Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL

A420U10-1

S19-A420U10-1

PHYSICS – A level component 1
Newtonian Physics

MONDAY, 20 MAY 2019 – AFTERNOON

2 hours 15 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**9**	
	2.	**6**	
	3.	**10**	
	4.	**14**	
	5.	**16**	
	6.	**15**	
	7.	**10**	
Section B	**8.**	**20**	
	Total	**100**	

A420U101
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet.**

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B.**

Section **A**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.

Section **B**: 20 marks. Comprehension. You are advised to spend about 40 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

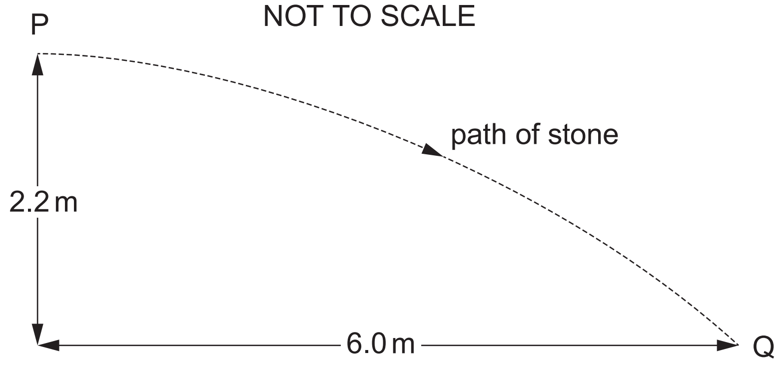
The assessment of the quality of extended response (QER) will take place in question **7*(b)*(ii)**.

Examiner only

SECTION A

*Answer **all** questions.*

1. *(a)* In an investigation of projectile motion, a student throws a stone. It is moving horizontally when it leaves his hand (at point P). It reaches the ground at point Q.



(i) By analysing a video of the stone's flight, its horizontal velocity component, v_h, is found to be almost constant. Discuss whether or not this is to be expected. [2]

....

....

....

(ii) The approximate value of v_h obtained from the video was $9.0\,m\,s^{-1}$. Determine whether this value is consistent with the measured distances recorded in the diagram. Show your reasoning clearly. [3]

....

....

....

....

....

....

Examiner only

(b) Calculate the magnitude **and direction** of the stone's velocity just before it hits the ground. [4]

....

....

....

....

....

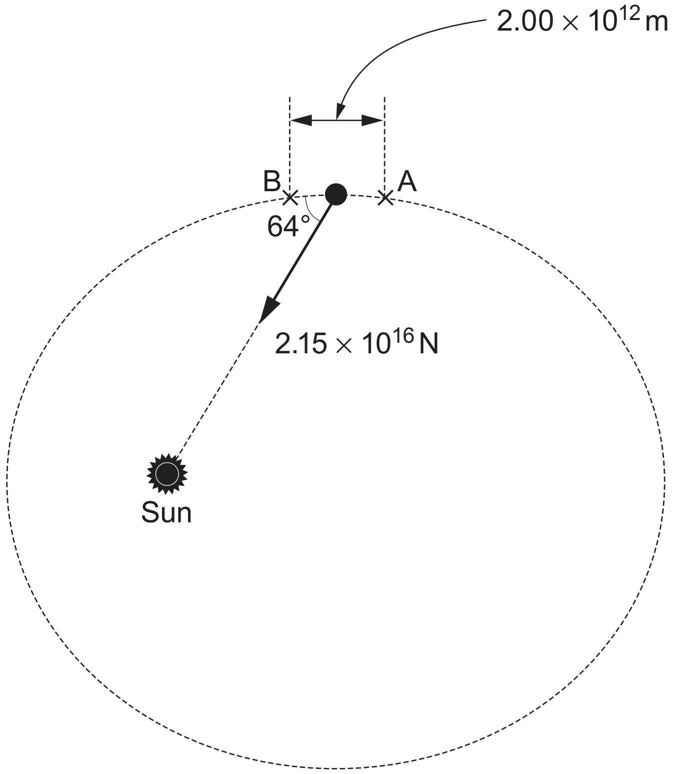
....

9

A420U101 03

Examiner only

2. The diagram shows the dwarf planet, Eris, at one point in its orbit.



(a) Explain why the *moment* (about the centre of the Sun) of the Sun's force on Eris is zero. [1]

....

....

(b) Calculate the *work* done by the Sun's gravitational force on Eris as Eris moves from A to B. The mean values of the force and the angle at which it acts are shown on the diagram. [2]

....

....

....

Examiner only

(c) Showing your reasoning clearly, determine whether your answer to *(b)* is consistent with these data:

Mass of Eris = 1.66×10^{22} kg

Speed of Eris at A = $3460\,\mathrm{m\,s^{-1}}$

Speed of Eris at B = $3770\,\mathrm{m\,s^{-1}}$ [3]

....

....

....

....

....

....

6

A420U101 05

Examiner only

3. *(a)* State the principle of conservation of momentum. [2]

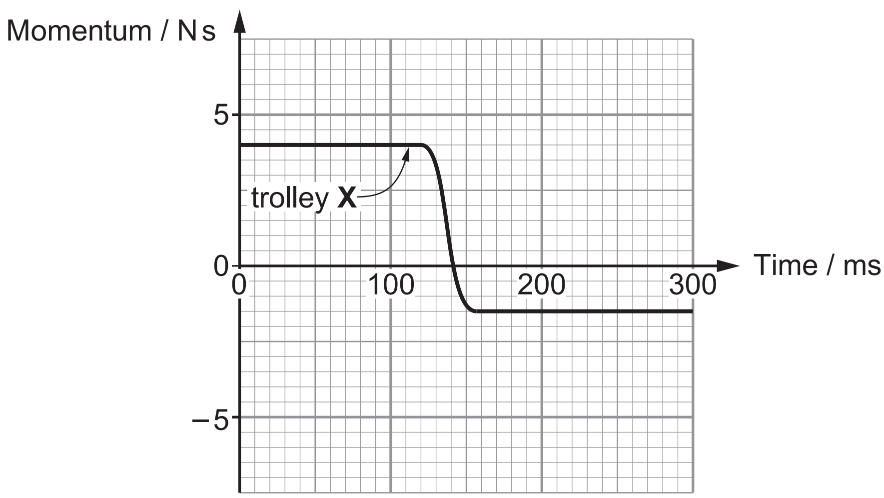
....

....

....

(b) A trolley, **X**, travels towards a stationary trolley, **Y**. See diagram.

The trolleys collide head-on. A momentum-time graph is given for trolley **X**.



(i) Trolley **Y** has a mass of 2.4 kg. Determine its velocity after the collision. [3]

....

....

....

....

....

....

Examiner only

(ii) **Using the same graph grid (opposite)** carefully sketch a graph of **Y**'s momentum between 0 and 300 ms. [3]

(iii) Use the momentum-time graph for **X** to estimate the mean *force* on **X** during the collision. [2]

....

....

....

....

10

A420U101 07

Examiner only

4. *(a)* A fairground ride rotates at a rate of 8.20 revolutions per **minute**.

(i) Calculate:

I. the angular velocity in radians per second; [2]

....

....

....

....

II. the time taken to travel an arc of length 10.0 m for a point P on the ride at 3.80 m from the central axis around which the ride is rotating; [2]

....

....

....

....

III. the acceleration of point P. [2]

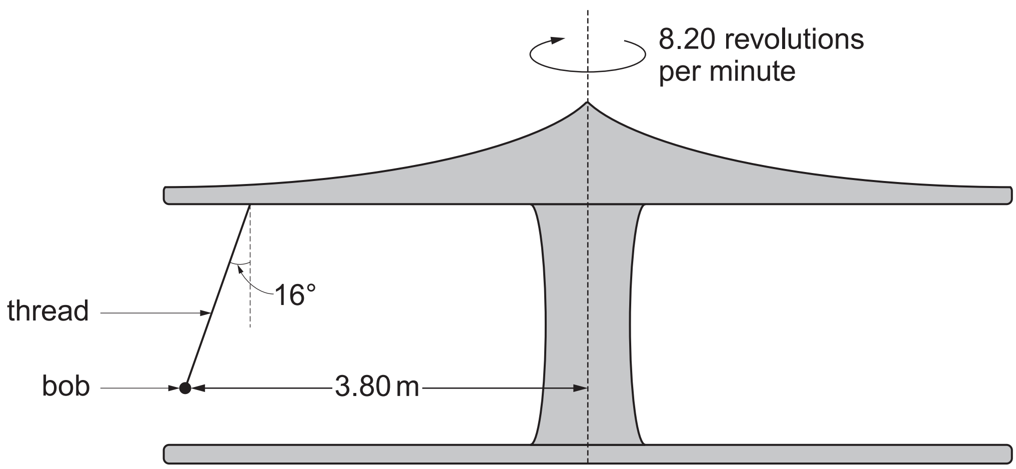
....

....

....

....

(ii) Annushka has been given permission to tie a simple pendulum from the ceiling of the rotating ride. She finds that, when the pendulum has stabilised, it hangs at 16° to the vertical, with its bob at 3.80 m from the central axis (see diagram).



Examiner only

I. The mass of the bob is 0.270 kg. By considering the **vertical** force components on the bob, calculate the tension in the thread. [2]

II. State what provides the centripetal force on the bob and show clearly whether or not this is consistent with the acceleration calculated in *(a)*(i)III. [3]

A420U101 09

(b) Discuss **one** way in which our knowledge of the magnitude of centripetal force has been applied in the design of roads **or** railways **or** a domestic appliance. [3]

14

Examiner only

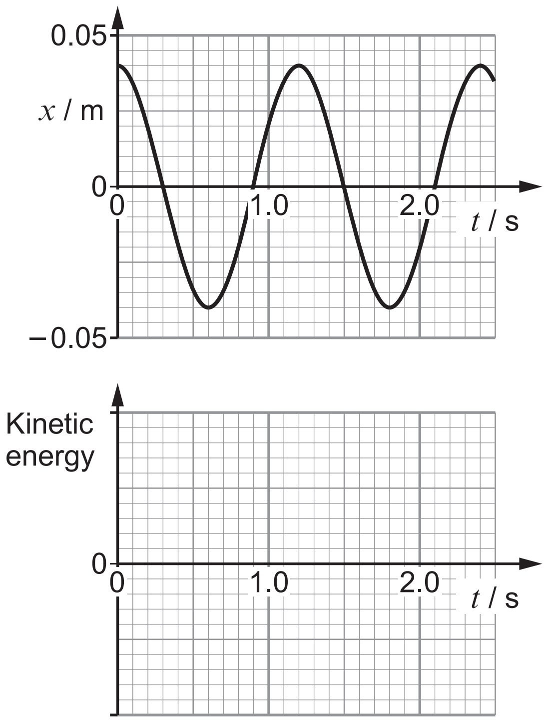
5. *(a)* Define *simple harmonic motion*. [2]

....

....

....

(b) A metal sphere of mass 0.175 kg hangs from a spring whose top end is clamped. The sphere is set oscillating up and down, and a displacement-time graph is plotted.



GRID FOR *(b)*(iii)

(i) Calculate the stiffness constant, k, of the spring. [3]

....

....

....

....

....

....

Examiner only

(ii) Calculate the maximum kinetic energy of the sphere. [3]

....

....

....

....

....

....

(iii) Carefully sketch a graph of the sphere's kinetic energy against time **on the axes provided on the opposite page**. A vertical scale is **not** needed. [3]

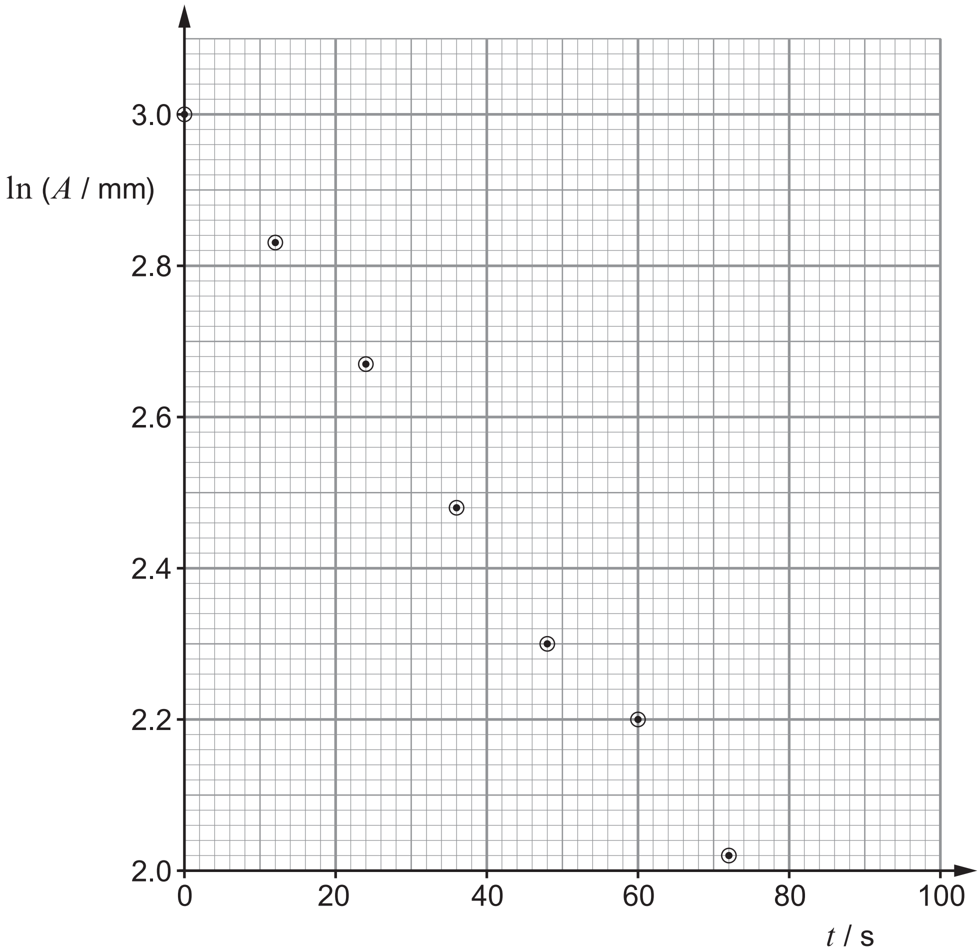
A420U101 11

Examiner only

(c) Over several oscillations it is clear that the amplitude of the sphere's motion is decreasing. Evgeniya suspects that the amplitude is decreasing exponentially, according to the equation:

$$A = A_0 e^{-\lambda t}$$

To check this idea she uses readings of the amplitude, A, taken at regular intervals to plot $\ln (A / \text{mm})$ against time, t.



Evgeniya claims that the points she has plotted support the exponential decrease of amplitude. Justify her claim **and** determine a value for λ. [5]

....

....

....

....

....

....

....

16

A420U101
13

BLANK PAGE

Examiner only

6. *(a)* Vadim uses a ruler to measure the sides of a copper block. He records the measurements as:

length = 50 ± 1 mm, breadth = 42 ± 1 mm, height = 36 ± 1 mm.

Using an electronic balance he measures the mass of the block as 670.85 ± 0.01 g.

Use Vadim's data to answer the following.

(i) Determine a value for the density of copper in kg m^{-3} and the **absolute** uncertainty in this value. [4]

....

....

....

....

....

....

....

....

(ii) Determine the number of atoms per m^3 of copper. The uncertainty is **not** required. The atomic mass of copper is 63.5 u. [2]

....

....

....

....

Examiner only

(b) (i) I. Calculate the number of molecules per m^3 for a gas (assumed to be ideal) at a temperature of 15 °C and a pressure of 101 kPa. [3]

....

....

....

....

....

....

II. When asked why there are far fewer gas molecules per m^3 than atoms per m^3 in the copper block, a student replies, "Each molecule of the gas takes up much more space." Discuss whether or not he is right. [2]

....

....

....

....

(ii) I. Two gases have molecular masses $m_{(1)}$ and $m_{(2)}$. Show clearly that when the gases are at the same temperature, the ratio of the rms speeds of their molecules is: [2]

$$\frac{c_{\mathrm{rms}(1)}}{c_{\mathrm{rms}(2)}} = \sqrt{\frac{m_{(2)}}{m_{(1)}}}$$

....

....

....

....

Examiner only

II. Calculate the percentage difference in the rms speeds of nitrogen and oxygen molecules in the same sample of air. Take the percentage difference to be defined as:

$$\frac{\text{rms speed for nitrogen} - \text{rms speed for oxygen}}{\text{rms speed for oxygen}} \times 100\%$$

[Molecular mass for nitrogen = 28.0 u. Molecular mass for oxygen = 32.0 u.] [2]

....

....

....

....

....

....

15

BLANK PAGE

Examiner only

7. *(a)* State what is meant by the *heat*, Q, entering a system. [2]

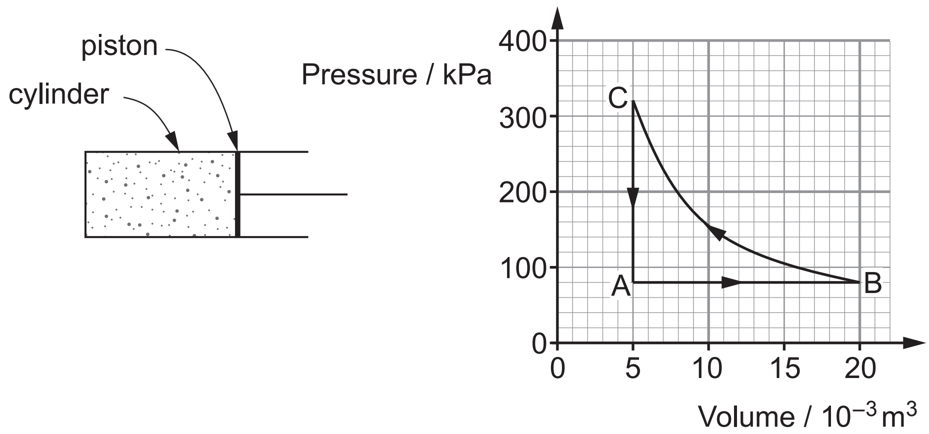
....

....

....

....

(b) A gas (assumed ideal) is contained in a cylinder with a moveable, leak-proof piston. The gas is taken through the cycle ABC shown on the graph. The stage BC takes place at constant temperature.



(i) Calculate the work done by the gas in the stage AB. [2]

....

....

....

....

Examiner only

(ii) For each of the stages AB, BC and CA separately, **and** for the cycle as a whole, use the first law of thermodynamics to explain whether heat flows into the system or out of the system. Calculations are **not** required. [6 QER]

10

SECTION B

Answer **all** *questions.*

8. Read through the following article carefully. Paragraph

A little bit of information about stars by Ignasi Lluis Marxuach

Figure 1 shows the three different routes for the life cycle of different sized stars, from small stars, through medium (Sun-like) stars to explosive high mass stars. For some reason, exam boards tend to ignore the smallest category of stars (red dwarfs) because their cores never become hot enough to produce red giant stars. 1

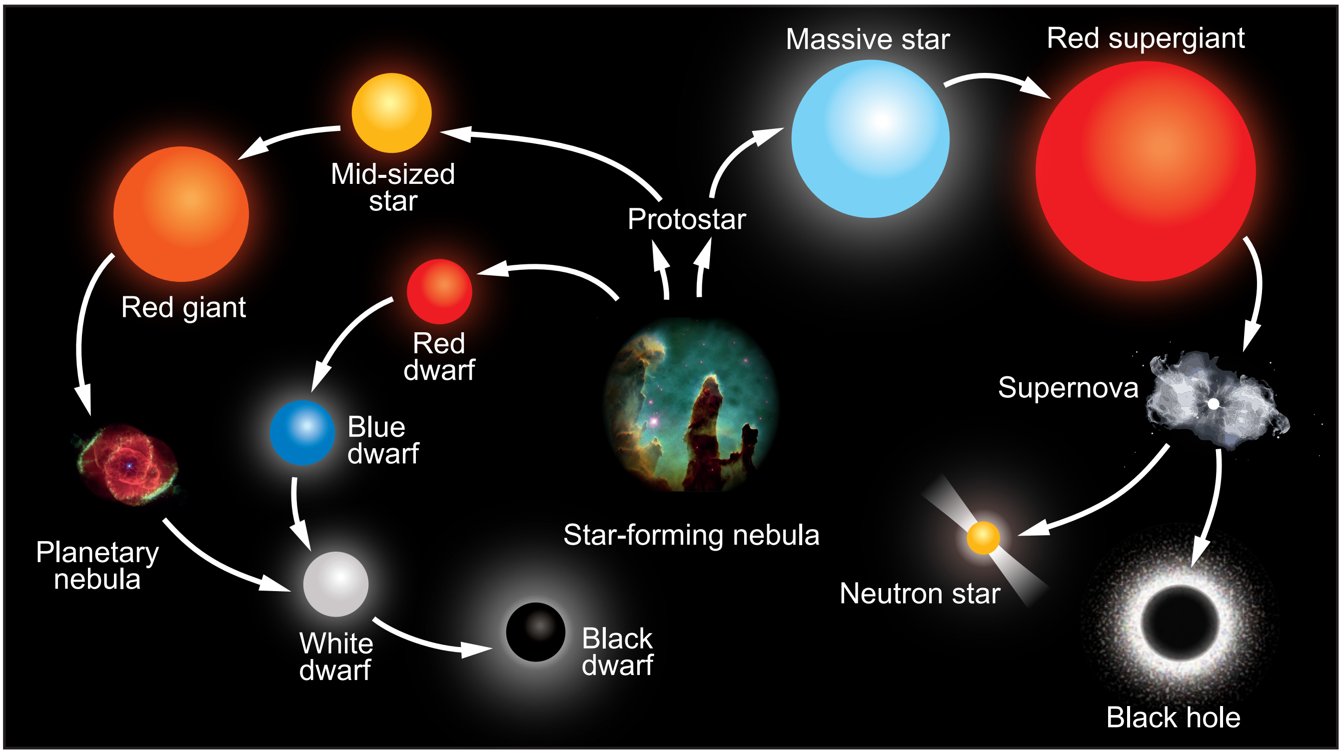


Figure 1

Stars are formed from the gravitational collapse of gas clouds called *nebulae*. Gravitational potential energy is converted to internal energy of hot gases which then emit radiation. This means that the search for new stars usually involves the use of infra-red telescopes in space. 2

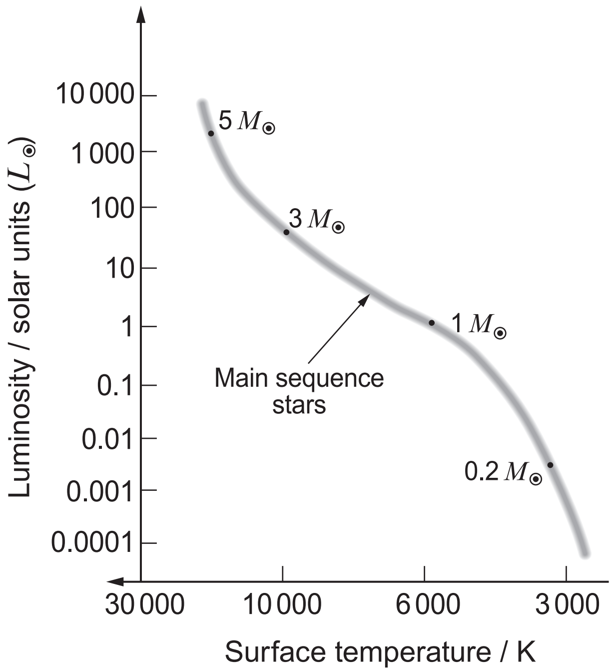
The images on the next page show the same gas clouds but the image on the right (**Figure 3**) is taken with visible light while the image on the left (**Figure 2**) is taken with infra-red. Notice how the gas clouds are transparent to infra-red so that stars behind the gas clouds become visible at infra-red wavelengths. The areas where stars are forming are those areas of the gas cloud that appear to be emitting radiation at both infra-red and visible wavelengths. 3

Paragraph

Figure 2 (infra-red image)

Figure 3 (visible light image)

Once the core of a young star is hot enough to initiate hydrogen fusion it is called a *main sequence star*. Such stars are stable, lasting for millions or billions of years and account for around 90% of all stars. They are stable because the outward pressures due to hot gases and electromagnetic radiation are balanced by the inward pressure due to gravity. 4
Larger main sequence stars have denser cores which means that the rate of fusion and the temperature are also greater. A graph of luminosity against temperature for main sequence stars is rather useful, although slightly less useful than it should be because astronomers, apparently, don't realise that values should increase going to the right on normal graphs.



$M_\odot$ = mass of the Sun
$L_\odot$ = solar unit (luminosity of the Sun)

Graph 1

Notice that nearly all main sequence stars have surface temperatures in the range 3 000 K to 20 000 K. This makes them suitable for analysing using visible light. 5

Paragraph

Another thing to note from the luminosity against surface temperature graph is that these factors seem to depend on the mass of the star. It turns out that there is only one factor that determines a star's position on the graph – its mass. The relationship between mass and luminosity for a star is quite complicated and comes in four parts. 6

$L = 0.23\,M^{2.3}$	for	$M < 0.43$	**Equation 1**
$L = M^4$	for	$0.43 < M < 2$	**Equation 2**
$L = 1.5\,M^{3.5}$	for	$2 < M < 20$	**Equation 3**
$L = 3200\,M$	for	$M > 20$	**Equation 4**

Note that these equations have been simplified by having the mass of the star (M) in units of the solar mass ($M_\odot$), and luminosity in units of the solar luminosity ($L_\odot$).

These relationships are rather useful and should explain why large mass stars can be found more easily using ultraviolet telescopes, but they can do so much more when combined with Einstein's equation. 7

$$E = \Delta mc^2 \qquad \textbf{Equation 5}$$

You might, in the first instance, be excused for thinking that a 10 $M_\odot$ star will burn 10 times longer than the Sun. This, however, could not be further from the truth. Use of Equation 3 should tell you that a 10 $M_\odot$ star will burn approximately 5000 times brighter. By using Einstein's equation and making a few simplifying assumptions, we find the expected lifetime of a 10 $M_\odot$ star to be, in fact, approximately 500 times less than that of the Sun. Some might say that a large star "burns the candle at both ends" but it's more accurate to say that it burns the candle at 5000 ends simultaneously. 8

It should be reasonably clear that there is a negative correlation between the mass of a star and its lifetime. Another two star variables that are (bizarrely) negatively correlated are the mass of a white dwarf and its radius. However, that is a completely different story which is beyond the remit of this 2019 Space Odyssey. 9

Examiner only

Answer the following questions in your own words. Extended quotes from the original article will not be awarded marks.

(a) Write down the complete life cycle of a mid-sized star (see **Figure 1**). [1]

Star-forming nebula →

(b) Suggest an advantage of placing telescopes *in space* to observe new stars (see Paragraph 2). [1]

....

....

....

(c) In **Figure 2** or **3** below, mark with an **X** one area where new stars are forming (see Paragraph 3 and **Figures 2** & **3**). [1]

Figure 2 (infra-red image)

Figure 3 (visible light image)

Examiner only

(d) Explain, using Newton's 2^{nd} law, how electromagnetic radiation exerts pressure inside a main sequence star (see Paragraph 4). [3]

(e) Explain why a more massive star has a higher density in its core and why this leads to a higher temperature (see Paragraph 4). [3]

(f) (i) Show that the wavelength of maximum emission for the hottest main sequence stars is approximately 150 nm (see Paragraph 5 or Graph 1). [2]

(ii) Discuss whether or not it is appropriate to analyse the hottest main sequence stars using visible light when their wavelength of maximum emission is 150 nm (see Paragraph 5). [2]

Examiner only

(g) Determine whether or not the star of mass 0.2 $M_{\odot}$ is plotted at approximately the correct luminosity in Graph 1 (see Equations 1–4 and Graph 1). [2]

(h) Explain why a 10 $M_{\odot}$ star has a lifetime that is 500 times shorter than that of the Sun, including any simplifying assumptions (see Paragraph 8 and Equations 1–5). [4]

(i) Explain **briefly** what the author means when he states that a white dwarf's mass and radius are negatively correlated (see Paragraph 9). [1]

20

END OF PAPER

BLANK PAGE

Examiner only

For continuation only.