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Mark Scheme (Standardisation)
Summer 2007

GCE

GCE Physics (6733/01)

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6733 Unit Test PHY3 (Topics) June 2007

Topic A - Astrophysics

(a)	Intensity and Luminosity		
	Luminosity = power [or energy / time, accept "per second"]	✓	
	Intensity = power (or energy / time) [e.c.f. from first mark] per unit area [accept per square metre]	✓	
	Luminosity: measured at star OR Intensity: measured at Earth / depends on distance (from star) / observed OR W with W m^{-2} OR $I = L \div 4 \pi D^2$	✓	**3**
(b)	Wavelength of Sun		
(i)	Use of Wien's law [accept any attempted use]	✓	
	5.0×10^{-7} m	✓	**2**
(ii)	Surface area of Sun		
	Use of $4 \pi r^2$	✓	
	6.1×10^{18} (m^2)	✓	**2**
(iii)	Luminosity of Sun		
	$L = \sigma A T^4$ [or $L = \sigma T^4 4 \pi r^2$]	✓	
	Correct substitution [e.c.f.]	✓	
	3.9×10^{26} W [accept 3.8 or 3.84×10^{26} W from 6×10^{18} m^2]	✓	**3**
(c)	Main sequence mass requirement		
	Quality of written communication	✓	
	(Main sequence requires) hydrogen fusion / burning	✓	
	Mass linked to gravitational forces / field [/energy]	✓	
	High forces [or temperature, pressure] required for fusion / burning / m.s.	✓	**4**
(d)	Hertzsprung-Russell diagram		
(i)	Axes change in (fixed) multiples [accept exponential changes]	✓	
	x-axis multiple: x ½ OR x 2	✓	**2**
(ii)	L on diagonal falling line in lower right quadrant	✓	
	W indicated mostly in lower left quadrant	✓	
	R indicated mostly in upper right quadrant [not on main sequence]	✓	
	S in line with 10^0 [± 2 mm to centre of S, to left of 5000 K. on m.s.]	✓	**4**

(e)	Parallax analogy		
(i)	5 tan 84^0 [beware 5 / cos 84^0 = 47.8 m]	✓	
	47.6 m	✓	**2**
(ii)	2 AU / Earth orbital radius x 2 / Earth orbital diameter / distance between Earth at a six month interval / 3 x 10^{11} m	✓	**1**
(iii)	Inaccurate readings / difficult to measure AND small angles / movement relative to background (stars)	✓	**1**
(f)	Black hole radius		
(i)	Correct substitution / 8.93 x 10^{-3} (m)	✓	
	R doubled OR 2 cm halved	✓	
	0.018 m OR 1.8 (cm) [accept 2 cm / 0.02 m from previously rounding]	✓	**3**
(ii)	Supernova	✓	**1**
	Mass of black hole		
(iii)	2.5 $M_\odot$	✓	**1**
(iv)	Substitution [allow R = 26.8]	✓	
	1.8 x 10^{31} (kg)	✓	
	9 ($M_\odot$) [no e.c.f.]	✓	**3**
		TOTAL	**32**

Topic B - Solid Materials

(a) Elastic and Plastic behaviour

Plastic = permanent AND elastic = reversible [may be implied anywhere] ✓

Elastic: bonds stretch but not broken / atoms move apart but then return ✓

Plastic: bonds broken (when stressed) / atoms do not return to original position (after stress) ✓ **3**

(b) Ultimate Tensile Strength

(i) (3.6 - 3.7) x 10^8 N m^{-2} / Pa ✓ **1**

Energy density estimate

(ii) Energy density = area [may be implied by working] ✓

Attempt at area [ignore 10^8 and 10^{-3}] (rectangle (and triangle) or counting squares) ✓

Range: 600 kJ m^{-3} - 700 kJ m^{-3} [accept N m^{-2}] ✓ **3**

Young modulus calculation

(iii) Attempt at gradient / stress ÷ strain [ignore 10^n] ✓

Valid pair of readings taken from graph [10^8 and 10^{-3} required] ✓

8.0 to 9.0 x 10^{11} N m^{-2} / Pa ✓ **3**

Tough or brittle explanation

(iv) Tough ✓

Any reference to plastic behaviour ✓

(Large area under) non-linear part of graph referred to ✓ **3**

(c) Definitions

(i) Stress = force ÷ area AND strain = extension ÷ original [initial] length ✓ **1**

(ii) E = stress ÷ strain [accept symbols here] ✓

$E = \frac{F/A}{\Delta l / l}$ ✓ **2**

Radius "show that" calculation

(iii) Correct substitution in $E = \frac{Fl}{A\Delta l}$ / A = 2.7 x 10^{-7} (m^2) ✓

$A = \pi r^2$ ✓

2.9 x 10^{-4} m / 0.29 (mm) ✓ **3**

(d)	Golf ball rubber		
(i)	Quality of written communication	✓	
	(Can absorb energy) elastically / elastic behaviour / not plastic	✓	
	Can release energy with high efficiency / greater transfer of energy (from club to ball) / small hysteresis loop	✓	
	Can withstand (very) large forces [or stress] / durable / elastomer	✓	**4**
	Hysteresis graph for rubber		
(ii)	Correct shape: steep-flatter-steep, and reverse	✓	
	Labels [one labelled curve scores 1/2]	✓	**2**
	Area difference explanation		
(iii)	Reference to area / difference in two areas	✓	
	Loop area linked to gain / internal energy / heat by rubber	✓	**2**
(e)	Steel tension members on boat		
(i)	$T_f \cos 30^0$ / 4 $\cos 30^0$ / $T_r \cos 45^0$ /2.8 $\cos 45^0$	✓	
	5.4 x 10^3 N	✓	**2**
	Moments calculation		
(ii)	Attempt at moments / moment = Force x (perpendicular) distance from P	✓	
	$\sin 45^0$ / $\sin 30^0$ multipliers used anywhere [accept $\cos 45^0$ AND $\cos 60^0$]	✓	
	Both shown to be 10 (kN m) OR subtract moments to zero	✓	**3**
		TOTAL	**32**

Topic C - Nuclear and Particle Physics

(a) Strong and weak interaction differences

Strong affects quarks (only) AND Weak affects any particle	✓	
Both exchange particles: gluon, either W or Z	✓	
Any two from: W^+, W^- and Z strength (S ≈ 10^5 W for touching protons) [accept S>>W] range (S ≈ 10^{-15} m, W ≈ 10^{-18} m) [accept S>W] mass (S = 0, W ≈ 89u) [accept W>S] Only W can change (quark) flavour / W involve in β -decay	**Any 2** ✓✓	**4**

(b) Alpha particle radius

(i)

$A = 4$	✓	
Use of $r = r_0 A^{⅓}$ [accept substitution if correctly written]	✓	
1.9 x 10^{-15} (m) [beware 1.6 x 10^{-15} m]	✓	**3**

(ii) Alpha particle density

use of $\rho = m \div V$	✓	
m = 4 x 1.66 x 10^{-27} (kg) / 6.64 x 10^{-27} (kg) [accept u as 1.7 x 10^{-27}]	✓	
4/3 π (1.9 x 10^{-15} m)^3 / 2.9 x 10^{-44} m^3 [e.c.f. only to 1.6 x 10^{-15} m]	✓	
2.3 x 10^{17} kg m^{-3} (allow 2 x 10^{17} kg m^{-3} but not 1.98 x 10^{17} kg m^{-3} [sf])	✓	**4**

(iii) Alpha particle spectrum

Single line / narrow peak only	✓	**1**

(c) Carbon – 14 formation

$$^{14}_{7}\mathrm{N} + {}^{0}_{-1}\beta \rightarrow {}^{14}_{6}\mathrm{C} + \nu_e$$

(i)

N, β, C and ν_e in correct equation [accept e or β]	✓	
Correct nucleon numbers: 14, 0, 14	✓	
Correct proton numbers 7, -1, 6 [all A and Z interchanged scores 1/2]	✓	**3**
(ii) Proton turns into a neutron / up to down / uud to udd [ignore leptons]	✓	**1**

(iii) Initial activity calculation

(almost) two half lives / 11460 years (is almost 12 000 years) / 2.09 ✓

4800 /5000 (Bq) [or $2^{2.09}$ or exponential equation route = 5124 Bq] ✓ **2**

(d) Pair production explanation

Quality of written communication ✓

Photon / gamma (ray) initially [not photons, accept Z^0] ✓

Converted into particle and antiparticle / matter and antimatter ✓

Two examples: e^+, e^- / p, $\bar{p}$ / ν, $\bar{\nu}$ / q, $\bar{q}$ / etc. [not "anti-electron"] ✓ **4**

(e) Hadron definition

(i) (Particle) composed of quarks ✓ **1**

(ii) Quark flavours

Charm, strange, top [any order]

All three in correct position: c… t… s… ✓ **2**

(iii) Baryon charge permutations

Baryon = qqq [may be implied] ✓

+2, +1, 0, –1 [accept 2, 1, 0, -1] ✓

Addition shown four times (+ ⅔ + ⅔ + ⅔ = +2, etc.) ✓ **3**

[Only three additions scores max ✓✓✗]

–2 ✓ **1**

(iv) Pion compositions

$\pi^+ = u\bar{d}$ ✓

$\pi^- = d\bar{u}$ ✓

$\pi^0 = u\bar{u}$ and $d\bar{d}$ ✓ **3**

TOTAL **32**

Topic D - Medical Physics

(a) Ultrasound and X-ray imaging

Labelled diagram with transducer (source and detector) touching patient ✓

Labelled diagram with X-ray source : (patient) : film ✓

Any two pairs from:

Ultrasound	**AND**	X-rays
(high frequency) longitudinal sound / mechanical waves		(high energy) electromagnetic / transverse waves / photons
Coupling medium needed		(tube) not in contact with patient
Reflection (at interface)		Attenuation / absorption
No ionisation / radiation risk		Ionisation / radiation dose
Limited resolution / detail		Better resolution
Specific acoustic impedance		Proton number dependence
Soft tissue imaging / Doppler		Bones usually imaged

Any 2 ✓✓ **Max 4**

(b) Molybdenum

(i) ${}^{99}_{42}\text{Mo} \rightarrow {}^{99m}_{43}\text{Tc} + {}^{0}_{-1}\beta$ [accept e or β with all six values, ignore neutrinos] ✓ **1**

(ii) Neutron irradiation / bombardment OR (uranium) fission ✓ **1**

Gamma radiation advantages

(iii) (Half-life of 6 h) – neither too long (damage to patient) not too short (sufficient for study to take place) ✓

Lowest ionisation / no α or β, so less damage / safer (to cells / patient) ✓

Can be **detected** outside body / by gamma camera ✓ **3**

(c) X-rays in diagnosis and therapy

(i) Diagnosis: imaging / examining patient AND therapy: treatment ✓ **1**

(ii) Diagnosis: (60 – 150) keV [values not required, allow 1 - 999] ✓

Therapy: (4 – 25) MeV [values not required, allow 1 - 999] ✓ **2**

(iii) Diagnosis: depends on Z; Therapy: **no** Z dependence ✓ **1**

(iv) Quality of written communication ✓

Rotating or multiple beams / alignment devices clearly shown in diagram ✓

Tumour always targeted [may be in diagram] ✓

Surrounding tissue only sometimes receives radiation ✓ **4**

(d)	Ultrasound medium properties		
(i)	Use of $Z = \rho$ x c	✓	
	A = 1570 (m s^{-1})	✓	
	B = 1026 / 1030 (kg m^{-3})	✓	**3**
	Reflection coefficient calculation		
(ii)	$(1.70 - 1.38)^2 \div (1.70 + 1.38)^2$	✓	
	0.011 / 1.08% / 1.1%	✓	
	98.9% / 100% - their value (ecf) / statement 1% reflected, 99% transmitted	✓	**3**
(e)	Half-life definition		
(i)	Time taken for activity (of radionuclide) to half due to excretion (from body or organ) OR time for body to excrete half of sample [accept "get rid of…"]	✓	**1**
(ii)	Effective half-life calculation		
	$1/t_e = 1/13 + 1/11$	✓	
	5.96 (h) / 6.0 h [accept 5.95h, but not 5.8h nor 5.9h]	✓	**2**
(iii)	Half-life plot		
	Smooth, falling, concave curve, not touching x-axis, to 12 h	✓	
	Starting at (0,1000)	✓	
	Plots or line through (0,1000), (6,500) AND (12,250)	✓	**3**
	Radioisotope Y effective half-life		
(iv)	4 h	✓	**1**
(v)	Curve through (0,2000), (4,1000) AND (8,500)	✓	**1**
(vi)	12 h	✓	**1**
		TOTAL	**32**