| Surname | | Other Names | |
|---|---|---|---|
| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

| For Examiner's Use |
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General Certificate of Education
June 2008
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

**PHYSICS (SPECIFICATION A)** **PHA3/P**
**Practical (Unit 3)**

Wednesday 14 May 2008 1.30 pm to 3.15 pm

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

Time allowed: 1 hour 45 minutes

**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 30.
- 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.
- You are advised to spend no more than 30 minutes on Question 1.

| For Examiner's Use | | | |
|---|---|---|---|
| Question | Mark | Question | Mark |
| 1 | | | |
| 2 | | | |
| Total (Column 1) → | | | |
| Total (Column 2) → | | | |
| TOTAL | | | |
| Examiner's Initials | | | |

Answer **both** questions.

You are advised to spend no more than 30 minutes on Question 1.

**1** A student has devised a novel way of measuring the refractive index of a transparent liquid. The apparatus to be used is shown in **Figure 1**.

A thin beam of light from a laser pointer passes through one of two holes in a fixed horizontal mask. The beam is reflected from a reflective surface on the bottom of a rectangular container supported above the bench. Fine adjustment can be made to the vertical position of the container using a rack and pinion mechanism, similar to that used to focus a laboratory microscope. By rotating the pinion, the vertical position of the container is adjusted until the reflected beam of light passes through the second hole in the mask.

Liquid is added to the container and due to refraction at the surface, the reflected beam no longer passes through the second hole in the mask, as shown in **Figure 2**. The container is then lowered until the light beam is once again transmitted through both holes in the mask, as shown in **Figure 3**.

The refractive index, $n$, of the liquid in the container is given by

$$n = \frac{d}{d - h}$$

where $d$ is the depth of liquid in the container and $h$ is the vertical distance through which the container is lowered from the position shown in **Figure 2** to the position shown in **Figure 3**.

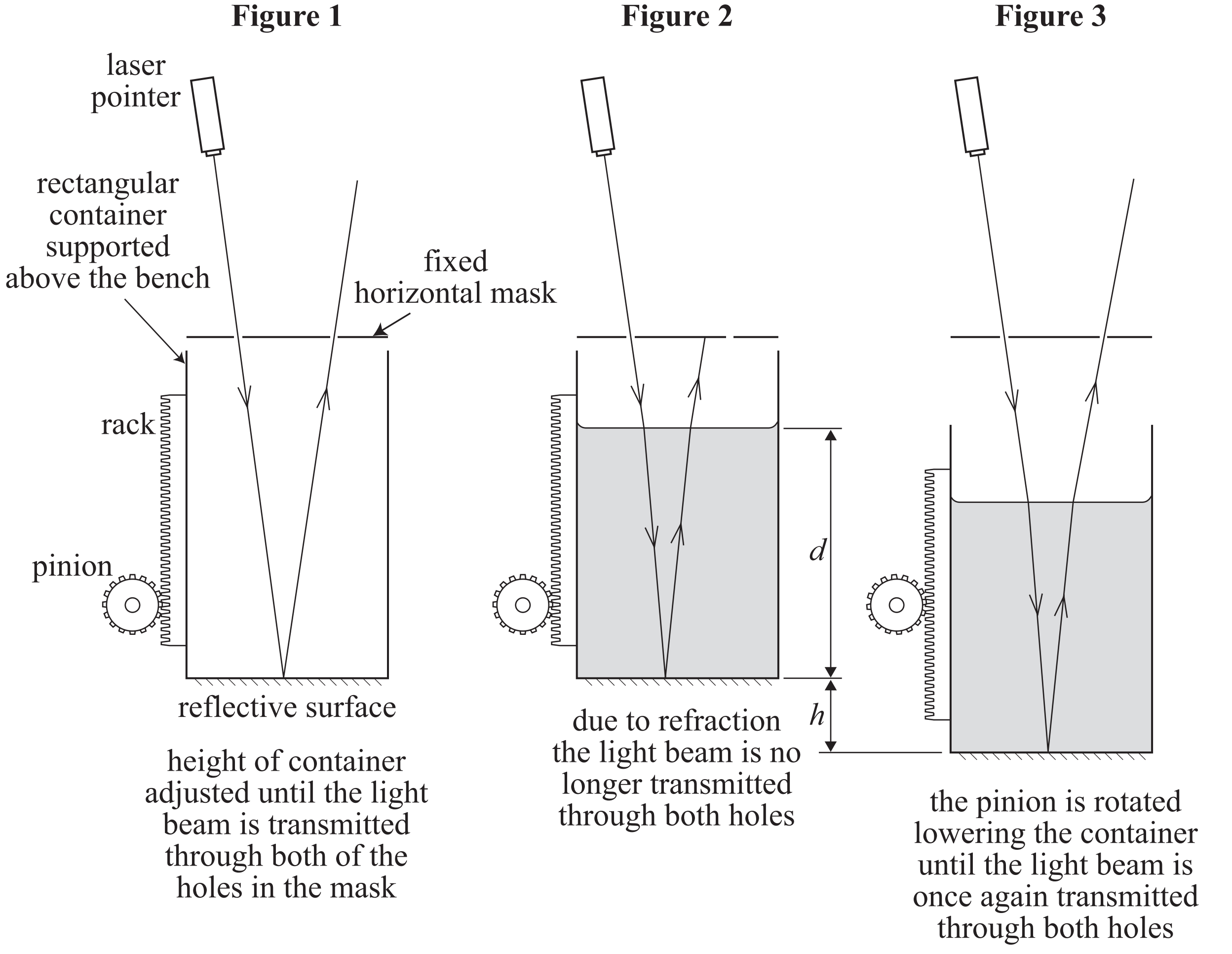
The student intends to use this technique to determine how the refractive index of a sugar solution depends on the percentage of sugar, by mass, in the solution.
Preliminary work was done with pure water in the container. A measurement of $h$ was made with $d$ set at 250 mm. Sugar was then added until the percentage of sugar, by mass, in the solution was 50%. It was found that the presence of the sugar required $h$ to be increased by about 10 mm so that the light beam was once again transmitted through both holes.

Describe a suitable procedure that the student should carry out to investigate how the percentage of sugar, by mass, in the solution affects the refractive index.
You should assume that the normal laboratory apparatus used in schools and colleges is available for the student to use.

Your answer should

- identify the quantities that should be measured and explain how these measurements will be made,
- explain how the measurements will be used to determine the percentage of sugar, by mass, in the solution,
- explain how the student could discover how the percentage of sugar, by mass, in the solution affects the refractive index of the solution,
- list any factor(s) that should be controlled during the proposed experiment and explain how this will be done,
- identify any difficulties in obtaining reliable results that might be encountered and explain safe and relevant procedures that will enable these difficulties to be overcome.

Write your answer to Question 1 on **pages 4 and 5** of this booklet. *(8 marks)*



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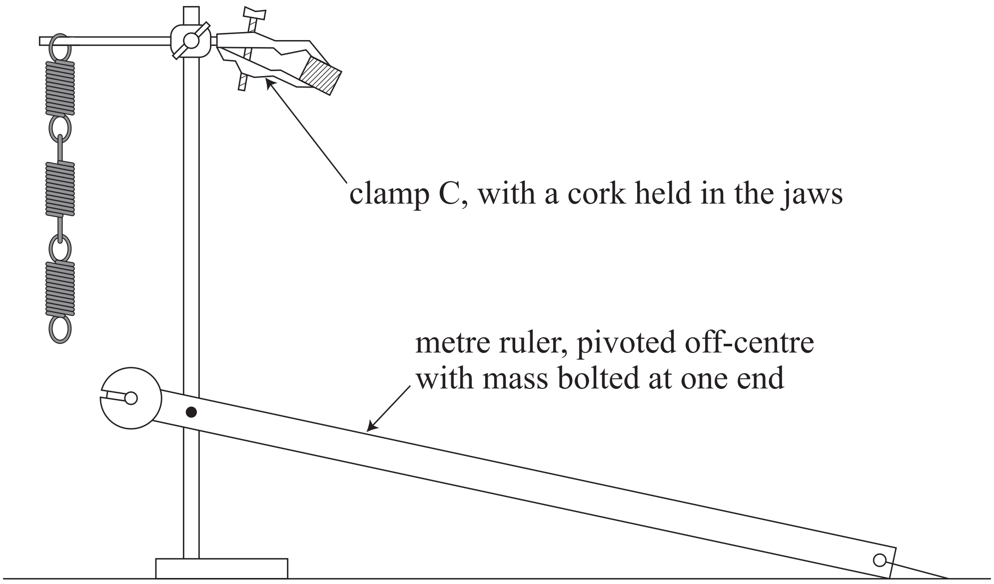
**2** You are to investigate the equilibrium conditions for a pivoted metre ruler.
**No description of the experiment is required.**

You are provided with a metre ruler, pivoted off-centre, with a mass bolted to one end.
You are also provided with three springs, connected in series.
**Do not disconnect the three springs from each other during the experiment.**

The pivot holding the ruler is attached to a retort stand.
A cork is held in the jaws of a clamp, C, which is attached to the top of this stand.
**Do not remove the cork from the jaws of the clamp during the experiment.**

Three springs are suspended above the bench from the stem of clamp C, as shown in **Figure 4**.

**Figure 4**




**2** (a) Suspend the mass hanger from the lower end of the springs.

**2** (a) (i) Measure and record the vertical distance $h_0$ from the lower surface of the mass hanger to the bench.

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$h_0$ = ...................................

**2** (a) (ii) Place a single slotted mass on the hanger so that the total mass supported by the springs is now increased by 100 g.
Measure and record the new vertical distance, $h_1$, from the lower surface of the mass hanger to the bench.

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$h_1$ = ...................................

*(1 mark)*

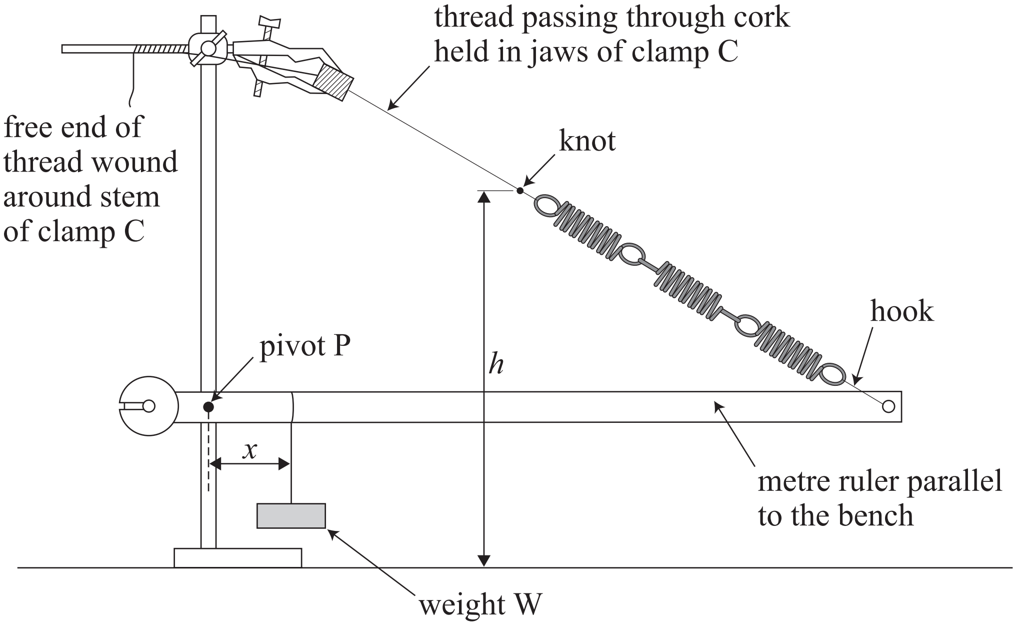
Remove the mass hanger and the springs from the stem of the clamp. Attach one end of the springs to the hook passing through the right-hand end of the pivoted metre ruler.

You are provided with a piece of thread; tie one end of the thread to the free end of the springs.
Tie a knot in the thread about 30 mm from the point at which it is attached to the springs.
Pass the thread through the hole in the cork clamped in the jaws of clamp C.

(b) Suspend the weight W from the metre ruler at a horizontal distance, $x$, about 100 mm to the right of the pivot, P.
Pull gently on the free end of the thread so the springs go into tension then adjust the tension until the ruler is supported by the springs and is approximately parallel to the bench.
Wind the free end of the thread around the stem of clamp C so that the thread is prevented from slipping back through the hole in the cork.
Make fine adjustments to the position of weight W until the ruler is parallel to the surface of the bench.

The apparatus should now appear as in **Figure 5**.

**Figure 5**




Measure $x$, the horizontal distance between pivot P and the point of attachment of weight W to the ruler.
Measure $h$, the vertical height of the knot above the surface of the bench.

Record these data on **page 8** of the answer booklet.

**Question 2 continues on the next page**

**Turn over ▶**

**2** (c) Find additional values of $h$ corresponding to **five** larger values of $x$.
You should use the method employed in part (b), (i.e. set an approximate value for $x$, then adjust the tension in the thread until the ruler is roughly parallel to the bench; then make fine adjustments to the position of weight W until the ruler is parallel to the surface of the bench).

Record your measurements and observations from part (b) and part (c) below.

*(7 marks)*

**2** (d) (i) Plot a graph with $h$ on the vertical axis and $x$ on the horizontal axis.

*(5 marks)*

(ii) Measure and record the gradient, $G$, of your graph.

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$G$ = ....................................

(iii) Evaluate $\frac{h_0 - h_1}{G}$ .

$\frac{h_0 - h_1}{G}$ = ..........................

*(3 marks)*

**Question 2 continues on the next page**

**Turn over ▸**

**2** (e) (i) State and explain which of the measurements made in part (a) contained the greater uncertainty.

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**2** (e) (ii) If the experiment had been carried out with two, rather than three springs connected together, what impact would this have had on the uncertainty in the result for *G*?

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**2** (e) (iii) A student decided to place a small spirit level of unknown mass on the top edge of the metre ruler to check that the ruler was parallel to the bench.
State and explain where the student must place the spirit level so as not to affect the measurement of *h*.

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*(6 marks)*

**END OF QUESTIONS**

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General Certificate of Education
June 2008
Advanced Subsidiary Examination

**PHYSICS (SPECIFICATION A)** **PHA3P**
**Practical (Unit 3)**

## Data Sheet

### Fundamental constants and values

| *Quantity* | *Symbol* | *Value* | *Units* |
|---|---|---|---|
| speed of light in vacuo | $c$ | $3.00 \times 10^{8}$ | $m\ s^{-1}$ |
| permeability of free space | $\mu_0$ | $4\pi \times 10^{-7}$ | $H\ m^{-1}$ |
| permittivity of free space | $\varepsilon_0$ | $8.85 \times 10^{-12}$ | $F\ m^{-1}$ |
| charge of electron | $e$ | $1.60 \times 10^{-19}$ | C |
| the Planck constant | $h$ | $6.63 \times 10^{-34}$ | J s |
| gravitational constant | $G$ | $6.67 \times 10^{-11}$ | $N\ m^2\ kg^{-2}$ |
| the Avogadro constant | $N_A$ | $6.02 \times 10^{23}$ | $mol^{-1}$ |
| molar gas constant | $R$ | 8.31 | $J\ K^{-1}\ mol^{-1}$ |
| the Boltzmann constant | $k$ | $1.38 \times 10^{-23}$ | $J\ K^{-1}$ |
| the Stefan constant | $\sigma$ | $5.67 \times 10^{-8}$ | $W\ m^{-2}\ K^{-4}$ |
| the Wien constant | $\alpha$ | $2.90 \times 10^{-3}$ | m K |
| electron rest mass (equivalent to $5.5 \times 10^{-4}$u) | $m_e$ | $9.11 \times 10^{-31}$ | kg |
| electron charge/mass ratio | $e/m_e$ | $1.76 \times 10^{11}$ | $C\ kg^{-1}$ |
| proton rest mass (equivalent to 1.00728u) | $m_p$ | $1.67 \times 10^{-27}$ | kg |
| proton charge/mass ratio | $e/m_p$ | $9.58 \times 10^{7}$ | $C\ kg^{-1}$ |
| neutron rest mass (equivalent to 1.00867u) | $m_n$ | $1.67 \times 10^{-27}$ | 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 | $1.661 \times 10^{-27}$ | kg |

### Fundamental particles

| *Class* | *Name* | *Symbol* | *Rest energy /MeV* |
|---|---|---|---|
| photon | photon | $\gamma$ | 0 |
| lepton | neutrino | $\nu_e$ | 0 |
| | | $\nu_\mu$ | 0 |
| | electron | $e^{\pm}$ | 0.510999 |
| | muon | $\mu^{\pm}$ | 105.659 |
| mesons | pion | $\pi^{\pm}$ | 139.576 |
| | | $\pi^{0}$ | 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* $= Tt$

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

$\Delta W = p\Delta V$

$pV^{\gamma}$ = 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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

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**Turn over ▸**

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

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

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

**Mechanical and Thermal Properties**

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

*energy stored* $= \frac{1}{2} Fe$

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

$\Delta Q = ml$

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

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

**Nuclear Physics and Turning Points in Physics**

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

*force* $= Bev$

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

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

*work done* $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

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

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

**Astrophysics and Medical Physics**

| *Body* | *Mass*/kg | *Mean radius*/m |
|---|---|---|
| Sun | $2.00 \times 10^{30}$ | $7.00 \times 10^{8}$ |
| Earth | $6.00 \times 10^{24}$ | $6.40 \times 10^{6}$ |

1 astronomical unit = $1.50 \times 10^{11}$ m

1 parsec = 206265 AU = $3.08 \times 10^{16}$ m = 3.26 ly

1 light year = $9.45 \times 10^{15}$ m

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

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

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

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

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

$v = Hd$

$P = \sigma A T^4$

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

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

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

**Medical Physics**

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

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

*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

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

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

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

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

**Alternating Currents**

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

**Operational amplifier**

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

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

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

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