MJSO

Malta Junior Science Olympiad

2020 | Physics

SCIENCE CENTRE
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MEDE

Acknowledgments

The examination questions included in this Malta Junior Science Olympiad booklet are the result of a team effort and reflect the contributions of Ms Penelope Fitzgerald, Mr Michael Mercieca and Ms Audrey Vella Bondin.

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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 and write the units where necessary.
- Whenever necessary, take g, acceleration due to gravity, as 10 m/s^2.
- 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

Moments	Moment = F x perpendicular distance	
Energy and Work	E = Pt	PE = mgh
Force and Motion	unbalanced force = ma	momentum = mv
Waves	$v = f\lambda$	
Electricity	E = QV	

Section A: Multiple choice questions (15 marks)

Each question has only one correct answer.
Underline the correct answer.

1) Which of the following is the best estimate of the volume of an orange?
   a) 3×10^{-5} m^3
   b) 3×10^{-4} m^3
   c) 3×10^{-3} m^3
   d) 3×10^{-2} m^3.

2) Two cylinders P and Q are made of copper as shown in Figure 1 below.

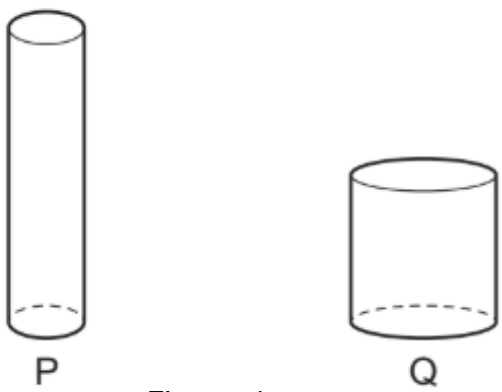


Figure 1

The height of cylinder P is twice the height of cylinder Q. The diameter of cylinder P is half the diameter of cylinder Q.
Choose the correct statement about the densities of cylinders P and Q:
   a) the density of cylinder P is four times that of cylinder Q
   b) the density of cylinder P is twice that of cylinder Q
   c) the density of cylinder P is equal to that of cylinder Q
   d) the density of cylinder P is half that of cylinder Q.

3) A metal lid fits tightly on a glass jar.
Choose the process that makes it easier to remove the lid from the jar:
   a) cool the lid only
   b) put the jar and lid in a refrigerator
   c) warm the jar only
   d) warm the lid only.

4) The speed of sound varies with:
   a) humidity only
   b) temperature only
   c) pressure
   d) humidity and temperature.

5) Choose the correct statement for sound waves:
   a) sound waves are longitudinal
   b) sound waves are electromagnetic
   c) sound waves cannot be reflected
   d) sound waves are transverse.

6) Kate has a tub of ice cream and plans to take it on her trip to Gozo. She does not have a cooler available, so she wraps the ice cream tub in a jumper. Is this a good idea?
   a) Yes. The jumper will hold the cold in the ice cream
   b) No. The jumper always moves the cold to outside it
   c) Yes. The jumper will prevent the heat getting to the ice cream
   d) No. The jumper won't make any difference to what happens to the ice cream.

7) The Earth and the Moon both exert gravitational forces on objects in their vicinity. Imagine a line joining the Earth to the Moon, and extending to either side, as shown below (Figure 2 not to scale).
   Choose the position that an object should be placed along this line such that the net gravitational force on the object due to the Earth and the Moon equal to zero.

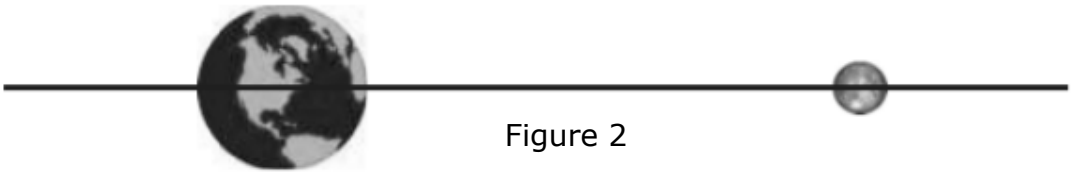


Figure 2

   a) on the far side of the Earth from the Moon
   b) between the Earth and the Moon, but closer to the Earth than to the Moon
   c) halfway between the Earth and the Moon
   d) between the Earth and the Moon, but closer to the Moon than to the Earth.

8) A construction worker drops a stone from the roof of a single–storey house. The stone:
   a) reaches a maximum speed quite soon after release and then falls at a constant speed the rest of the way to the ground
   b) speeds up during its entire fall to the ground because the gravitational attraction gets considerably stronger as the stone gets closer to the Earth
   c) speeds up during its entire fall to the ground because of a constant force of gravity acting on it
   d) falls to the ground because of the combined effects of the force of gravity pushing it downward and the air resistance pushing it downward.

9. A battery of 10V is connected to a resistor, as shown in the diagram (Figure 3 below.

   A charge of 2.0 coulombs passes through the resistor.
   How much work is done as the charge passes through the resistor?
   a) 20 J
   b) 2.0 J
   c) 5.0 J
   d) 0.20 J.

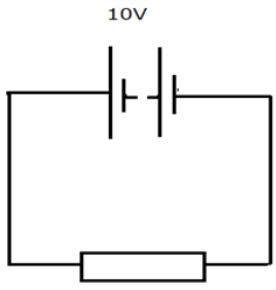


Figure 3

10) A large bulky pigeon and a small light quail which are both flying in mid-air, have the same kinetic energy. Which of the following statements is true?
   a) The pigeon has a greater speed than the quail
   b) The quail has a greater speed than the pigeon
   c) The pigeon and the quail have the same speed
   d) The direction of the quail and the pigeon must be taken into account before a decision can be made.

11) A book lies at rest on a table. The table is at rest on the surface of the Earth. Newton's Third Law reaction force to the gravitational force of the Earth on the book is:
   a) the gravitational force exerted by the Earth on the book
   b) the normal force exerted by the table on the book
   c) the gravitational force exerted by the table on the book
   d) the gravitational force exerted by the book on the Earth.

12) Read the given statements and select the correct option.

Statement 1: A concave mirror and a convex lens both have the same focal length in air. When they are submerged in water, they will still have the same focal length. **Statement 2:** The refractive index of water is greater than the refractive index of air.

   Choose the correct answer according to the guidelines below:
   a) both statements 1 and 2 are true and statement 2 is the correct explanation of statement 1
   b) both statements 1 and 2 are true but statement 2 is not the correct explanation of statement 1
   c) statement 1 is true but statement 2 is false
   d) statement 1 is false but statement 2 is true.

13) When a filament lamp has a current passing through its filament, the filament heats and its resistance increases. Complete the statement by choosing the correct answer from a,b,c or d below.

   Statement: If the light bulb is connected to a constant voltage source:

   a) the resistance increases at a roughly constant rate and the current through the light bulb decreases correspondingly
   b) the resistance increases at a roughly constant rate and the current through the light bulb increases correspondingly
   c) the resistance increases but the current remains the same
   d) the resistance increases at a decreasing rate and the current decreases at a decreasing rate until they are both roughly constant.

14) A large breed dog weighing 60 kg runs into a cat weighing 8 kg. The dog was moving at 1.5 m/s and the cat was resting in the sun. Assume that both the dog and cat continue moving together. What is the final speed of the combined cat/dog furball?
    a) 0.18 m/s
    b) 0.75 m/s
    c) 1.32 m/s
    d) 11.30 m/s.

15) Sarah claims to have built a refrigerator alternative which works without any power supply. It is a box with a wet blanket over it. The blanket is kept wet as a tap is allowed to drip water onto its corner.

    Choose the answer which best describes how this refrigerator alternative works.

    a) it takes energy to make water evaporate and that energy comes from heat energy in the blanket and surroundings, so the blanket and also the box stay cold
    b) the water from the tap is cold, so it keeps the box cold. If she used water at room temperature it wouldn't work
    c) the drips from the tap can provide enough power to generate electricity to run a refrigerator. The blanket is just hiding the electric part
    Sarah makes the box cold using a real fridge first and then puts the wet blanket over it, completely insulating the box so it can never warm up.

Total: 15 marks

Section B: Short answer questions (30 marks)

1) a) An aeroplane becomes positively charged as it flies through the air because of loss of particles from its metal surface.

i) Name the particles lost from the metal surface.

_____ (1)

ii) The tyres of the aeroplane are made from an electrical conductor. Explain what happens to the charge on the aeroplane when it lands.

_____

_____ (2)

iii) Explain why it is necessary to keep an aeroplane connected electrically to earth during refuelling.

_____

_____ (2)

b) The balance point or centre of gravity is very important during flight because of its effect on the stability and performance of the aeroplane and must remain within carefully defined limits at all stages of flight. Figure 4 shows the forces acting on an aeroplane.

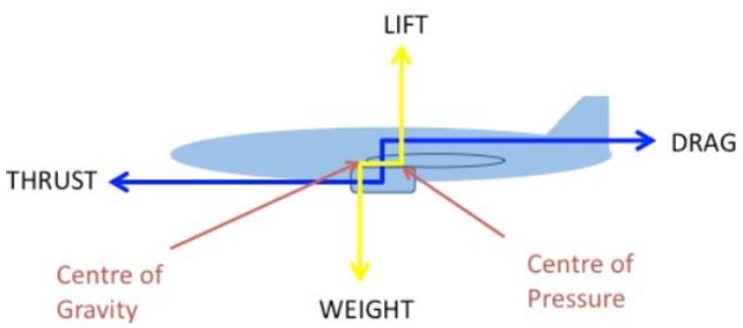


Figure 4

The centre of gravity will move if the distribution of the load changes. List two ways in which the distribution of the load might change during flight.

_____

_____ (2)

c) Pilots are able to steer a plane by moving flaps on the wings up and down. These flaps are called elevators. For example, if the elevator on the right wing is up, and the elevator on the left wing is down, the right wing will have more drag. The plane will slow down on the right side causing the plane to turn to the right. Explain what will happen if the elevators on both wings are in the up position.

_____

_____

_____

_____

_____ (3)

(Total 10 marks)

2) Figure 5 (not to scale) shows a motor used to operate an elevator (lift). There is a man inside the lift. The input power to the motor is 6200W.
The lift and the man have a total mass of 580kg. The lift moves up a distance of 12m in 15s.

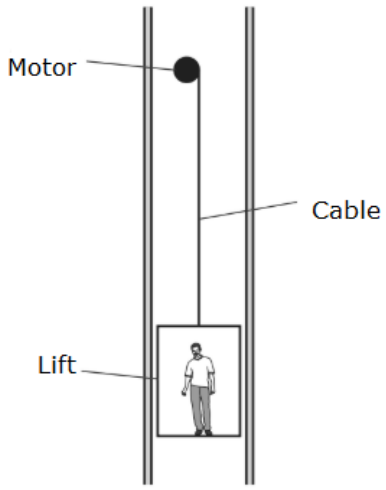


Figure 5

a) Calculate:
i) The tension in the cable when the lift is moving at constant speed.

_____ (1)

ii) Calculate the increase in potential energy of the lift and the man.

_____

_____ (2)

b) Calculate the efficiency of the motor.

_____

_____ (2)

c) Give two reasons why the electrical power supplied to the motor is greater than its useful output power.

_____

_____ (2)

(Total 7 marks)

3) In hospitals, nurses and doctors use lever operated sink taps like the one shown in Figure 6 below. They operate these taps using their elbows in order to avoid contamination and maintain a sterile environment.

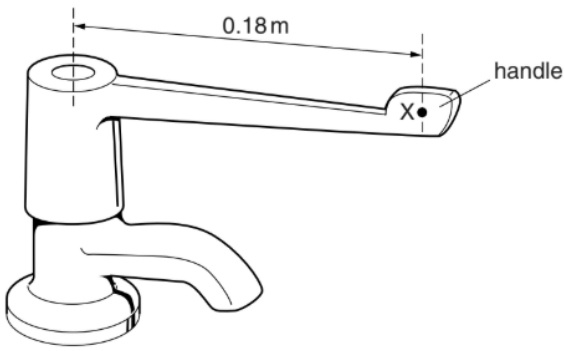


Figure 6

a) A nurse applies a force of 2.5N about point X. Calculate the maximum moment about the axis that this force can produce.

_____

_____

_____ (2)

b) The moment produced by the nurse is less than the maximum value. Give one reason for this.

_____ (1)

c) Explain why long handles are used in lever operated sink taps.

_____

_____ (2)

d) Alternatively, sensor taps such as the one shown in Figure 7 below can be used to avoid cross-infection. A sensor tap must have power from an electricity supply.

Figure 7

The sensor can detect an object, like a hand, opposite the basin tap. A solenoid valve opens when an obstruction is perceived. This way, water flows through the pipe and spout.

i) Name the type of electromagnetic radiation used by the sensor to detect an object such as a hand.

_____ (1)

ii) Write one advantage and one disadvantage of using sensor taps.

_____

_____

_____

_____ (2)

(Total: 8 marks)

4) A free-fall parachutist jumps from a plane but does not open his parachute for some time.

Figure 8 below shows the speed-time graph for his fall. Point B on the graph indicates the time when he opens his parachute.

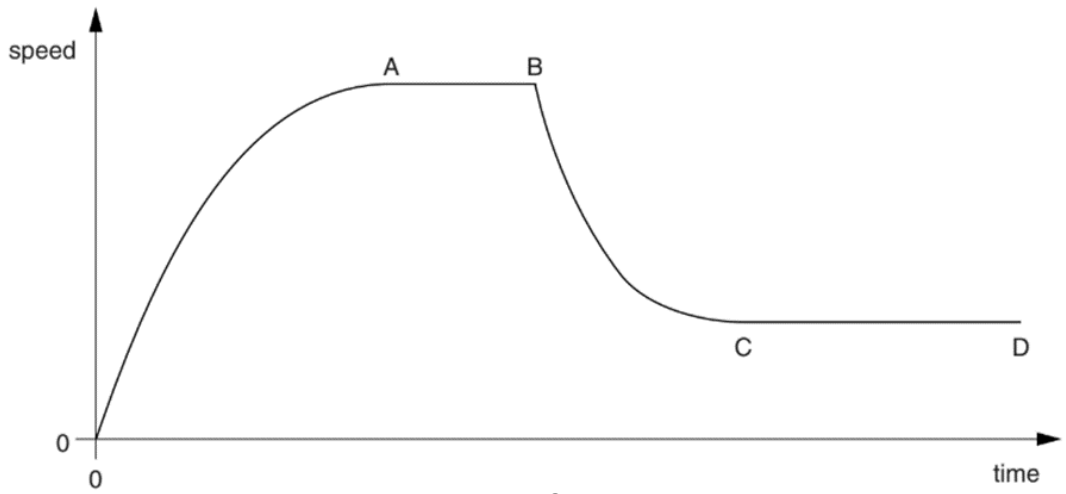


Figure 8

a) State the value of the gradient of the graph immediately after time t=0.

_____ (1)

b) Explain why the gradient has this value.

_____ (1)

c) State what happens to the acceleration between time t=0 and the time to A.

_____ (1)

d) Explain in terms of forces, what is happening in section AB of the graph.

_____

_____ (2)

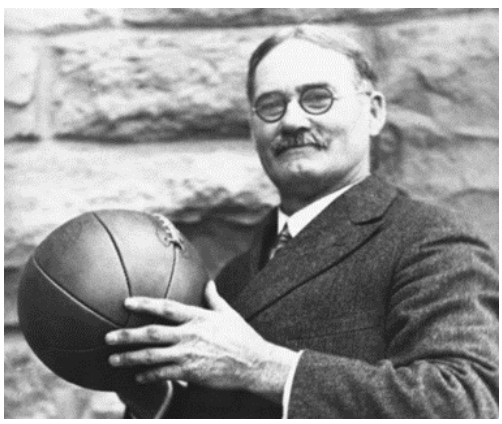
(Total 5 marks)

Section C: Comprehension (20 marks)

Read the text below and answer the questions that follow.

The Physics of Basketball

Pass, dribble and shoot! It is time for basketball. Bouncing the ball on the ground, passing to your teammate and shooting at the goal, all depend on physics, maths and the laws of motion. *(para 1)*



https://howtheyplay.com/team-sports/

Basketball is considered the first sport that completely originated in the United States. It was invented in December of 1891 when Dr. James Naismith nailed up some peach baskets in a gym. Basketballs today are designed to bounce around the court and soar in an arc from your hands into the basket. When the sport was first invented, soccer balls were used, and players had a harder time holding on to and dribbling the ball than they engaged in shooting a basket. *(para 2)*

Changes made to the ball included making them bigger and adding bumps to the leather surface. Modern basketballs are hollow with an inflatable inner rubber bladder and have a small opening that allows the control of the air pressure. This hollow centre is generally wrapped in layers of fibre and finally covered with leather, which is usually bright orange so that players can easily see the ball. *(para 3)*

commons.wikipedia.org/w/index.php

Basketballs bounce because of the pressurized air inside of them, gravity and Newton's Laws of Motion. When you dribble a basketball, your hand and gravity both push the ball towards the ground. As it drops, the ball accelerates and speeds up. It wants to stay in motion so the ball pushes into the ground when it hits, compressing the air inside. The ground pushes up with an equal, but opposite amount of force resulting in the ball bouncing back up into your hand. The energy in the compressed air is transferred back to the ball pushing it back into motion. If you were to take your hand away and stop dribbling, the ball would continue to bounce but would slow down and eventually stop due to friction. The more air pressure inside, the harder it will push on the sides of the ball and the more bounce you'll get. *(para 4)*

Over the years, the last detail added to the new ball included little bumps on the surface of the leather called pebbling. Adding these bumps was all about friction. When forces collide, friction naturally slows things down over time and the more points of contact an object has with another surface the more friction comes into play. This makes the pebbled ball ideal for a player to grip, pass quickly, and dribble without fear that the ball will slip away in a random direction. *(para 5)*

Image Source: Pixabay.com

Basketballs left out in the cold at night have been observed to go flat and so care must be taken to store equipment properly. *(para 6)*

The physics aspect of shooting a free throw involves *distance* and *deviation*. Distance is determined by two factors: launch angle and launch speed. Launch angle is simply the angle at which the player launches the basketball towards the basket. Having your arm straight out and parallel to the floor is a 0-degree angle. Having your arm straight up pointing to the ceiling is a 90-degree angle. Halfway in-between these two extremes would be a 45-degree angle. The player's distance from the goal and the release height of his/her shot determine the ideal launch angle for a slow-moving ball at the rim. *(para 7)*

Next time you shoot, observe all the features of the basketball that make it special. It's a great example of engineering and American innovation in action! *(para 8)*

Adapted from:https://sciencemadefun.net/blog/the-science-of-basketball

Questions:

1) Newton's laws of motion are applied when a player dribbles a basketball. From paragraph 4, find the text that explains the movement of the basketball in terms of Newton's first, second and third law and write it in the space below:

Newton's first law:

_____

_____ (2)

Newton's second law:

_____

_____ (2)

Newton's third law:

_____

_____ (2)

2) Explain why an under-inflated ball will not bounce so well.

_____

_____ (2)

3) Explain in terms of air molecules how air pressure is increased by pumping in more air into the basketball.

_____

_____ (2)

4) What does the term 'pebbling' refer to in the design of the basketball?

_____ (1)

5) Explain how the force of friction is increased through the ball design in order to allow players to grip and dribble without having the ball slip out of the hands.

_____

_____ (2)

6) Explain, in terms of air molecules, why a basketball left in the cold goes flat.

_____

_____

_____ (3)

7) Name the factor that determines the launch speed in a free throw.

_____ (1)

8) The release height of the basketball shot is largely determined by the height of the player who is shooting.
State whether the launch angle should decrease or increase with the height of player.

_____ (1)

Explain your answer.

_____

_____

_____ (2)

Total: 20 marks

Section D: Long structured questions (35 marks)

Write your answers for Section D in the space provided.

1) a) Kylie observes a mass as it moves down and then up again on the end of a spring.

Figure 9 shows the position of the mass at times t = 0.10s, t = 0.20s and t = 0.25s.

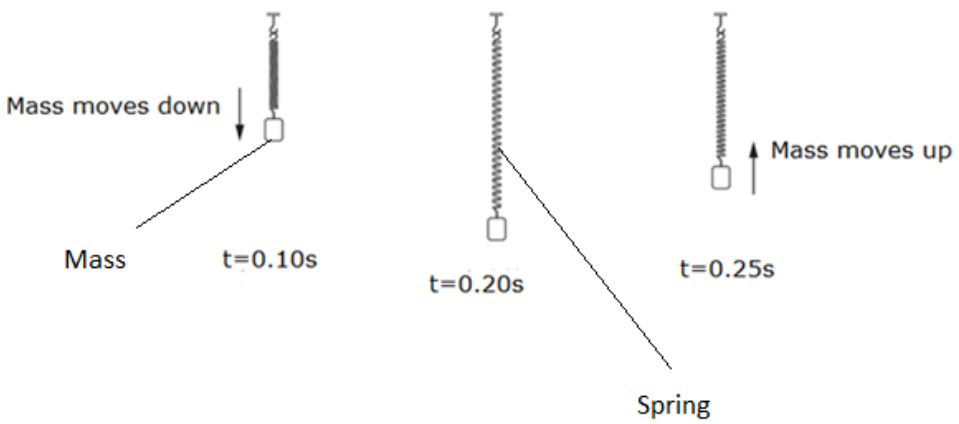


Figure 9

i) Use forces to explain why the mass moves down and then up again. (3)

ii) The mass on the spring is 0.20kg. Calculate the force needed to accelerate this mass by 35m/s^2. (1)

b) Kylie then attaches a piece of card to the bottom of the mass, as shown in Figure 10 and repeats the experiment.

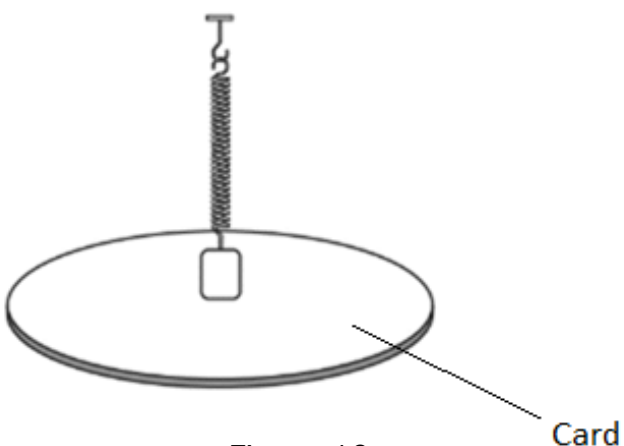


Figure 10

i) Predict how the card will affect the maximum speed of the moving mass. (1)

ii) Explain your answer. (2)

b) Chris is using a chest expander like the one shown in Figure 11 which is made up of five identical springs in parallel.

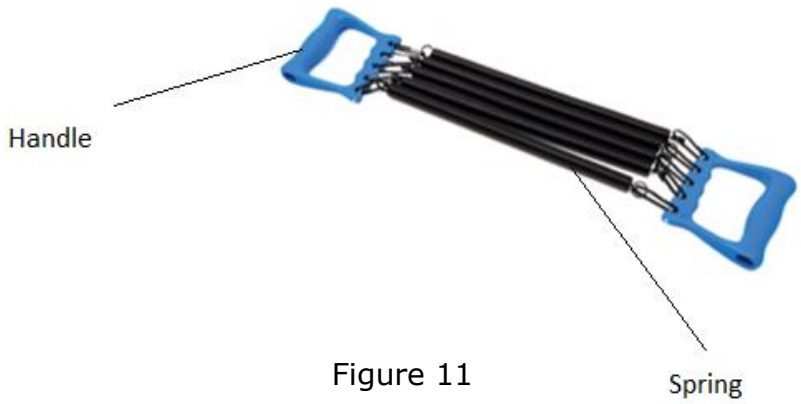


Figure 11

Each spring obeys Hooke's law.

The force F needed to create an extension of Δl can be calculated by using the equation $F = k\,\Delta l$ where k is a constant known as the spring constant. The spring constant quantifies stiffness, and it has a unit of newton per metre (Nm^{-1}).

i) When a force of 100N is applied to the handles of the chest expander, the springs extend by 1cm. Find the spring constant. (2)

ii) Using the equation, $E = \frac{1}{2} F\,\Delta l$, where E is the energy stored in the springs, calculate the energy stored in the springs when extended. (2)

iii) Chris wants to increase the work he does in stretching the springs of the chest expander, so he dismantles it and connects the springs in series (end to end) instead. He secures one end to the wall and pulls the other end with the same force as before, 100 N. Explain how this increases the work done. (4)

(Total 15 marks)

2. Our sun emits different amounts of radiation at different wavelengths. The graphs in Figure 12 show the amount of radiation measured for a given wavelength just outside the Earth's surface and at the Earth's surface.

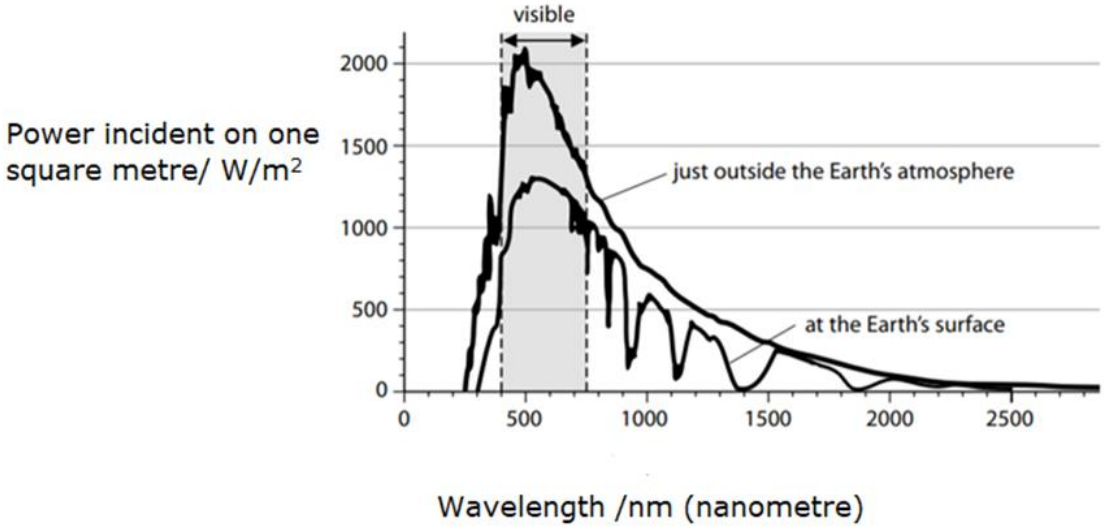


Figure 12

a)

i) Write the approximate value for the minimum wavelength of radiation received from our Sun at the Earth's surface. (1)

ii) Name the type of radiation that has a wavelength of 800 nm. (1)

iii) Explain why there is a difference in the two graphs at a wavelength of 1850 nm. (2)

b) The velocity of light in a vacuum is 300 000 000 m/s (3×10^8 m/s). Calculate the frequency of radiation that has a wavelength of 800 nm. 1 nm = 10^{-9} m (1 / 1 000 000 000 m). (2)

c) Some light is emitted with a wavelength of 600 nm from our Sun. When measured in the spectrum of another star, the light has a wavelength of 598.8 nm. Explain what information this gives about the star. (2)

d) A telescope is used to observe celestial objects. Figure 13 below shows a diagram of a telescope that is being used to look at the Moon. The telescope consists of two converging lenses.

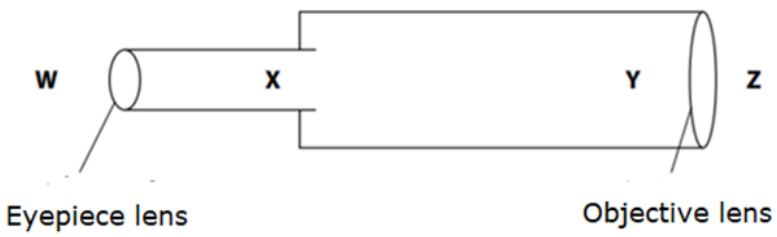


Figure 13

i) The objective lens produces a real image of the Moon. State the position on the diagram which shows where the real image of the Moon is formed. (1)

ii) Describe ONE function of the eyepiece lens. (2)

e) The focal point of a lens is the point where rays from a distant object meet after passing through the lens. Define the term focal length of a lens. (2)

f) Figure 14 shows a ray of light from an object at P. The ray travels through a glass lens to the focal point, F, of the lens.

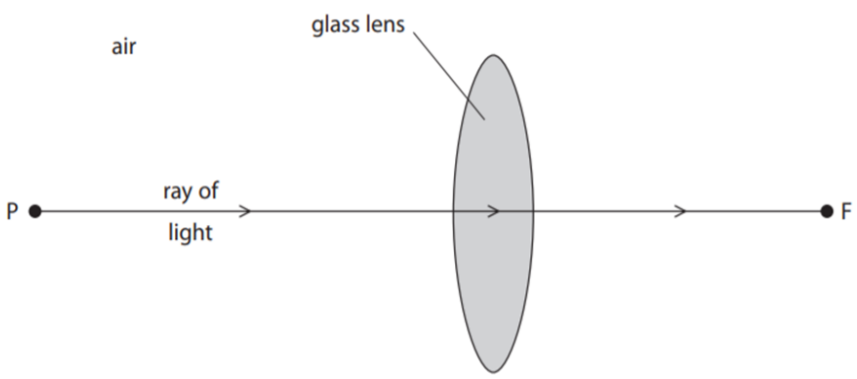
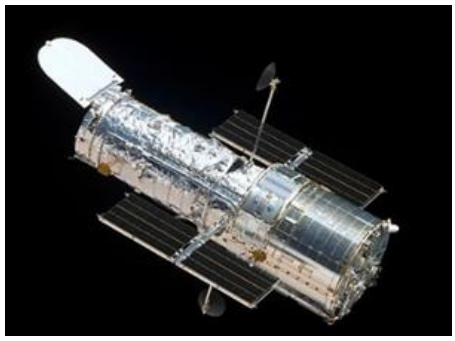


Figure 14

Sketch a graph to show how the speed of the ray varies as it travels from P to F. Speed of the ray in air is 3×10^{8} m/s while the speed of light in glass is 2×10^{8} m/s. (No calculation is required). (4)

g) The Hubble Space Telescope is a space telescope that was launched into low Earth orbit in 1990 and remains in operation. It is not the first space telescope, but it is one of the largest and most versatile. The Hubble telescope is named after astronomer Edwin Hubble and is one of NASA's Great Observatories.



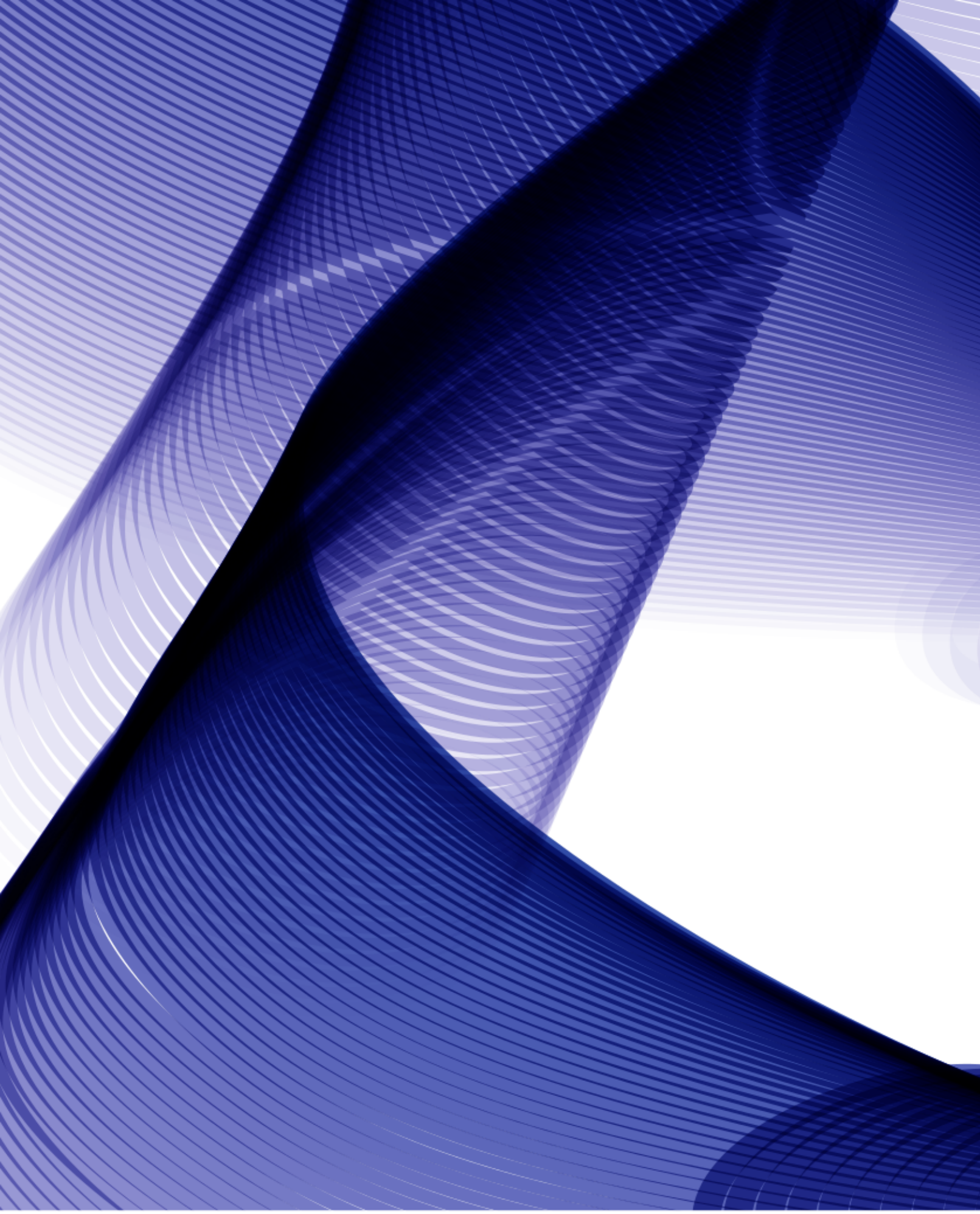
Both the Hubble telescope and the Moon orbit the Earth. The table below shows data of these orbits.

	Average radius of orbit (km)	Time of orbit
Moon	385000	27 days
Hubble telescope	560	96 minutes

i) Find the closest distance between the Moon and the Hubble telescope. (1)

ii) Explain why the distance between the Moon and the Hubble telescope changes. (2)

(Total 20 marks)



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