EXAMINATION PAPER CONTAINS STUDENT'S ANSW

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The Handbook of Mathematics, Physics and Astronomy Data is provided

KEELE UNIVERSITY

EXAMINATIONS, 2011/12

Level I

Monday 21st May 2012, 09.30-11.30

PHYSICS/ASTROPHYSICS

PHY-10023

ELECTRICITY & STELLAR STRUCTURE

Candidates should attempt ALL of PARTS A and B, and ONE question from each of PARTS C and D. PARTS A and B should be answered on the exam paper; PARTS C and D should be answered in the examination booklet which should be attached to the exam paper at the end of the exam with a treasury tag. PART A yields 16% of the marks, PART B yields 24%, PART C yields 30%, PART D yields 30%.

Please do not write in the box below

A		C1		Total
B		C2		
		D1		
		D2		

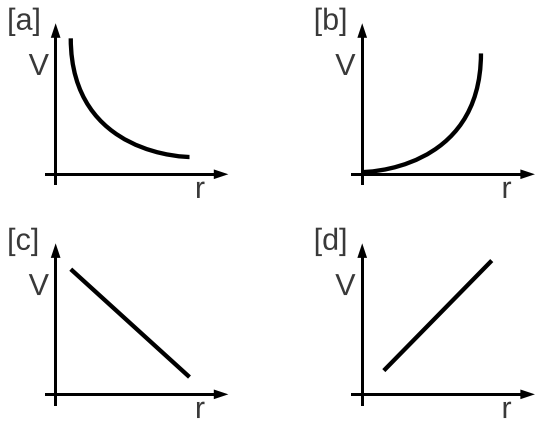
NOT TO BE REMOVED FROM THE EXAMINATION HALL

PART A Tick one box by the answer you judge to be cor
(marks are not deducted for incorrect answers)

A1 The electrostatic force between two point charges is 20 N. If the distance between the charges is doubled, then the force will be:

☐ 5 N ☐ 10 N ☐ 40 N ☐ 80 N [1]

A2 Which of the following graphs illustrates the variation of the electrostatic potential, V, with distance from a point charge.



☐ a ☐ b

☐ c ☐ d [1]

A3 The potential energy of a dipole in an electric field is *maximum* when the dipole is:

☐ parallel to the electric field

☐ perpendicular to the electric field

☐ anti-parallel to the electric field (180° between the two vectors)

☐ at an angle of 135° to the electric field [1]

/Cont'd

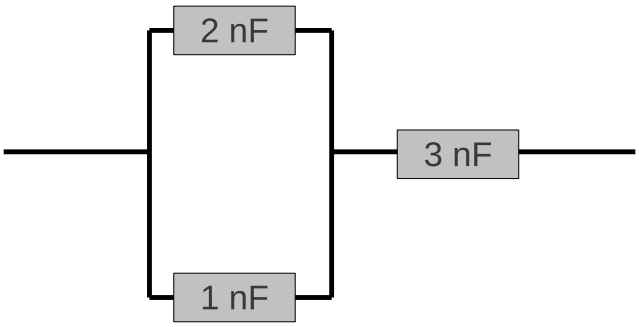
A4 The electric potential inside a conductor is always:

- ☐ dependent on the shape of the conductor
- ☐ constant
- ☐ dependent on the size of the conductor
- ☐ zero [1]

A5 What is the electric potential across a distance of 10 m in a uniform electric field, $E = 200\,\mathrm{V/m}$.

☐ 20 V ☐ 200 V ☐ 400 V ☐ 2000 V [1]

A6 What is the equivalent capacitance of the following circuit:



☐ 1 nF ☐ 1.5 nF ☐ 3 nF ☐ $\frac{11}{3}$ nF [1]

A7 The cyclotron frequency of a particle in a magnetic field is *independent* of:

- ☐ the particle velocity
- ☐ the particle mass
- ☐ the particle charge
- ☐ the magnitude of the magnetic field [1]

/Cont'd

A8 An electron is moving horizontally (parallel to the ground) from to east at constant velocity. Given that the earth's magnetic fi is horizontal and points to the north, in which direction does the magnetic force on the electron point?

- ☐ South
- ☐ Vertically upwards (towards the sky)
- ☐ East
- ☐ Vertically downwards (towards the ground) [1]

A9 A $5\,M_\odot$ star in the main-sequence has a approximate luminosity

☐ $0.1\,L_\odot$ ☐ $1\,L_\odot$ ☐ $5\,L_\odot$ ☐ $125\,L_\odot$ [1]

A10 The main-sequence lifetime of a star is mainly determined by its

☐ radius ☐ pressure ☐ mass ☐ temperature [1]

A11 During the formation of a star, contraction stops when

- ☐ hydrogen burning becomes the main energy source
- ☐ it becomes a red giant
- ☐ it collapses into a white dwarf
- ☐ hydrogen is exhausted in its core [1]

A12 The internal structure of a red giant star consists of

- ☐ hydrogen throughout the star
- ☐ helium throughout the star
- ☐ a core of hydrogen ash surrounded by a helium burning shell
- ☐ a core of helium ash surrounded by a hydrogen burning shell [1]

A13 The spectral type is an indicator of the star's:

☐ age ☐ luminosity ☐ radius ☐ temperature [1]

/Cont'd

A14 Radiative transport is the dominant energy transport mechanis

- ☐ in the Sun's interior
- ☐ in the Sun's outer layers
- ☐ everywhere throughout the Sun
- ☐ nowhere in the Sun [1]

A15 The most massive star in the main sequence of cluster A has a mass of $6\,M_\odot$; the most massive star in the main sequence of cluster B has a mass of $1\,M_\odot$. Which cluster is older?

- ☐ cluster A
- ☐ cluster B
- ☐ they are the same age
- ☐ it is not known [1]

A16 Jeans' instability criterion describes

- ☐ the equilibrium between pressure and gravity
- ☐ the necessary condition for the onset of gravitational collapse
- ☐ how many stars form in a cluster
- ☐ the necessary condition for red giant expansion [1]

/Cont'd

PART B Answer all EIGHT questions

B1 Calculate the ratio of the electric force to the gravitational force between two protons. [3]

B2 State Gauss's law and which physical quantity is usually determined using this law. [3]

/Cont'd

B3 Sketch the electric potential due to a pair of charges −q and −q separated by a distance d. [3]

B4 How does the velocity selected by a velocity selector apparatus depend on the magnetic and electric fields used (justify your answer)? [3]

/Cont'd

B5 Describe briefly the main nuclear reaction that occurs in the co
of the Sun, stating how much energy is released per reaction. [3]

B6 What is the average mass of a particle in the interior of a star made of fully ionised helium? [3]

/Cont'd

B7 Draw a schematic Hertzsprung-Russell diagram, indicating on it the Sun's evolution. Label the axes, the Sun's position and the location of the main evolutionary stages. [3]

B8 Two stars in a binary have the same radius. Star A has luminosity $2\,L_\odot$ and effective temperature 6500 K. If star B has luminosity $20\,L_\odot$, what is its effective temperature? [3]

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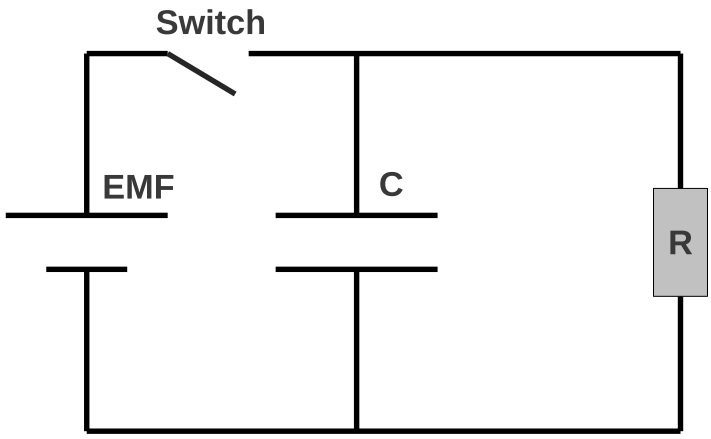
PART C Answer ONE out of TWO questions

C1 The switch in the circuit diagram below is initially closed.



(a) What is the initial charge on the capacitor if its capacitance is $100\,\mu$F and the *emf* is 50 V? [3]

(b) The switch is opened at $t = 0$ s. The capacitor discharges and the charge on the capacitor at time t is given by $Q(t) = Q_0\, e^{-t/(RC)}$ with $R = 10\,\Omega$.

i. How long does it take for the charge on the capacitor to reach 10% of the initial value? [8]

ii. Derive an expression for the time evolution of the current in the circuit. [7]

iii. What is the magnitude of the current at the time determined in part (i)? [8]

iv. Which quantities influence the rate of discharge of the capacitor? [4]

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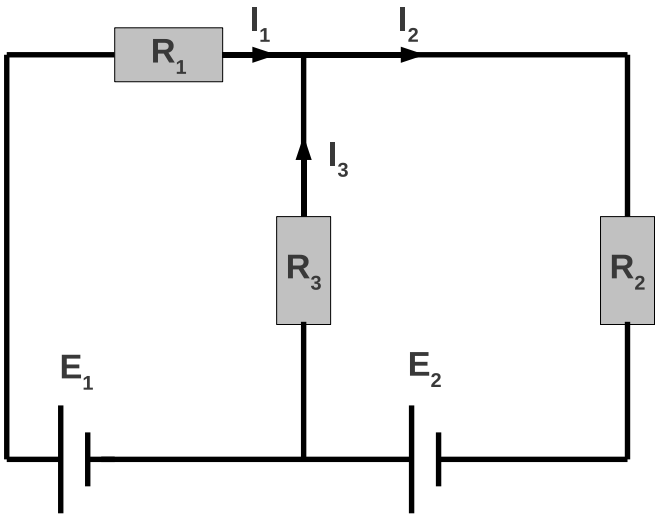
C2 In the circuit diagram below, $I_1 = 4\,\text{A}$, $I_2 = 6\,\text{A}$, $R_1 =$ [illegible] $R_2 = 10\,\Omega$, and $R_3 = 5\,\Omega$.



(a) Using Kirchhof's laws, calculate the potential difference across each of E_1 and E_2. [14]

(b) State the rules to calculate the equivalent resistance for series and parallel combinations of resistors. [6]

(c) Calculate the new current I_2 if the *emf* E_1 is replaced by a fourth resistor $R_4 = 5\,\Omega$. [10]

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PART D Answer ONE out of TWO questions

D1 (a) By considering the balance of forces acting on a thin shell in the interior of a spherical star, derive the hydrostatic equilibrium equation

$$\left(\frac{d\,P}{d\,r}\right) = -\frac{G\,M(r)\,\rho(r)}{r^2}. \qquad [9]$$

(b) Use the hydrostatic equilibrium equation to show that the central pressure in a star with uniform density is given by:

$$P_{\rm c} = \frac{3\,G\,M^2}{8\,\pi\,R^4} \qquad [14]$$

(c) For the Sun the central pressure and temperature are respectively $P_{\rm c} \sim 10^{16}\,{\rm Pa}$ and $T_{\rm c} \sim 16 \times 10^6\,{\rm K}$. Explain briefly why the material inside the star behaves like an ideal gas. [7]

/Cont'd

D2 (a) Name and describe briefly the two main mechanism for ene transport inside the Sun. In which regions are those mechanism dominant? [6]

(b) i. Name and describe briefly the main opacity mechanism deep in the interior of the Sun. [3]

ii. If $n_{\rm e}$ and $\sigma_{\rm T}$ are respectively the electron density and cross-section, show that the mean free path of a photon l is

$$l = \frac{1}{n_{\rm e}\sigma_{\rm T}} \qquad [6]$$

iii. If the gas inside the Sun is ionised hydrogen show that

$$l = \frac{4\,\pi\,m_{\rm p}R_{\odot}^3}{3\,\sigma_{\rm T}M_{\odot}} \qquad [7]$$

(c) If the total distance travelled by a photon is given by $D^2 = Nl^2$, where N is the number of scatterings, calculate the time for a photon to diffuse out of the Sun. [8]