Centre No.						Paper Reference							Surname	Initial(s)
Candidate No.						6	7	3	3	/	0	1	Signature	

Paper Reference(s)

6733/01

Edexcel GCE

Physics

Advanced Subsidiary

Unit Test PHY3: Topics

Thursday 15 January 2009 – Afternoon

Time: 30 minutes

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1A	
2B	
3C	
4D	
Total	

Materials required for examination	Items included with question papers
Nil	Nil

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your surname, initial(s) and signature.
Answer ONE question only.
Indicate which Topic you are answering by putting a cross in the box (☒) at the start of the Topic.
If you change your mind, put a line through the box (☒) and then indicate your new question with a cross (☒).
In calculations you should show all the steps in your working, giving your answer at each stage.
Calculators may be used.
Include diagrams in your answers where these are helpful.

Information for Candidates

The marks for individual questions and the parts of questions are shown in round brackets.
The total mark for this paper is 32.
The list of data, formulae and relationships is printed at the end of this booklet.

Advice to Candidates

You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking account of your use of grammar, punctuation and spelling.

Printer's Log. No.
H32827A
W850/R6733/57570 6/6/6/5/2/1

H32827A0124

Turn over

edexcel
advancing learning, changing lives

Leave blank

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

Topic A – Astrophysics

1. (a) On the axes, sketch a graph to illustrate Wien's law. You do not need to add scales but should include labels and units for each axis.

(3)

(b) The star Suhail (λ-Vel) has a very high luminosity of 9900 $L_\odot$, and a surface area of 2.6×10^{23} m^2. $L_\odot$ represents the luminosity of the Sun: $L_\odot = 3.9 \times 10^{26}$ W.

(i) Show that the surface temperature of Suhail is approximately 4000 K.

....

....

....

....

(3)

(ii) The radius of the Sun $r_\odot$ is 6.96×10^{8} m. Calculate the radius of Suhail in terms of $r_\odot$.

....

....

....

....

....

(3)

Leave blank

(iii) Suggest what type of star Suhail is. Justify your answer, referring to all relevant numerical values.

....

....

....

....

....

....

....
(4)

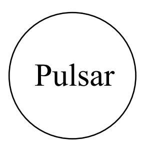
(c) (i) What type of star is a pulsar?

....
(1)

(ii) State the minimum mass of a pulsar in terms of solar masses.

....
(1)

(iii) Complete a labelled diagram of a pulsar. Show clearly its axis of rotation, the shape of its magnetic field and where it emits radio waves from.



(3)

Leave blank

(iv) Explain why a pulsar that emits continuous radio waves appears to emit pulses of radio waves.

....

....

....

....

(2)

(d) (i) Cepheid variable stars have an imbalance in the forces within them which causes them to expand and contract regularly. Explain how observations of Cepheids can be used to estimate distances to nearby galaxies. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

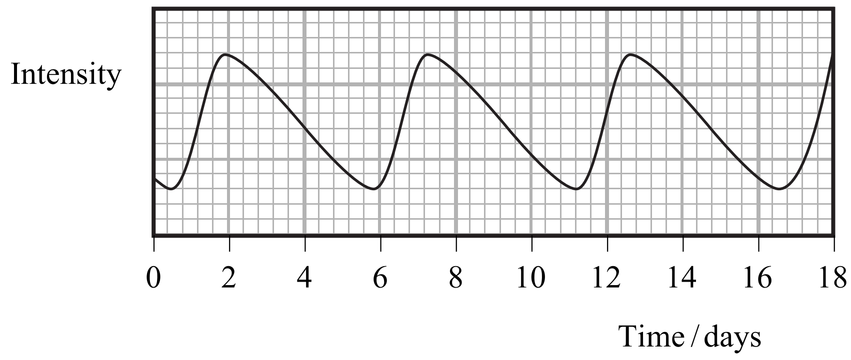
....

....

....

(4)

(ii) The varying luminosity of the Cepheid variable star δ – Cephei is shown in the graph.



Take readings from the graph to determine accurately the period of this Cepheid variable.

....

....

....

....
(2)

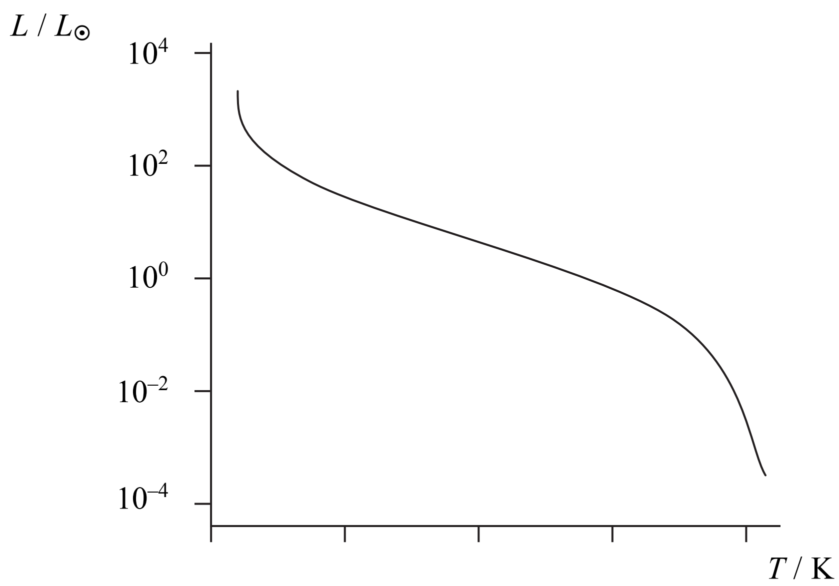
Leave blank

H 3 2 8 2 7 A 0 5 2 4

Turn over

Leave blank

(e) Astronomers can use a Hertzsprung-Russell diagram to classify stars.



(i) Add a suitable scale to the T-axis.

(2)

(ii) Sirius A and Sirius B form a binary star system. Sirius A is a hydrogen-fusing star with a temperature of 9900 K. Sirius B has a temperature of 25 000 K but is smaller than the Earth.

Mark the positions of these stars on the Hertzsprung-Russell diagram.

(2)

(iii) What type of star is Sirius B?

....

(1)

(iv) Suggest why astronomers would have difficulty in observing both stars in this binary system.

....

....

(1)

Q1

(Total 32 marks)

H 3 2 8 2 7 A 0 6 2 4

BLANK PAGE

H 3 2 8 2 7 A 0 7 2 4

Leave blank

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

Topic B – Solid Materials

2. (a) On the axes, sketch a graph to illustrate Hooke's law. You do not need to add scales but should include labels and units for each axis.

(3)

(b) (i) Complete the table of definitions.

Term	**Definition**
Ductile	
	The stress at which plastic deformation begins when a material is loaded.
	Heat treatment that involves heating followed by rapid cooling.
Elastic	
	Behaviour which occurs when a loaded material deforms plastically with no additional force.
	Failure mechanism caused by repeatedly stressing a material.

(6)

Leave blank

(ii) State the difference between a brittle material and a tough material.

....

....

....
(2)

(c) To search for oil underground, holes that are several kilometres deep are drilled. The drill has an average diameter of 12.7 cm. It is stressed longitudinally by a force of 1.42 MN.

(i) Show that the average stress exerted on the drill is approximately $1 \times 10^8\,\mathrm{N\,m^{-2}}$.

....

....

....

....

....
(4)

(ii) Calculate the average strain in the drill. The average Young modulus of the material from which the drill is made is 1.65×10^{11} Pa.

....

....

....

....
(2)

(iii) When this force is exerted on the drill it extends by 1.33 m.

Calculate the initial length of the drill.

....

....

....
(2)

Leave blank

(iv) Calculate the strain energy stored in the drill when it is stressed in this way.

....

....

....

....

(2)

(d) (i) Draw a labelled diagram to show what is meant by an edge dislocation.

(2)

(ii) Add a labelled line to your diagram to show a slip plane.

(1)

(iii) Describe how the presence of dislocations can reduce the risk of metals failing by cracking. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

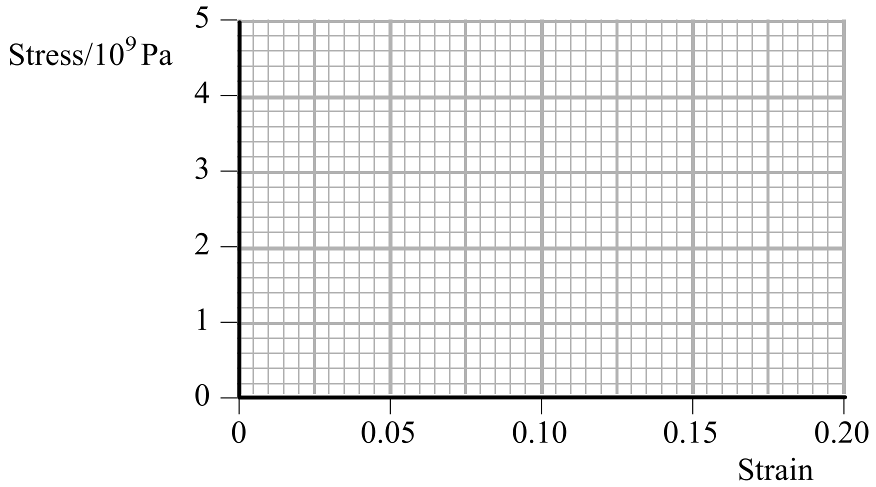
....

....

....

(4)

(e) A sample of copper has a Young modulus of 1.3×10^{11} Pa. It behaves elastically up to a strain of 0.030 and can withstand a maximum stress of 5.0×10^{9} Pa. It has an energy density of 800 MJ m^{-3} just before it breaks. Use this data to plot a stress-strain graph for copper, showing clearly any calculations you make.



....

....

....

....

....

(4)

(Total 32 marks)

Leave blank

Q2

H32827A01124

Turn over

Leave blank

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

Topic C – Nuclear and Particle Physics

3. (a) (i) On the axes, sketch a graph to illustrate the energy spectrum of beta-minus particles. You do not need to add scales but should include labels for each axis.

(3)

(ii) Write an equation to show what happens when a neutron decays in a nucleus. You should include proton and nucleon numbers where appropriate.

....

(2)

(b) A nucleus is held together by a combination of the electromagnetic (or electrostatic) force and the strong nuclear force. Complete the table to indicate whether these forces are attractive or repulsive, what particle(s) they act upon and their ranges.

Force	Attractive or Repulsive	Acts upon	Range
Electromagnetic (or Electrostatic)			
Strong nuclear			

(3)

(c) (i) Use the data to show that the binding energy per nucleon of oxygen ${}^{16}_{8}O$ is approximately 8 MeV.

mass of proton = 1.007 276 u

mass of neutron = 1.008 665 u

mass of oxygen nucleus = 15.990 527 u

....

....

....

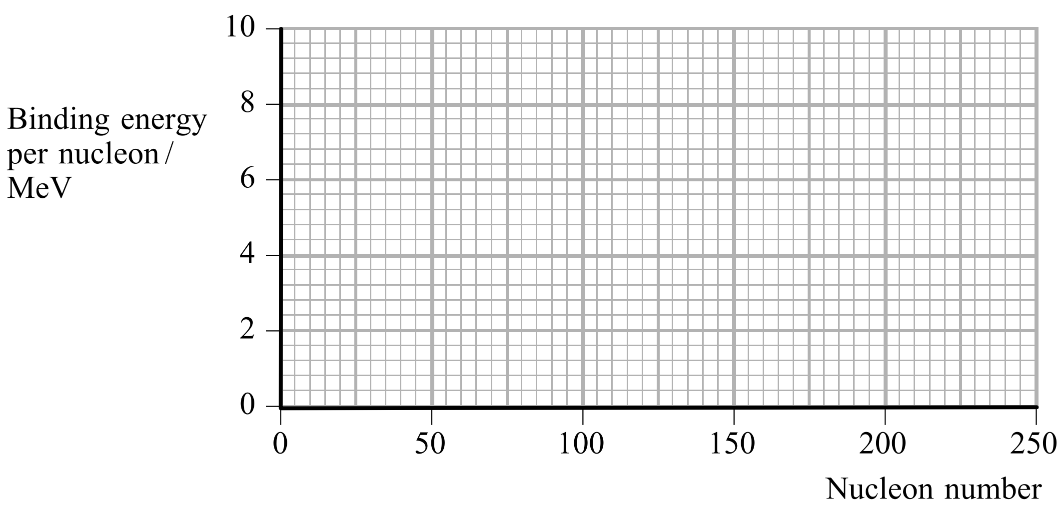
....

....

....

(4)

(ii) On the axes below plot the position of ${}^{16}_{8}O$.



(1)

(iii) On the axes sketch a graph of binding energy per nucleon against nucleon number.

(1)

(iv) From your graph, suggest a value for the binding energy per nucleon of iron.

....

(1)

Leave blank

Leave blank

(d) Show that the radius of the nucleus of an atom of uranium $^{238}_{92}U$ is approximately twice the radius of the nucleus of an atom of phosphorus $^{31}_{15}P$.

....

....

....

....

(3)

(e) The omega minus particle Ω^- was first discovered in 1964 and is composed of three strange quarks. It is not a long-lived particle and it decays in various ways. One of these involves the following series of decays:

1	Ω^- (sss)	$\longrightarrow$	Ξ^0 (uss)	+	π^- ($\bar{u}d$)
2	Ξ^0 (uss)	$\longrightarrow$	Λ^0 (uds)	+	π^0
3	Λ^0 (uds)	$\longrightarrow$	X (qqq)	+	π^- ($\bar{u}d$)

(i) In decay 3, a strange quark turns into a down quark. Deduce the quark structure of particle X and hence name X. Show how you did this.

....

....

....

....

....

(3)

(ii) Apart from the two gamma rays released in decay 2, the particles in these decays all contain quarks. Classify these five particles by writing their symbols in the appropriate columns of the table.

Baryon	Meson	Lepton	Hadron

(3)

Leave blank

(iii) Use the information in these decays to calculate the charge on a strange quark. Justify your answer.

....

....

(1)

(iv) A student suggests that the electromagnetic force must mediate decay 2. Another student suggests that decay 3 must be mediated by the strong force because it involves quarks.

Explain why both of these suggestions are incorrect. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

(4)

(v) The following decays show three further ways in which an omega minus particle might decay. Only one of these is possible.

A	Ω^-	$\longrightarrow$	η^0	+	K^-
	(sss)		($\bar{s}$s)		($\bar{u}$s)
B	Ω^-	$\longrightarrow$	Λ^0	+	K^-
	(sss)		(uds)		($\bar{u}$s)
C	Ω^-	$\longrightarrow$	Ξ^0	+	π^0
	(sss)		(uss)		($\bar{u}$u)

Use appropriate conservation laws to show which of these decays are not possible and why they cannot take place.

....

....

....

....

(3)

Q3

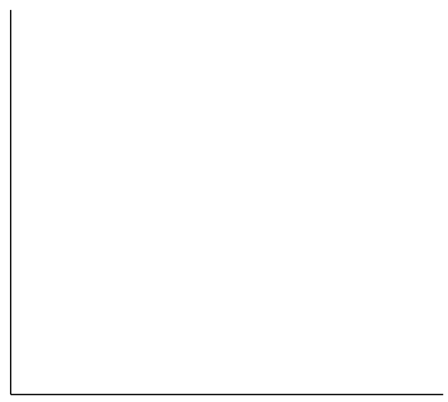
(Total 32 marks)

Leave blank

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

Topic D - Medical Physics

4. (a) On the axes, sketch a graph to illustrate the inverse square law for X-rays from a point source. You do not need to add scales but should include labels and units for each axis.



(3)

(b) (i) When an ultrasound investigation is carried out, a layer of gel is applied between the patient's skin (soft tissue) and the ultrasound transducer.

Show that the reflection coefficient for a gel-soft tissue boundary is approximately 2×10^{-4}. Values of specific acoustic impedance Z are given in the table below.

Medium	Z / kg m^{-2} s^{-1}
Soft tissue	1.63×10^{6}
Gel	1.58×10^{6}

....

....

....

....

....

....

(3)

H 3 2 8 2 7 A 0 1 7 2 4

Turn over

Leave blank

(ii) Calculate the percentage of the incident ultrasound that will be **transmitted** through a gel-soft tissue boundary.

....

....

....

....
(2)

(iii) Explain why a layer of gel must be used.

....

....

....

....
(2)

(c) Describe how information about the depth of a structure in the human body can be obtained by using an ultrasonic A-scan. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

....

....
(5)

Leave blank

(d) (i) Complete the table to summarise X-ray properties.

X-ray use	Typical accelerating voltage	Dependence of absorption on proton number
Diagnosis		
Therapy		

(2)

(ii) Give a reason why ultrasound is used in preference to X-rays for investigating the development of unborn babies.

....

....

....
(1)

(e) (i) State the function of the following parts of an X-ray tube:

1. the filament

....

....

2. the evacuated glass tube which encloses the anode and filament

....

....

3. the high voltage supply

....

....
(3)

Leave blank

(ii) State **and** explain two features of the target anode in an X-ray tube.

....

....

....

....

....

....

....

....
(4)

(f) A radionuclide can be used to investigate the blood volume of a patient. During this investigation, the patient is injected with a known volume of a radioactive tracer of known activity. At the same time an equal volume of the tracer is diluted in 6 litres of water. After 15 minutes, a sample of the patient's blood is taken and its activity measured and compared with the activity of the diluted tracer.

(i) Suggest why the tracer that is not injected into the patient is diluted in about 6 litres of water.

....

....

....

....
(1)

(ii) Suggest why it is necessary to wait for fifteen minutes between injecting the patient and then removing a blood sample.

....

....

....
(1)

Leave blank

(iii) A patient is injected with 10.0 cm^3 of tracer of initial activity 125 kBq.

Show that the activity of 5.0 cm^3 of the diluted tracer will be approximately 100 Bq after 15 minutes. You should neglect any radioactive decay of the tracer.
6 litres = 6000 cm^3.

....

....

....

....

....

....

....

(3)

(iv) The 5.0 cm^3 of blood removed from the patient has an activity of 120 Bq.

Calculate the volume of this patient's blood.

....

....

....

....

....

(2)

Q4

(Total 32 marks)

TOTAL FOR PAPER: 32 MARKS

END

List of data, formulae and relationships

Data

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

Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

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

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

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 $\quad F = m\dfrac{\Delta v}{\Delta t} = \dfrac{\Delta p}{\Delta t}$

Impulse $\quad F\Delta t = \Delta p$

Mechanical energy

Power $\quad P = Fv$

Radioactive decay and the nuclear atom

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

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

Electrical current and potential difference

Electric current	$I = nAQv$	
Electric power	$P = I^2 R$	

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 ΔT)
Celsius temperature	$\theta/°\mathrm{C} = T/\mathrm{K} - 273$	

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 ΔQ; Work done on body ΔW)
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	$L = \sigma T^4 \times$ surface area	(Luminosity L; Stefan constant σ)
Wien's law	$\lambda_{\max} T = 2.898 \times 10^{-3}$ 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	

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 ρ)

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

$\sin(90° - \theta) = \cos\theta$

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: $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

$\cos\theta \approx 1$