

____

____

____

____

____

____

____

____

____

____ (7)

d. Describe how the graph would change if the wires were longer than 8 cm.

____

____ (2)

Total: 20 marks

5. A hot water tank that is covered in foam insulation contains a total of 120 litres of water. It has two electric heaters, Heater 1 and Heater 2, either of which may be used to heat water to the same final temperature. Figure 5 shows a simplified diagram of the hot water tank.

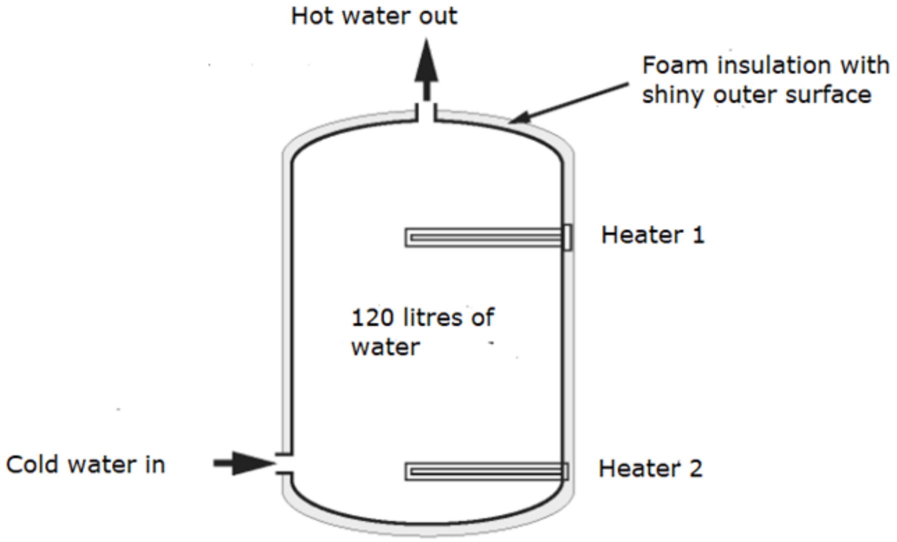


Figure 5

a. Explain why Heater 1 does not heat all the water in the tank.

____

____ (2)

b. The following table gives information about heating water by either of the two heaters.

	Electric Heater 1	**Electric Heater 2**
Volume of water heated (litres)	30	120
Time to heat this volume of water (hours)	0.5	3
Power (kW)	4	2
Cost per unit (c)	16	5

Martin has to decide which Heater (1 or 2) to use. He needs to heat 30 litres of water. Use the data in the table above to compare the two methods of heating in terms of:

- the number of units used to heat water
- cost of electricity used
- impact on the environment
- include any advice that should be given to Martin.

Assume that the water in the tank is initially cold.

____

____

____

____

____

____

____

____

____

____

____

____

____

(8)

Total: 10 marks

Section D: Design task (30 marks)

6. Louisa set up a line of dominoes and toppled them in a visually interesting chain reaction. Her elder sister, Martina, who was observing, told her that physics concepts such as gravity, momentum, and force vector analysis are involved in chains of falling dominoes.

   Louisa and Martina request your help to design an experiment to investigate the following:

Figure 6: https: istockphoto.com/dominoes-falling

How does the distance between dominoes affect the speed at which they fall?

a. Name the apparatus you would use for this investigation.

____

____ (2)

b. State the dependent and independent variables

____

____ (2)

c. Describe the procedure which you would adopt for this investigation.

____

____

____

____

____

____

____

____

____ (3)

d. In the space below, show how you would tabulate results.

(4)

e. Write down the equation that you would use to calculate speed.

____

____ (1)

f. Name the TWO quantities listed in your answer in part (d) that need to be used to calculate the speed with which the dominoes fall.

____

____ (2)

g. Indicate how the results can be presented graphically.

____

____ (2)

h. Predict the relationship between distance between dominoes and the speed with which they fall.

____

____

____ (3)

i. Explain why the distance between dominoes affects the speed of a domino chain reaction.

____

____

____ (3)

j. Identify THREE precautions necessary to ensure accuracy in the results.

____

____ (3)

k. State TWO main variables that need to remain constant to ensure fair testing.

____

____ (2)

l. Name THREE factors that are affected by the distance between dominoes and which in turn affect the speed of a domino chain reaction, contributing to a cumulative effect.

____

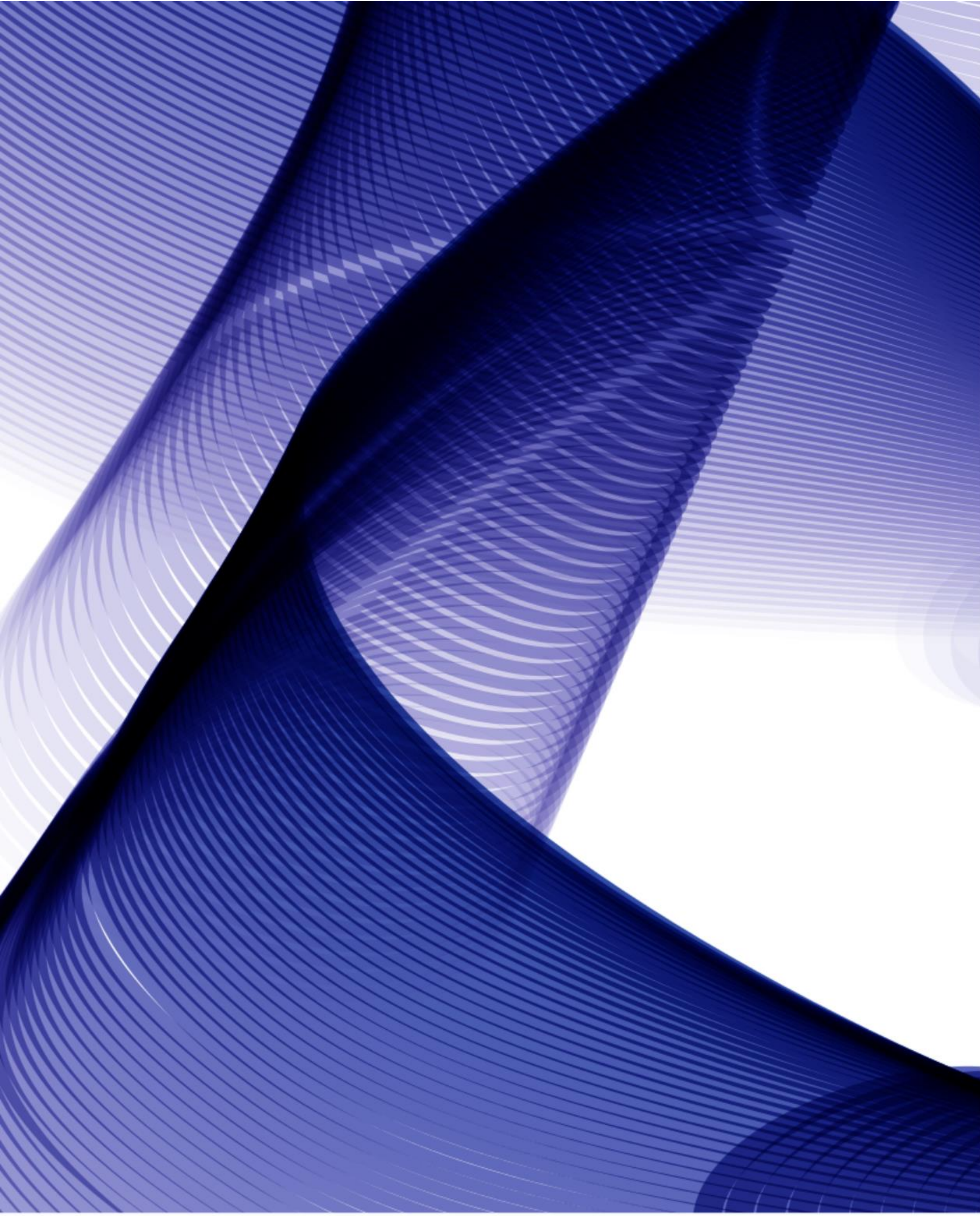
____

____ (3)

Total: 30 marks

Blank Page

Blank Page



SCIENCE CENTRE
PEMBROKE MALTA

MINISTRY FOR EDUCATION
Directorate for Learning and Assessment Programmes