Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2008
Advanced Level Examination

PHYSICS (SPECIFICATION A) **PA10**
Unit 10 The Synoptic Unit

Tuesday 17 June 2008 1.30 pm to 3.30 pm

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

Time allowed: 2 hours

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 80. This includes up to 2 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.
- You are reminded of the need for good English and clear presentation in your answers. Questions 5(a) and 6(a)(ii) should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

For Examiner's Use			
Question	Mark	Question	Mark
1			
2			
3			
4			
5			
6			
7			
8			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
TOTAL			
Examiner's Initials			

Answer **all** questions.

1 A car of total mass 1600 kg travels at a steady speed on a level road. The driver applies the brakes so that the car decelerates uniformly and stops 120 m further along the road 8.0 s later.

1 (a) Calculate the speed and kinetic energy of the car before the brakes are applied.

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(3 marks)

1 (b) (i) Braking of the car is assisted by a generator which is turned by the car wheels. The generator transfers part of the car's kinetic energy to a battery as the car slows down. It consists of a coil that spins in the magnetic field of a permanent magnet. In terms of the forces acting on the coil, explain why the coil experiences an electromagnetic force opposing its motion when it generates current.

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1 (b) (ii) During braking, the generator delivers an average current of 90 A at 12 V to the battery. Calculate the percentage of the car's initial kinetic energy that is transferred to the battery.

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(5 marks)

8

Turn over for the next question

Turn over ▸

2 A data logger in a remote location uses a 20 F capacitor, charged by a panel of solar cells, as its electricity supply.

2 (a) During the night, the capacitor pd falls from 12.0 V to 11.0 V. During the day, the solar cells charge the capacitor back to 12.0 V.

2 (a) (i) Show that the capacitor gains 230 J of electrical energy when it is charged from 11.0 V to 12.0 V.

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2 (a) (ii) Give **one** reason why the solar panel needs to supply more energy than the energy calculated in (i) to recharge the capacitor.

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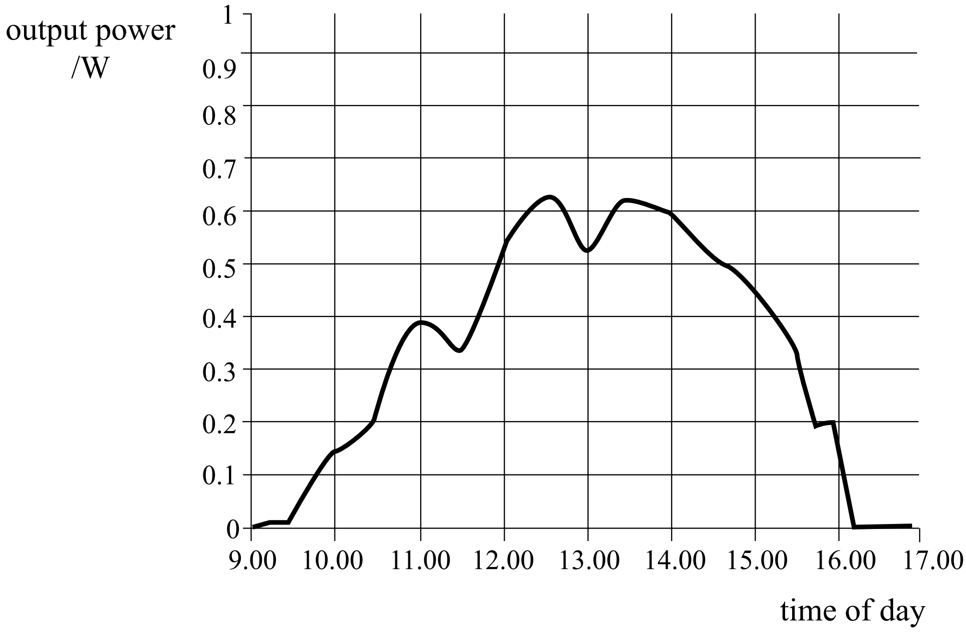
(3 marks)

2 (b) On a certain day, the output power of the solar cell panel varied as shown on the graph.



2 (b) (i) Use the graph to show that approximately 10 000 J of electrical energy was supplied by the solar cell panel.

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2 (b) (ii) The capacitor stores energy at a rate of 5% of the output power of the solar cell panel. Estimate the time taken for the capacitor to recharge from 11.0 V to 12.0 V on this day.

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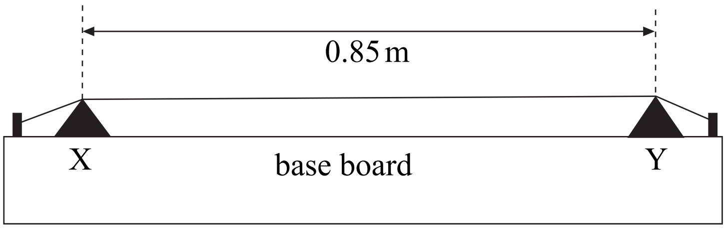
(6 marks)

9

Turn over ▸

3 A steel wire is stretched between two fixed points across two 'bridges' X and Y, 0.85 m apart, as shown in **Figure 1**.

Figure 1



3 (a) When plucked at its centre, the wire vibrates in its fundamental mode and produces sound waves of frequency 150 Hz.

3 (a) (i) With the aid of a sketch, describe the relative amplitude and phase of the particles along the wire.

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3 (a) (ii) Calculate the wavelength of the fundamental mode of vibration of the wire.

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(3 marks)

3 (b) The fundamental frequency of vibration, f_o, of the wire is given by

$$f_o = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

where l is the length of the wire, μ is the mass per unit length of the wire and T is the tension in the wire.

3 (b) (i) If the diameter of the wire is 0.26 mm, show that μ is $4.1 \times 10^{-4}\,\text{kg}\,\text{m}^{-1}$.

density of steel = $7800\,\text{kg}\,\text{m}^{-3}$

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3 (b) (ii) Calculate the tension in the wire.

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(4 marks)

3 (c) The breaking stress of steel is 1.2×10^9 Pa. Discuss whether or not the wire is in danger of breaking if its tension is increased to raise the frequency of its fundamental vibrations to 300 Hz.

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(3 marks)

10

Turn over ▸

4 (a) (i) Light takes 43 minutes to travel from the Sun to Jupiter. Calculate the distance from the Sun to Jupiter.

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4 (a) (ii) The mass of the Sun is 1040 times the mass of Jupiter. Show that the resultant gravitational field strength is zero at a distance of 2.3×10^{10} m from Jupiter.

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(4 marks)

4 (b) Jupiter has a mean radius of 7.1×10^{7} m and a mass of 1.92×10^{27} kg.

4 (b) (i) Show that the gravitational potential due to Jupiter at its surface is $-1800\,\text{MJ kg}^{-1}$.

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Areas outside the box will not be scanned for marking

4 (b) (ii) A distant comet is attracted by Jupiter and hits the planet. Estimate the speed of impact of the comet at Jupiter's surface, stating **one** assumption made in your method.

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(5 marks)

9

Turn over for the next question

5 In a vapour lamp, the vapour is heated to a temperature of 3000 K to make its atoms collide and undergo excitation by collision.

5 (a) (i) Estimate the mean kinetic energy of an atom of the vapour at a temperature of 3000 K.

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5 (a) (ii) Explain why the vapour emits light when its temperature is 3000 K but not when its temperature is 300 K.

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

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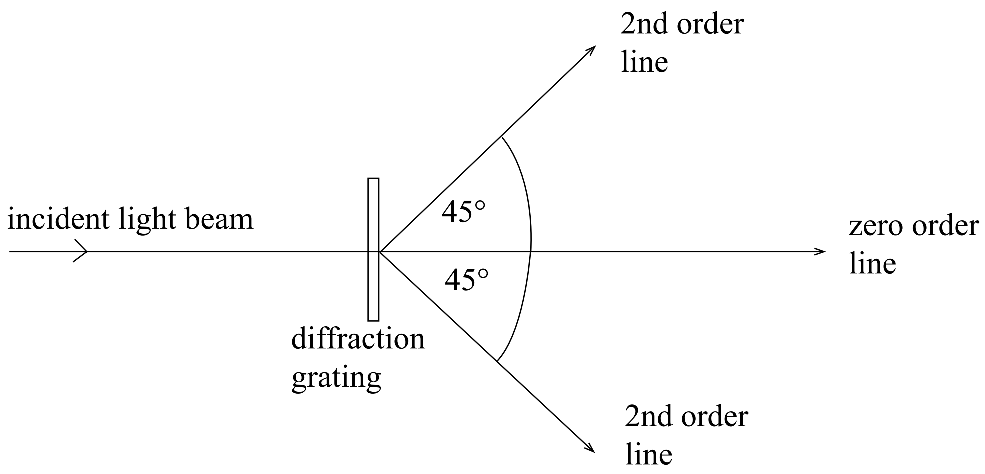
(5 marks)

5 (b) A transmission diffraction grating has 600 lines per millimetre. A narrow beam of light from a sodium vapour lamp is passed through the diffraction grating at normal incidence, as shown in **Figure 2**. A prominent yellow line is observed in the second order spectrum at an angle of diffraction of 45°.

Figure 2



5 (b) (i) Calculate the wavelength of this line.

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5 (b) (ii) Calculate the energy of a photon of this wavelength.

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Question 5 continues on the next page

5 (b) (iii) Discuss the relevance of your calculation of the photon energy to your explanation in part (a)(ii).

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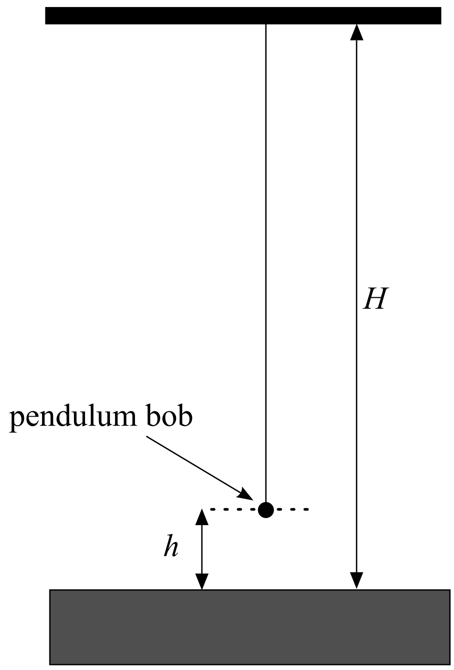
(6 marks)

11

6 A long simple pendulum was used in an experiment to measure *g*, the acceleration of free fall, as shown in **Figure 3**. By shortening the thread, the height of the pendulum bob above the floor was altered. The time period was measured for different measured heights of the pendulum from the centre of the bob to the floor

Figure 3



6 (a) Outline how you would use a stopwatch to measure the time period of the oscillations as accurately as possible.

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

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(3 marks)

Question 6 continues on the next page

Turn over ▸

Areas outside the box will not be scanned for marking

6 (b) The time period, T, of a simple pendulum at height h above the floor is given by

$$T = 2\pi\sqrt{\frac{H-h}{g}}$$

where H is the height of the point of suspension of the pendulum above the floor.

Rearrange this formula to show that $T^2 = a - bh$, where a and b are constants, and use your rearrangement to give expressions for a and b.

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(3 marks)

6 (c) The following measurements of T and h were made.

height h / mm	time period T / s	(time period)^2 T^2 / s^2
50	3.60	
253	3.48	
445	3.35	
656	3.24	
860	3.12	
1042	2.99	

6 (c) (i) Complete the table above and plot a suitable graph to show that $T^2 = a - bh$

Question 6 continues on page 16

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Turn over

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6 (c) (ii) Use your graph to determine *g*.

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(9 marks)

15

7 Two protons moving at high speed towards each other collide and fuse together to form a $^{2}_{1}H$ nucleus accompanied by the emission of two other particles.

7 (a) (i) Complete the nuclear equation below.

$$p \quad + \quad p \quad \rightarrow \quad ^{2}_{1}H \quad + \ldots\ldots\ldots\ldots \quad + \ldots\ldots\ldots\ldots$$

7 (a) (ii) State the quark composition of a proton and of a $^{2}_{1}H$ nucleus.

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7 (a) (iii) Describe, in terms of quarks, the changes that take place in the above reaction.

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(5 marks)

Question 7 continues on the next page

7 (b) Discuss the role of each of the following three forces when two protons collide, fuse and form a ${}^{2}_{1}H$ nucleus.

the electrostatic force ....

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the strong nuclear force ....

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the weak interaction ....

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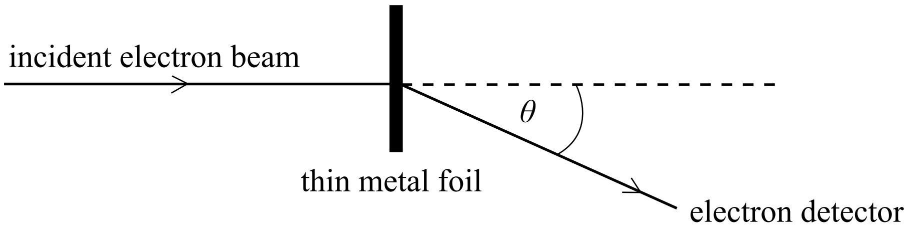
(3 marks)

8

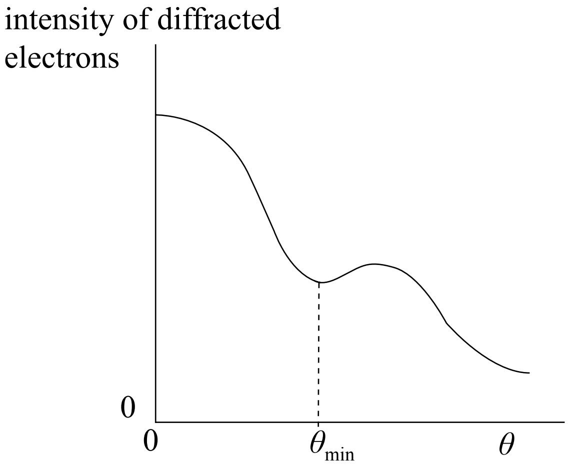
Areas outside the box will not be scanned for marking

8 A beam of monoenergetic electrons is directed at a thin metal foil. The electrons passing through the foil are diffracted by the nuclei of the atoms in the foil, as shown in **Figure 4**.

Figure 4



The graph below shows how the intensity of the diffracted electrons varies with the angle of diffraction, θ, shown in **Figure 4**.



8 (a) If the speed of the electrons was increased, state and explain what the effect would be on

8 (a) (i) the de Broglie wavelength of the electrons in the beam,

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8 (a) (ii) the angle of diffraction, θ_{min}, at which the intensity of the diffracted electrons is a minimum.

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(4 marks)

Question 8 continues on the next page

Turn over ▸

Areas outside the box will not be scanned for marking

8 (b) The radius of the nucleus of an atom can be determined from electron diffraction measurements. The results show that the radius, r, of a nucleus depends on its mass number, A, according to the equation

$$r = r_o A^{\frac{1}{3}}, \text{ where } r_o \text{ is a constant equal to } 1.2\,\text{fm}.$$

8 (b) (i) Use this expression to show that the density of a spherical nucleus is independent of A.

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8 (b) (ii) Estimate the density of nuclear matter.

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(4 marks)

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Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

General Certificate of Education
June 2008
Advanced Level Examination

PHYSICS (SPECIFICATION A) **PA10**
Unit 10 The Synoptic Unit
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 $= \frac{\textit{power output}}{\textit{power input}}$

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

This insert should **not** be sent to the examiner

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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}

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

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