Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2008
Advanced Subsidiary Examination

PHYSICS (SPECIFICATION A) **PHA3/W**
Unit 3 Current Electricity and Elastic Properties of Solids

Thursday 22 May 2008 1.30 pm to 2.30 pm

For this paper you must have:
- a pencil and a ruler
- a calculator
- a data sheet insert.

Time allowed: 1 hour

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

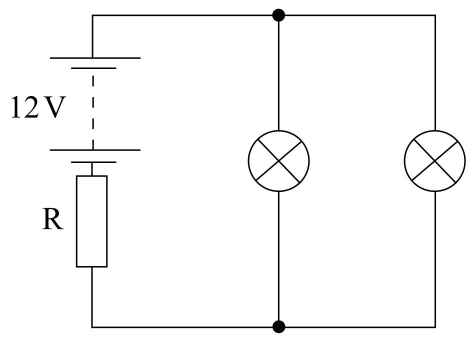
Information
- The maximum mark for this paper is 50. This includes up to two marks for the Quality of Written Communication.
- The marks for questions are shown in brackets.
- A *Data Sheet* is provided as a loose insert to this question paper.
- You are expected to use a calculator where appropriate.
- Questions 2(a)(ii) and (iii) and 4(b)(i) should be answered in continuous prose. In these questions you will be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

For Examiner's Use			
Question	Mark	Question	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
TOTAL			
Examiner's Initials			

Answer **all** questions in the spaces provided.

1 Two parallel identical lamps are connected to a resistor R and a 12 V battery of negligible internal resistance, as shown in **Figure 1**.

Figure 1



1 (a) Each lamp is rated at 2.0 W at a voltage of 8.0 V.
Calculate the resistance of a lamp at this voltage.

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(1 mark)

1 (b) The resistance of R is chosen so that the lamps are to operate at their normal working voltage of 8.0 V.
Calculate

1 (b) (i) the current supplied by the battery,

....

....

....

1 (b) (ii) the resistance of R.

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(3 marks)

1 (c) When the lamps are at their correct working voltage,

1 (c) (i) calculate the time taken for a charge of 20 C to pass through **one** of the lamps,

....

....

1 (c) (ii) calculate the total energy dissipated in **both** lamps in this time,

....

....

1 (c) (iii) state why the energy calculated in part (c)(ii) is less than the total energy supplied by the battery in this time.

....

....

(3 marks)

7

Turn over for the next question

2 (a) A student is required to carry out an experiment and to draw a suitable graph in order to obtain a value for the resistance of a resistor.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

2 (a) (i) Draw a circuit diagram which would enable a range of measurements to be made.

2 (a) (ii) State how the student should make the necessary measurements, ensuring that a range of readings is recorded.

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2 (a) (iii) Describe how the results would be used to obtain a value for the resistance of the resistor from a graphical method.

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(7 marks)

Areas outside the box will not be scanned for marking

2 (b) An electric heater is required to produce 1.2 kW when connected to the 230 V rms ac mains. The heating element consists of a single uniform wire of an alloy, of cross-sectional area $9.4 \times 10^{-8}\,m^2$, wound around an insulator.
Calculate the length of wire required to make the element.

resistivity of the alloy = $4.7 \times 10^{-7}\,\Omega\,m$

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(3 marks)

10

Turn over for the next question

3 The circuit in **Figure 2** shows a sinusoidal ac source connected to two resistors R_1 and R_2, which form a potential divider. Oscillosocope 1 is connected across the ac source and oscilloscope 2 across resistor R_2.

Figure 2

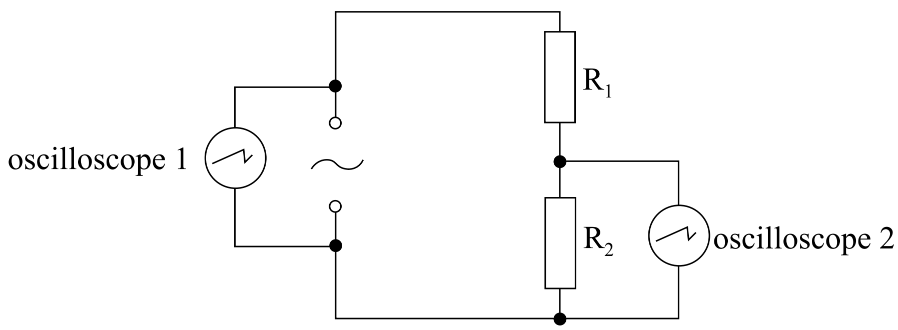
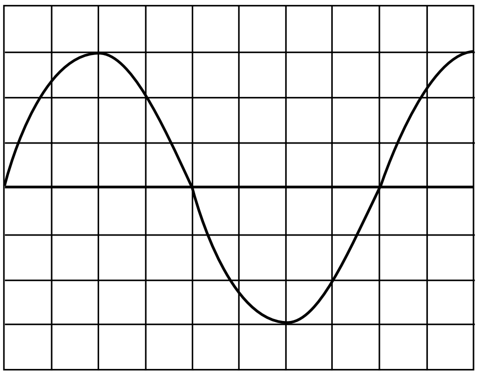


Figure 3 shows the waveform seen on the screen of oscilloscope 1 when the voltage sensitivity is set at 30 V div^{-1} and the time base at 5 ms div^{-1}.

Figure 3



3 (a) Calculate, for the ac source,

3 (a) (i) the frequency,

....

....

3 (a) (ii) the rms voltage.

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(3 marks)

3 (b) The two resistors have the following values $R_1 = 400\,\Omega$, $R_2 = 80\,\Omega$.
Draw on **Figure 4** the waveform which would be seen on the screen of oscilloscope 2 if the sensitivity of oscilloscope 2 is set at $10\,\text{V div}^{-1}$, the time base setting being the same as that of oscilloscope 1.

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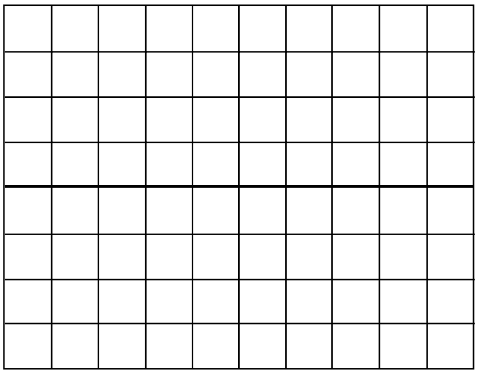
Figure 4



(3 marks)

6

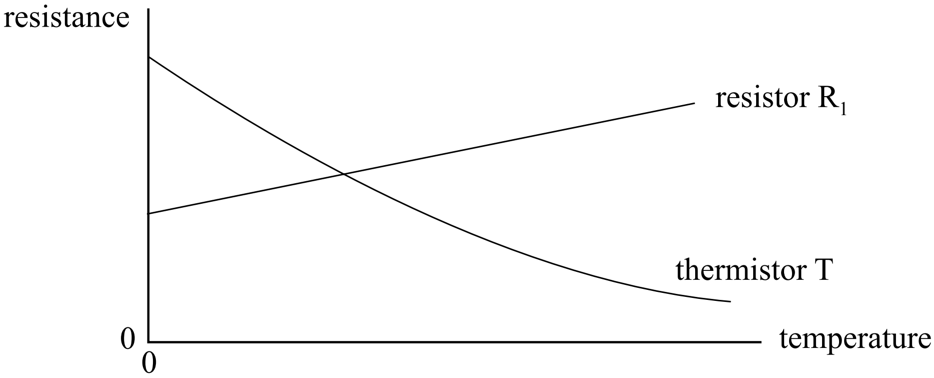
Turn over for the next question

Turn over ▸

Areas outside the box will not be scanned for marking

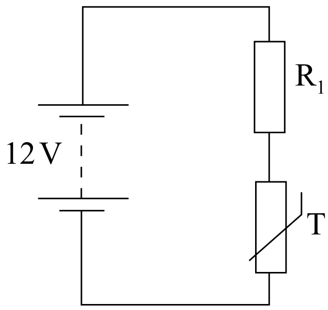
4 The graph in **Figure 5** shows how the resistance of a resistor, R_1, and the resistance of a thermistor, T, change with temperature.

Figure 5



4 (a) The circuit in **Figure 6** shows R_1 and T connected in series to a 12 V battery of negligible internal resistance.

Figure 6



At a certain temperature the resistance of R_1 is equal to the resistance of T.
State the voltage across R_1 and the voltage across T at this temperature.

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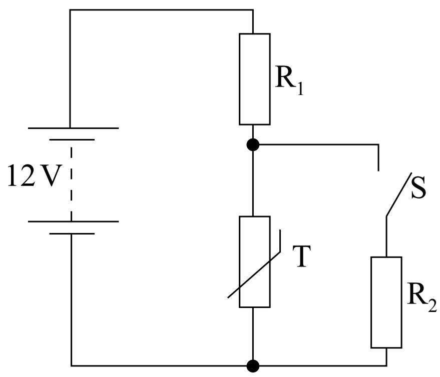
(1 mark)

Areas outside the box will not be scanned for marking

4 (b) A second resistor, R_2, having the same resistance as R_1 is connected in series with a switch across the thermistor, as shown in **Figure 7**. The temperature of R_1 and T is the same as that in part (a).

Figure 7



4 (b) (i) The switch S is now closed.
Deduce, **without calculation**, whether the separate voltages across R_1 and T will increase or decrease.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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4 (b) (ii) The effect of the resistor R_2 on the voltage across R_1 and the voltage across T could have been obtained by changing the temperature of R_1 and T in the circuit of **Figure 6**.

State, with a reason, whether the temperature should have been decreased or increased. Assume that the temperatures of R_1 and T are always equal to each other.

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(5 marks)

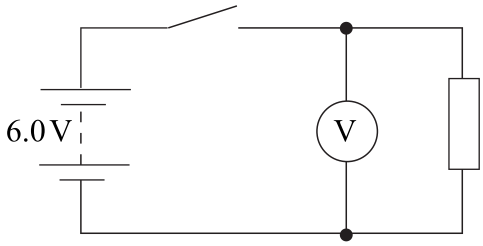
6

Turn over ▸

Areas outside the box will not be scanned for marking

5 (a) In the circuit shown in **Figure 8**, the battery has an emf of 6.0 V. With the switch closed, the reading of the voltmeter is 5.5 V.

Figure 8



Explain, **without calculation**, why the voltmeter reading is less than the emf of the battery.

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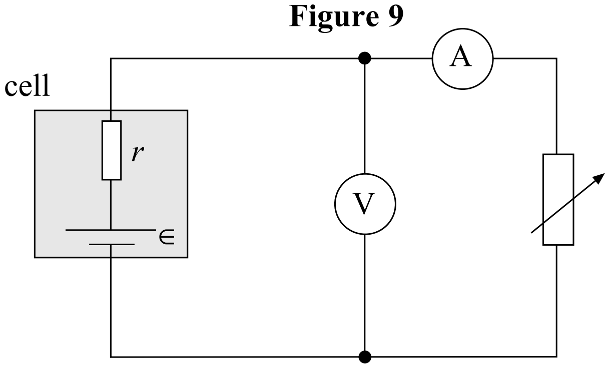
(3 marks)

5 (b) In the circuit shown in **Figure 9** the cell has an emf $\in$ and internal resistance r. The voltage V across the cell is read on the voltmeter, which has infinite resistance, and the current I through the variable resistor is read on the ammeter, which has negligible resistance.

Figure 9

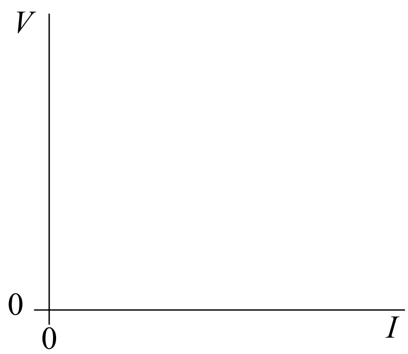


5 (b) (i) Show that $V = \in - Ir$.

....

....

5 (b) (ii) By altering the value of the variable resistor, a set of values of V and I is obtained. Sketch on the axes below, the graph you would expect to obtain when these values are plotted.



5 (b) (iii) State and explain how the values of $\in$ and r may be obtained from this graph.

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(5 marks)

8

Turn over ▸

6 (a) The Young modulus, E, for a material in the form of a wire is given by $E = \frac{Fl}{Ae}$.
State what each symbol represents.

F ....

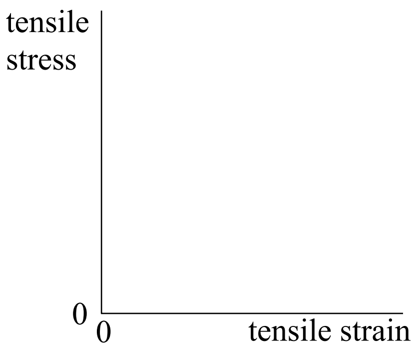
l ....

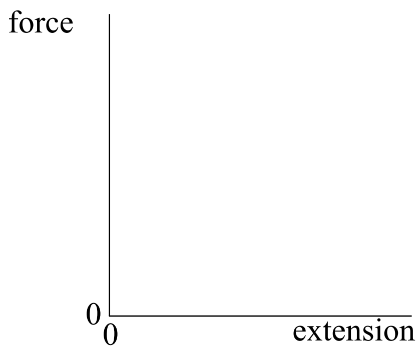
A ....

e ....

(1 mark)

6 (b) (i) A wire, **P**, is subjected to an increasing tensile stress by application of a force.
This results in a tensile strain being produced in the wire.
On each set of axes provided, sketch a graph which represents the behaviour of the wire up to its elastic limit.





6 (b) (ii) A wire, **Q**, is made from the same material as wire **P** and is the same length as **P**, but the cross-sectional area of wire **Q** is half that of **P**.
On the same set of axes, sketch the corresponding graphs for wire **Q** over the same range of tensile stress.
Label clearly which graph represents **Q** and which represents **P**.

6 (b) (iii) Explain the graphs you have drawn for wire **Q**, with reference to their position relative to the graphs for wire **P**.

tensile stress vs *tensile strain* graph: ....

....

....

....

6 (b) (iii) *force* vs *extension* graph: ....

....

....

....

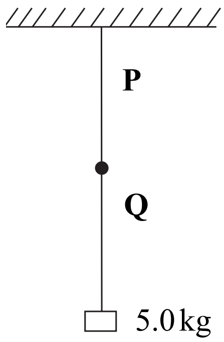
....

....

(7 marks)

6 (c) The two wires, **P** and **Q**, are joined together and fixed to a horizontal support. A mass of 5.0 kg is suspended from the free end, as shown in **Figure 10**.

Figure 10



length of each wire = 1.8 m
cross-sectional area of wire **P** = $2.0 \times 10^{-7}\,\text{m}^2$
the Young modulus of the material of the wires = 4.6×10^{11} Pa

Calculate the total extension of the combined wire.

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(3 marks)

11

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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PHYSICS (SPECIFICATION A) **PHA3W**
Unit 3 Current Electricity and Elastic Properties of Solids
Data Sheet

Fundamental constants and values

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ε_0	8.85×10^{-12}	F m^{-1}
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	N m^{2} kg^{-2}
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	J K^{-1} mol^{-1}
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	W m^{-2} K^{-4}
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4}u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728u)	m_p	1.67×10^{-27}	kg
proton charge/mass ratio	e/m_p	9.58×10^{7}	C kg^{-1}
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

Fundamental particles

Class	*Name*	*Symbol*	*Rest energy* /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^{\pm}$	0.510999
	muon	$\mu^{\pm}$	105.659
mesons	pion	$\pi^{\pm}$	139.576
		π^{0}	134.972
	kaon	$K^{\pm}$	493.821
		K^{0}	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

Type	*Charge*	*Baryon number*	*Strangeness*
u	$+\frac{2}{3}$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}$	$+\frac{1}{3}$	–1

Geometrical equations

arc length $= r\theta$

circumference of circle $= 2\pi r$

area of circle $= \pi r^2$

area of cylinder $= 2\pi rh$

volume of cylinder $= \pi r^2 h$

area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$

Mechanics and Applied Physics

$v = u + at$

$s = \left(\frac{u+v}{2}\right)t$

$s = ut + \frac{at^2}{2}$

$v^2 = u^2 + 2as$

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

$efficiency = \frac{power\ output}{power\ input}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

pV^{γ} = constant

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)

friction power = indicated power – brake power

$efficiency = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

maximum possible efficiency $= \frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$g = -\frac{\Delta V}{\Delta x}$

$V = -\frac{GM}{r}$

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

$\lambda = \frac{h}{p} = \frac{h}{mv}$

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2}QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

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$$\textit{magnitude of induced emf} = N\frac{\Delta\Phi}{\Delta t}$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

Mechanical and Thermal Properties

$$\textit{the Young modulus} = \frac{\textit{tensile stress}}{\textit{tensile strain}} = \frac{F}{A}\frac{l}{e}$$

$$\textit{energy stored} = \tfrac{1}{2}Fe$$

$$\Delta Q = mc\,\Delta\theta$$

$$\Delta Q = ml$$

$$pV = \tfrac{1}{3}Nm\overline{c^2}$$

$$\tfrac{1}{2}m\overline{c^2} = \tfrac{3}{2}kT = \frac{3RT}{2N_A}$$

Nuclear Physics and Turning Points in Physics

$$\textit{force} = \frac{eV_p}{d}$$

$$\textit{force} = Bev$$

$$\textit{radius of curvature} = \frac{mv}{Be}$$

$$\frac{eV}{d} = mg$$

$$\textit{work done} = eV$$

$$F = 6\pi\eta rv$$

$$I = k\frac{I_0}{x^2}$$

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$N = N_0 e^{-\lambda t}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

$$R = r_0 A^{\frac{1}{3}}$$

$$E = mc^2 = \frac{m_0c^2}{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

$$l = l_0\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}$$

$$t = \frac{t_0}{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

Astrophysics and Medical Physics

Body	*Mass*/kg	*Mean radius*/m
Sun	2.00×10^{30}	7.00×10^{8}
Earth	6.00×10^{24}	6.40×10^{6}

1 astronomical unit = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

Hubble constant (H) = 65 km s^{-1} Mpc^{-1}

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

$$M = \frac{f_o}{f_e}$$

$$m - M = 5\log\frac{d}{10}$$

$$\lambda_{\text{max}}T = \text{constant} = 0.0029\text{ m K}$$

$$v = Hd$$

$$P = \sigma AT^4$$

$$\frac{\Delta f}{f} = \frac{v}{c}$$

$$\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$$

$$R_s \approx \frac{2GM}{c^2}$$

Medical Physics

$$\textit{power} = \frac{1}{f}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad \text{and} \quad m = \frac{v}{u}$$

$$\textit{intensity level} = 10\log\frac{I}{I_0}$$

$$I = I_0 e^{-\mu x}$$

$$\mu_m = \frac{\mu}{\rho}$$

Electronics

Resistors

Preferred values for resistors (E24)
Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms
and multiples that are ten times greater

$$Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$

$$C_T = C_1 + C_2 + C_3 + \cdots$$

$$X_C = \frac{1}{2\pi fC}$$

Alternating Currents

$$f = \frac{1}{T}$$

Operational amplifier

$$G = \frac{V_{\text{out}}}{V_{\text{in}}} \quad \text{voltage gain}$$

$$G = -\frac{R_f}{R_1} \quad \text{inverting}$$

$$G = 1 + \frac{R_f}{R_1} \quad \text{non-inverting}$$

$$V_{\text{out}} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right) \quad \text{summing}$$