



If you answer this Topic put a cross in this box .

**Topic A – Astrophysics**

1. (a) A student writes out some revision notes about astrophysics, putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

A white dwarf has a **high** luminosity and a high temperature.  
low

There are **three** errors for you to correct in the sentences below.

Photographic emulsion can give a **higher** resolution than a CCD.

A **red giant** can be used to find the distance to nearby galaxies.

A **white dwarf** will eventually turn into a black hole.

Luminosity has the same units as **power**.

A Hertzsprung-Russell diagram shows **luminosity** against temperature.

A star spends most of its life as a **red giant**.

(6)



(b) Wien's law can be written as

$$\lambda_{\max} T = 2.90 \times 10^{-3} \text{ m K}$$

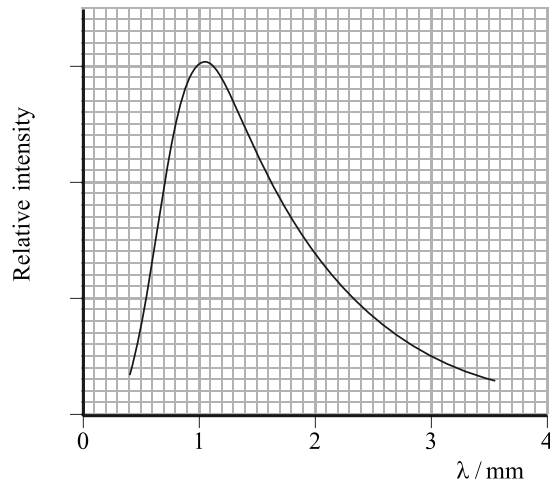
(i) Explain clearly what is meant by each symbol in Wien's law.

$\lambda_{\max}$  .....

$T$  .....

(2)

(ii) The graph shows the wavelength distribution for radiation detected by the COBE satellite.



To what part of the electromagnetic spectrum does this radiation belong?

.....  
(1)

(iii) Use the graph to determine the temperature of the source of these emissions.

.....  
.....  
.....

Temperature = .....  
(3)



(c) A star that is considerably more massive than the Sun may end its life as a supernova. During a supernova explosion approximately  $1 \times 10^{46}$  J of energy can be released.

(i) State the minimum mass of a star that can become a supernova.

.....  
(1)

(ii) Use the data below to estimate how much energy is given off by the Sun during its approximate lifetime.

$$\text{Luminosity} = 3.9 \times 10^{26} \text{ W}$$

$$\text{Approximate lifetime} = 1 \times 10^{10} \text{ y}$$

.....  
.....  
.....

$$\text{Energy} = \text{.....}$$

(3)

(iii) Estimate the ratio of the energy that is released when a supernova explodes to the total energy given off by the Sun during its lifetime.

.....  
.....

$$\text{Ratio} = \text{.....}$$

(2)

(iv) When a supernova explodes, the mass of its core remnant determines its future. State the two possible outcomes and how each depends on the mass of the remnant.

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.....  
.....  
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.....  
.....  
.....  
(3)



Leave blank

- (d) (i) If the Earth (mass =  $6.0 \times 10^{24}$  kg) had the same density as a neutron star it would be approximately 150 m in radius. Show that the average density of such an object would be approximately  $4 \times 10^{17}$  kg m<sup>-3</sup>.

.....  
.....  
.....  
.....

(2)

- (ii) Explain how the neutrons in a neutron star were formed, both during and after the main sequence. You may be awarded a mark for the clarity of your answer.

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.....  
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.....  
.....  
.....

(4)

- (e) (i) Use the data below to calculate the intensity of the Sun as measured from Mars and from Earth.

Luminosity of the Sun =  $3.90 \times 10^{26}$  W

Sun – Mars distance =  $2.28 \times 10^8$  km

Sun – Earth distance =  $1.50 \times 10^8$  km

.....  
.....  
.....  
.....

Intensity from Mars = ..... Intensity from Earth = .....

(3)

- (ii) Hence show that the brightness of the Sun as seen from Mars is approximately 40% of its brightness from Earth.

.....  
.....

(2)

(Total 32 marks)

Q1  
□ □



If you answer this Topic put a cross in this box .

**Topic B – Solid Materials**

2. (a) A student writes out some revision notes about solid materials, putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

A **malleable** material will not deform plastically.  
brittle

There are **three** errors for you to correct in the sentences below.

Stress concentrations can build up around **cracks**.

An elastomer can be stretched **plastically** to over twice its original length.

Nylon and Perspex are examples of **rigid thermosets**.

Creep is caused by **plastic** flow in a material over time.

A metal can be **annealed** by heating it to red heat and then allowing it to cool slowly.

Chipboard is an example of a **fibre** composite material. (6)

- (b) Energy density, or work done per unit volume, can be calculated using the equation

$$\text{Energy density} = \frac{1}{2} \times \text{stress} \times \text{strain}$$

- (i) Show that this equation is homogeneous with respect to units.

.....  
.....  
.....  
.....

(3)



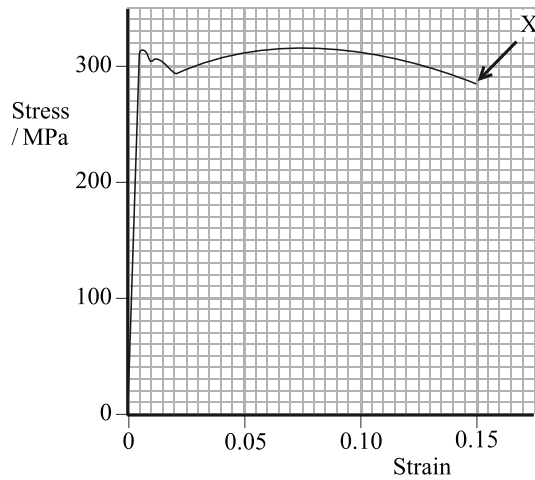
(ii) A material of initial length 2.0 m stretches elastically by 8.0 mm when a stress of  $5.2 \times 10^8 \text{ Pa}$  is applied. Calculate the work done per unit volume.

.....  
.....  
.....

Work done per unit volume = .....

(3)

(iii) A sample of mild steel stretches as shown.



Estimate the energy density of mild steel when stretched to its breaking point X.

.....  
.....  
.....  
.....

Energy density = .....

(3)



(c) Spider silk (or cobweb thread) has incredible properties. It is stronger than steel, extremely tough and can withstand great strain before it breaks. It can stop a relatively large insect, such as a bee, without breaking.

(i) Explain the meaning of the following words as used in the passage.

Tough .....

.....

Strong .....

.....

(3)

(ii) A bee flies into a cobweb thread of radius  $2.0 \mu\text{m}$ . This causes a stress of  $3.0 \times 10^8 \text{ Pa}$  in the thread. Calculate the force exerted by the bee.

.....

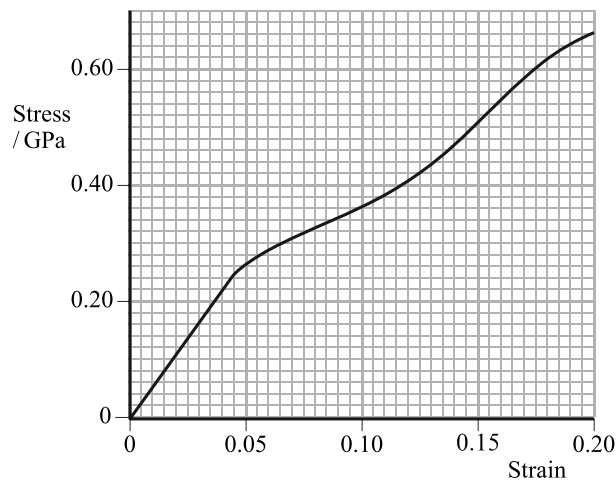
.....

.....

Force = .....

(3)

(iii) The graph below shows how the strain of spider silk varies as the stress applied to it varies.



Mark clearly on the graph the part of the line where the silk is most stiff.

(1)





Leave  
blank

(iv) Calculate the Young modulus of the silk when it is initially stressed.

.....  
.....  
.....

Young modulus = .....

**(3)**

(d) (i) Describe the processes of work hardening and quench hardening.  
You may be awarded a mark for the clarity of your answer.

.....  
.....  
.....  
.....  
.....  
.....  
.....

**(4)**

(ii) Name two properties of a metal that are increased when it is work hardened.

.....  
.....

**(2)**

(iii) What effect does work hardening have on the dislocations in a metal?

.....  
.....

**(1)**

**(Total 32 marks)**

**Q2**

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If you answer this Topic put a cross in this box .

**Topic C – Nuclear and Particle Physics**

3. (a) A student writes out some revision notes about nuclear and particle physics, putting some keywords in bold. Some of the keywords are wrong.

Circle the word or phrase that is incorrect and write below it a correct word or phrase which would take the place of the wrong word or phrase. An example is given.

The exchange particle for the electromagnetic interaction is the **gluon**.  
photon

There are **three** errors for you to correct in the sentences below.

In  **$\beta^+$  decay** an up quark turns into a down quark.

A **muon** is made from one quark and one antiquark.

Quarks with a  $+\frac{2}{3}$  charge are called **up, charm and strange**.

**Binding energy** is defined as the energy needed to split a nucleus into separate nucleons.

A baryon is a type of **hadron**.

Electrostatic repulsion acts between **neutrons** in a nucleus.

(6)



(b) (i) A neutron star is a star composed predominantly of neutrons. If the Earth (mass =  $6.0 \times 10^{24}$  kg) had the same density as a neutron star, it would be approximately 150 m in radius. Show that the average density of such an object would be approximately  $4 \times 10^{17}$  kg m<sup>-3</sup>.

.....  
.....  
.....  
.....  
(2)

(ii) Calculate the number of neutrons present in such an object. ( $u = 1.66 \times 10^{-27}$  kg)

.....  
.....  
Number of neutrons = .....  
(2)

(iii) By considering this object as a single, enormous nucleus, calculate the radius of a single neutron.

.....  
.....  
.....  
Radius = .....  
(2)

(iv) When a neutron star is formed, protons in a star combine with electrons to produce neutrons and neutrinos. Write a nuclear equation for this reaction, including proton and nucleon numbers.

(2)

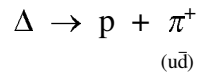


(v) State and explain what type of fundamental interaction must mediate this reaction. You may be awarded a mark for the clarity of your answer.

.....  
 .....  
 .....  
 .....

**(4)**

(c) The following strong reaction has been observed. The charge on the delta particle ( $\Delta$ ) has not been shown.



(i) Name the exchange particle that is involved in this decay.

.....

**(1)**

(ii) State the charge of the delta particle. Justify your answer.

.....  
 .....  
 .....

**(2)**

(iii) State the quark composition of the proton.

.....

**(1)**

(iv) Using appropriate conservation laws, explain what type of particle the delta particle is and deduce its quark composition.

.....  
 .....  
 .....  
 .....  
 .....

**(3)**



Leave blank

- (d) (i) On the axes below sketch a graph showing the energy spectrum for  $\beta^-$  decay from a single source.

Number of  $\beta^-$  particles



Kinetic energy of  $\beta^-$  particles

(2)

- (ii) Explain how this energy spectrum led to the suggestion that an additional undetected particle must be emitted during the decay.

.....  
.....  
.....  
.....  
.....  
.....  
.....

(3)

- (iii) State the full name of the other lepton that is emitted during the  $\beta^-$  decay.

.....

(2)

Q3

(Total 32 marks)

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N 2 3 5 7 5 A 0 1 3 2 0



(iii) Radioactive half-life is defined as the average time taken for the activity of a sample to fall to half of its initial value. Explain the difference between the radioactive half-life and the effective half-life. You may be awarded a mark for the clarity of your answer.

.....

.....

.....

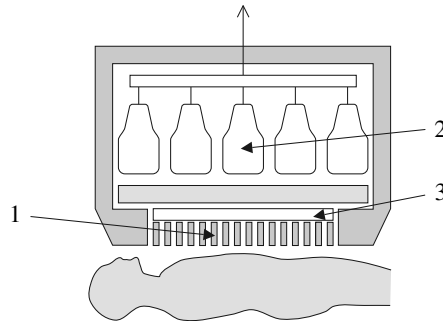
.....

.....

.....

(4)

(c) The diagram shows a simplified cross-section of a gamma camera.



Name and explain the function of the numbered parts of the gamma camera.

	Name	Function
1		
2		
3		

(6)



(d) The reflection coefficient  $\alpha$  for ultrasound travelling from soft tissue into bone is 0.30.

(i) What percentage of the ultrasound pulse that reaches the bone will be transmitted into the bone?

.....  
 (1)

(ii) The specific acoustic impedance of the soft tissue is  $1.63 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$ . Calculate the specific acoustic impedance of this bone. Use the equation below.

$$Z_1 = Z_2 \left( \frac{1 + \sqrt{\alpha}}{1 - \sqrt{\alpha}} \right)$$

.....  
 .....  
 .....  
 .....

Specific acoustic impedance = .....  
 (3)

(iii) The density of the soft tissue is  $1060 \text{ kg m}^{-3}$ . Calculate the speed of ultrasound as it travels through the tissue.

.....  
 .....  
 .....  
 .....

Speed = .....  
 (2)





Leave blank

(e) (i) Give two reasons why MeV X-rays are preferred to keV X-rays for therapy.

- 1. ....  
.....
  - 2. ....  
.....
- (2)**

(ii) Explain, with the aid of a diagram, the benefit to the patient of using a multiple beam technique during therapy.

- .....
  - .....
  - .....
  - .....
  - .....
- (3)**

(iii) A patient is 0.50 m from a point source of X-rays. The intensity of this X-ray beam at this point is  $8.0 \times 10^5 \text{ W m}^{-2}$ . Calculate the intensity of this beam for a radiographer who is 10 m from this source.

- .....
  - .....
  - .....
- (2)**

**Q4**

**(Total 32 marks)**

**TOTAL FOR PAPER: 32 MARKS**

**END**



### List of data, formulae and relationships

#### Data

Speed of light in vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$	
Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to the Earth)
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19} \text{ C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$	
Molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	

#### Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

$$x = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2ax$$

#### Forces and moments

Moment of  $F$  about  $O = F \times$  (Perpendicular distance from  $F$  to  $O$ )

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

#### Dynamics

Force  $F = m \frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$

Impulse  $F \Delta t = \Delta p$

#### Mechanical energy

Power  $P = Fv$

#### Radioactive decay and the nuclear atom

Activity  $A = \lambda N$  (Decay constant  $\lambda$ )

Half-life  $\lambda t_{\frac{1}{2}} = 0.69$



**Electrical current and potential difference**

Electric current  $I = nAQv$

Electric power  $P = I^2R$

**Electrical circuits**

Terminal potential difference  $V = \mathcal{E} - Ir$  (E.m.f.  $\mathcal{E}$ ; Internal resistance  $r$ )

Circuit e.m.f.  $\Sigma \mathcal{E} = \Sigma IR$

Resistors in series  $R = R_1 + R_2 + R_3$

Resistors in parallel  $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

**Heating matter**

Change of state energy transfer =  $l\Delta m$  (Specific latent heat or specific enthalpy change  $l$ )

Heating and cooling energy transfer =  $mc\Delta T$  (Specific heat capacity  $c$ ; Temperature change  $\Delta T$ )

Celsius temperature  $\theta / ^\circ\text{C} = T/\text{K} - 273$

**Kinetic theory of matter**

Temperature and energy  $T \propto$  Average kinetic energy of molecules

Kinetic theory  $p = \frac{1}{3}\rho\langle c^2 \rangle$

**Conservation of energy**

Change of internal energy  $\Delta U = \Delta Q + \Delta W$  (Energy transferred thermally  $\Delta Q$ ; Work done on body  $\Delta W$ )

Efficiency of energy transfer  $= \frac{\text{Useful output}}{\text{Input}}$

Heat engine maximum efficiency  $= \frac{T_1 - T_2}{T_1}$

**Astrophysics**

Stefan-Boltzmann law  $L = \sigma T^4 \times \text{surface area}$  (Luminosity  $L$ ; Stefan constant  $\sigma$ )

Wien's law  $\lambda_{\text{max}}T = 2.898 \times 10^{-3} \text{ m K}$

Estimating distance intensity =  $L/4\pi D^2$

Mass-energy  $\Delta E = c^2\Delta m$  (Speed of light in vacuum  $c$ )

**Solid materials**

Hooke's law  $F = k\Delta x$

Stress  $\sigma = \frac{F}{A}$

Strain  $\varepsilon = \frac{\Delta l}{l}$

Young modulus  $E = \frac{\text{Stress}}{\text{Strain}}$

Work done in stretching  $\Delta W = \frac{1}{2}F\Delta x$  (provided Hooke's law holds)

Energy density = Energy/Volume



N 2 3 5 7 5 A 0 1 9 2 0

***Nuclear and particle physics***

Nuclear radius	$r = r_0 A^{1/3}$	(Nucleon number $A$ )
Mass-energy	$1 \text{ u} = 930 \text{ MeV}$	
Quark charge/ $e$	up = $+\frac{2}{3}$ ; down = $-\frac{1}{3}$	

***Medical physics***

Effective half-life	$\frac{1}{t_e} = \frac{1}{t_r} + \frac{1}{t_b}$	(Radioactive half-life $t_r$ ; Biological half-life $t_b$ )
Inverse square law	$I = P / 4\pi r^2$	(Intensity $I$ ; Power $P$ of a point source; Distance $r$ from point source)
Acoustic impedance	$Z = c \rho$	(Speed of sound in medium $c$ ; Density of medium $\rho$ )
Reflection coefficient	$= (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$	

***Experimental physics***

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

***Mathematics***

	$\sin(90^\circ - \theta) = \cos \theta$	
Equation of a straight line	$y = mx + c$	
Surface area	cylinder = $2\pi rh + 2\pi r^2$ sphere = $4\pi r^2$	
Volume	cylinder = $\pi r^2 h$ sphere = $\frac{4}{3}\pi r^3$	
For small angles:	$\sin \theta \approx \tan \theta \approx \theta$ $\cos \theta \approx 1$	(in radians)

