PRIFYSGOL ABERYSTWYTH UNIVERSITY

EXAMINATION FOR ENTRANCE SCHOLARSHIPS JANUARY 2017

PHYSICS

Time allowed: **90 minutes**

Section A is a set of questions on data analysis. It requires work on graph paper.

Section B consists of nine questions. Attempt as many as time allows. Use the notebook(s) provided to work out your solutions. Clearly indicate each question number and please highlight your final numerical answers (including units) by, for example, underlining or framing them. Correct approaches, thoughts, and methods will be marked, even if the final answer is incorrect. No negative mark will be given for wrong answers.

Section A is worth 30% and Section B 70%. The numbers in brackets at the end of the questions are the marks for complete answers.

Standard booklets of fundamental constants or formulae, provided by your school, can be used. However, the lists on the next page should be enough for answering all the questions.

Calculators are allowed to be used.

Fundamental Constants

Electron charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
Electron mass	$m_\mathrm{e} = 9.11 \times 10^{-31}\,\mathrm{kg}$
Gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{m^3 kg^{-1} s^{-2}}$
Plank's constant	$h = 6.63 \times 10^{-34}\,\mathrm{m^2 kg\ s^{-1}}$
Speed of light	$c = 3.00 \times 10^{8}\,\mathrm{m/s}$
Gas constant	$R = 8.31\,\mathrm{J\,K^{-1} mol^{-1}}$

Further Useful Constants

Gravity	$g = 9.8\ \text{m.s}^{-2}$
Mass of the alpha particle	$m_\alpha = 6.64 \times 10^{-27}\ \text{kg}$
Water density	$\rho_\text{w} = 10^3\ \text{kg m}^{-3}$
Density of iron	$\rho_\text{Fe} = 7850\ \text{kg m}^{-3}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
Astronomical unit	$1\,\text{AU} = 1.5 \times 10^{11}\,\text{m}$
Ångström	$1\ \text{Å} = 10^{-10}\,\text{m}$
Electronvolt	$1\,\text{eV} = 1.6 \times 10^{-19}\,\text{J}$
Avogadro number	$N_\text{A} = 6.22 \times 10^{23}\ \text{mol}^{-1}$
Temperature conversion	$T_{[^\circ\text{C}]} = T_{[\text{K}]} + 273.15$

Useful Formulae

$$PV = NkT \qquad PV = nRT \qquad n = \frac{N}{N_\text{A}} \qquad M = \frac{m}{n}$$

$$v(t) \equiv \frac{dx(t)}{dt} \qquad a(t) \equiv \frac{dv(t)}{dt} \qquad \omega = \frac{2\pi}{T} \qquad a_\text{N} = \frac{v^2}{r}$$

$$s(t) = s_0 + u(t - t_0) + \frac{1}{2}a(t - t_0)^2 \qquad v(t) = u + a(t - t_0)$$

$$E_\text{kin} = \frac{1}{2}mv^2 = \frac{p^2}{2m} \qquad E_\text{pot}(r) = -\frac{GMm}{r} \qquad E_\text{pot} \approx mgh \qquad F_e(r) = k\frac{qQ}{r^2}$$

$$E = hf \qquad c = \lambda f \qquad \lambda_0 = 2L \qquad \lambda_\text{B} = \frac{h}{p} \qquad N(t) = 2^{-t/\tau} N_0$$

$$F = PA \qquad E = mc^2 \qquad g = \frac{GM}{R^2} \qquad \rho = \frac{m}{V} \qquad A = \pi r^2$$

$$U = IR \qquad Q = CU \qquad E = UQ \qquad Q = It$$

$$\sum I_i = 0 \qquad \sum U_i = 0 \qquad \frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

SECTION A

Experimental Data Analysis

A metal tank, filled with $m = 120\,\text{g}$ of hydrogen gas, was heated, while its temperature and pressure were monitored. The values were recorded nine times.

T (^{o}C)	18	30	53	75	100	125	165	200	212
P (kPa)	175	190	200	225	230	205	280	290	300

a) What is likely to be the uncertainty (e_P, reading error) on the pressure due to the resolution of the reading? [2]

b) Work out the temperature values on an absolute (Kelvin) scale. [2]

c) Draw a *PT* (pressure against temperature) diagram. Label the axes, and add error bars to the data points to indicate the uncertainty on the pressure data. [5]

d) The ideal (or perfect) gas law, $PV = nRT$, indicates a linear relationship between the pressure and temperature of an ideal gas. Do all the nine measurements seem to follow this law? [3]

e) Draw a line that fits the accepted measurements and read its gradient. [4]

f) One mole of hydrogen gas weighs 2 g, that is, the molar mass of the hydrogen molecule is M = 2 g mol^{-1}; and R is the universal gas constant (see the list of 'Fundamental Constants'). Using the formula $m = nM$, evaluate the product nR. [4]

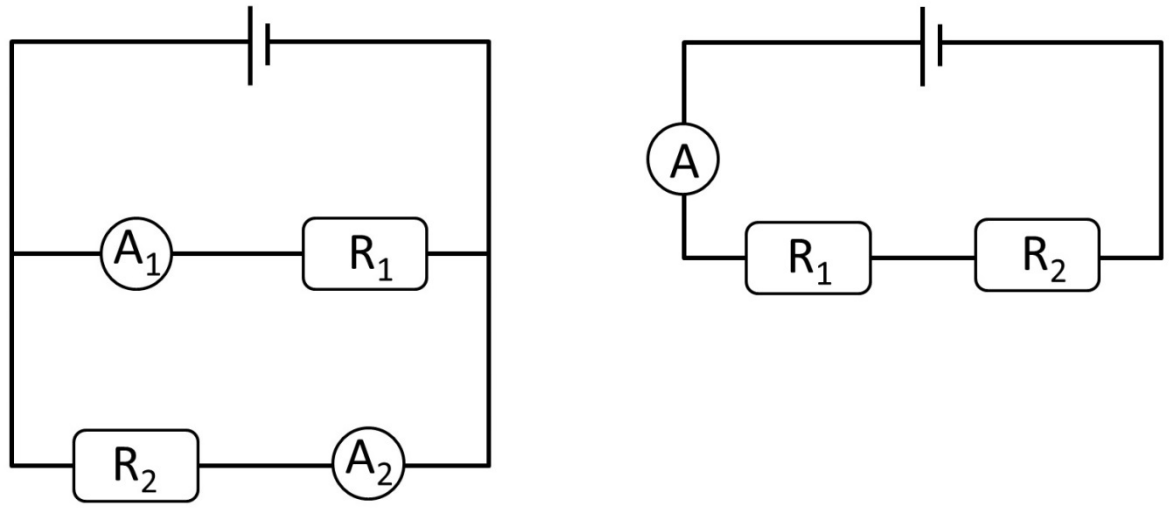
SECTION B

1 [5]

High up in the air, a balloon airship is rising with a constant speed of $u = 0.7\,\mathrm{m\,s^{-1}}$ when a bag of mass $m = 15\mathrm{kg}$ is thrown out of it with a horizontal speed of $w = 1.4\,\mathrm{m\,s^{-1}}$. What will be the kinetic energy of the bag $t = 4\,\mathrm{s}$ later? (Air resistance can be ignored.)

2 [5]

Two electronic devices, R_1 and R_2, are connected in parallel to a battery, as shown in the left circuit below. The readings on the ammeters are $I_1 = 3\,\mathrm{mA}$ and $I_2 = 5\,\mathrm{mA}$. What is the reading on the ammeter when the two gadgets are connected in series, as shown in the right circuit, with the same battery?



3 [5]

The radius of the circular path of an electron about a magnetic field line is $r = 1.2\,\mathrm{m}$. What is the de Broglie wavelength of the electron if the magnetic field strength is $B = 3\,\mathrm{G}$?

4 [5]

In an experiment with thulium-168, a radioactive isotope, the initial count rate was measured to be 100 counts per hour. After 123 days, the count rate had dropped to 40 counts per hour. How long would it take for the count rate to drop from 40 to 14 counts per hour?

5 [5]

What is the ratio between the angular speeds of the second and hour hands of a clock?

6 [5]

In a nuclear collision, ${}^{9}_{4}\mathrm{Be}$ and ${}^{4}_{2}\mathrm{He}$ fuses into ${}^{12}_{6}\mathrm{C}$. What is the other particle that is generated?

7 [5]

A thin optical lens of focal length 30 cm forms an image of a caterpillar of length 20 mm crawling towards the lens. How long is the image of the caterpillar when its head is at a distance of 10 mm from the lens?

8 [5]

Spica, the only first-magnitude star of the constellation Virgo, is 16.4 million AU (astronomical units) away from us. How many years does light take to travel from Spica to Earth?

9 [5]

When the distance between single point charges q and Q is *d*, the electrostatic force between them is $F = 100\ \mathrm{N}$.

What is the force on Q when eight point charges, each with charge q, are arranged around it at grid points A to H as shown, where point charge A is halfway between grid points C and G? (Each of the ten indicated distances between neighbouring point charges equals *d*.)