Aberystwyth University
Scholarship & Merit Awards
Examinations
February 2025

PHYSICS

Time Allowed – 1.5 hours

This examination paper consists of a data analysis exercise and six questions. Try to attempt all. Please indicate each question number at the beginning of your working and highlight your final numerical answers (including units) by, for example, underlining or framing.

Marks will be awarded for correct approaches, thoughts, ideas, or methods, even if the final answer is missing or incorrect. No negative marks will be given for inaccurate or faulty arguments or incorrect answers.

Feel free to use any standard booklets of fundamental constants and/or formulas, provided by your school or the short list of constants and formulas below.

Any calculators are allowed to be used.

Approximate values of a few Fundamental Constants

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

Further Useful Constants

Gravitational acceleration	$g = 9.8\ \mathrm{m\ s^{-2}}$
Mass of an alpha particle	$m_\alpha = 6.64 \times 10^{-27}\ \mathrm{kg}$
Boltzmann constant	$k_\mathrm{B} = 1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$
Astronomical unit	$1\ \mathrm{AU} = 1.5 \times 10^{11}\ \mathrm{m}$
Ångström	$1\ \mathrm{Å} = 10^{-10}\ \mathrm{m}$
Electronvolt	$1\ \mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}$
Avogadro number	$N_\mathrm{A} = 6.22 \times 10^{23}\ \mathrm{mol^{-1}}$
Temperature conversion	$T_\mathrm{K} - T_{^\circ\mathrm{C}} = 273.15$

Formulas

$PV = Nk_\mathrm{B}T$ $\quad PV = nRT$ $\quad n = \frac{N}{N_\mathrm{A}}$ $\quad M = \frac{m}{n}$

$\Delta U = Q_\text{to gas} - W_\text{by gas}$ $\quad \Delta U = cm\Delta T$ $\quad W_\text{by gas} = P\Delta V$

$v \equiv \frac{dx}{dt}$ $\quad a \equiv \frac{dv}{dt}$ $\quad \omega = \frac{2\pi}{T}$

$s = s_0 + ut + \frac{1}{2}at^2$ $\quad v = u + at$ $\quad a_n = \frac{v^2}{r}$

$y = u_y t - \frac{1}{2}gt^2$ $\quad x = u_x t$

$\tau = Fd$ $\quad \tau = I\alpha$ $\quad L = I\omega$ $\quad E_\mathrm{rot} = \frac{1}{2}I\omega^2$

$E_\mathrm{kin} = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $\quad E_\mathrm{pot} = -\frac{GMm}{r}$ $\quad E_\mathrm{pot} = mgh$

$F_\mathrm{e} = k\frac{qQ}{r^2}$ $\quad F_\mathrm{gr} = \frac{GMm}{r^2}$ $\quad \vec{\boldsymbol{r}}_\mathrm{cm} = \frac{\sum m_i \vec{\boldsymbol{r}}_i}{\sum m_i}$

$E = hf$ $\quad c = \lambda f$ $\quad \lambda_0 = 2L$ $\quad \lambda_\mathrm{B} = \frac{h}{p}$ $\quad N = N_0\, 2^{-\frac{t}{T_{1/2}}}$

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

$V = IR$ $\quad q = CV$ $\quad E_J = Vq$ $\quad q = It$ $\quad q = Ne$

$P = IV = I^2R = \frac{V^2}{R}$ $\quad \sum I_i = 0$ $\quad \sum V_i = 0$ $\quad c = \frac{c_\mathrm{vacuum}}{n}$

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i} \qquad M = \frac{i}{o} \qquad n_1 \sin\ \alpha_1 = n_2 \sin \alpha_2$$

$$N_\text{n} m_\text{n} c^2 + N_\text{p} m_\text{p} c^2 = m_\text{nucleus} c^2 + U_\text{binding}$$

Data Analysis Exercise

One of the radioactive isotopes of gold changes into a stable isotope of mercury by beta decay: $({}^{199}_{79}\text{Au} \rightarrow {}^{199}_{80}\text{Hg} + e^- + \bar{\nu}_e)$

The mass of the gold isotope $({}^{199}_{79}\text{Au})$ content in a Petri dish was measured seven times during a week, and the following values were obtained:

Monday 3 pm: $m_1 = 2.2\ \text{mg}$

Tuesday 3 am: $m_2 = 2.0\ \text{mg}$

Wednesday 3 am: $m_3 = 1.6\ \text{mg}$

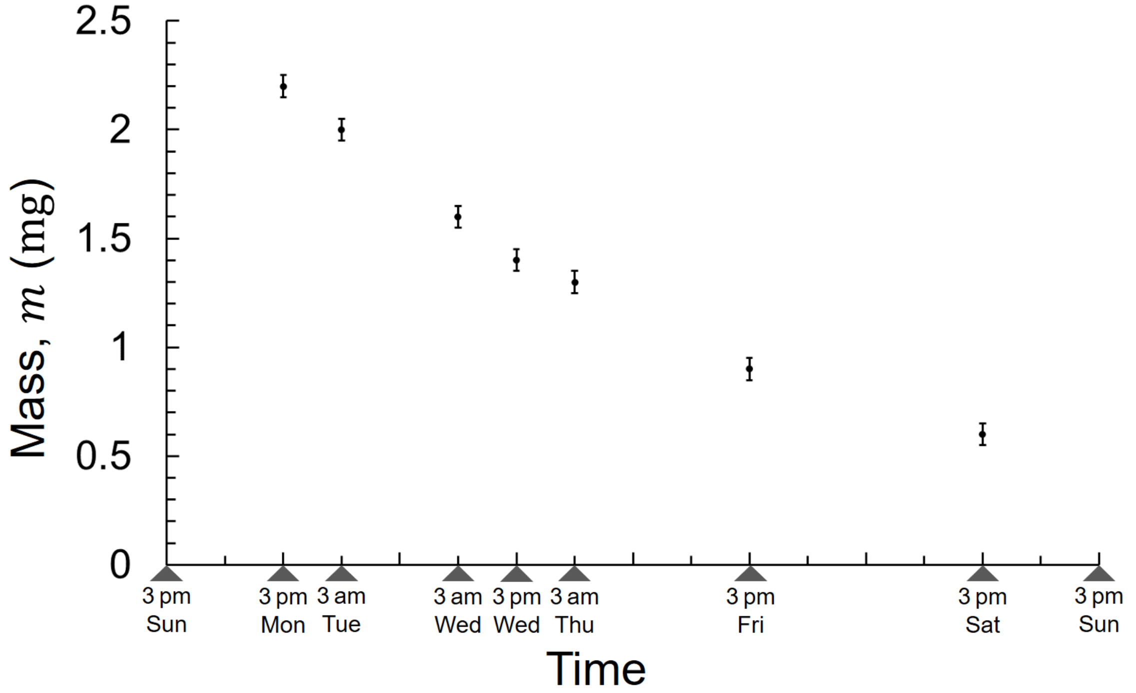
Wednesday 3 pm: $m_4 = 1.4\ \text{mg}$

Thursday 3 am: $m_5 = 1.3\ \text{mg}$

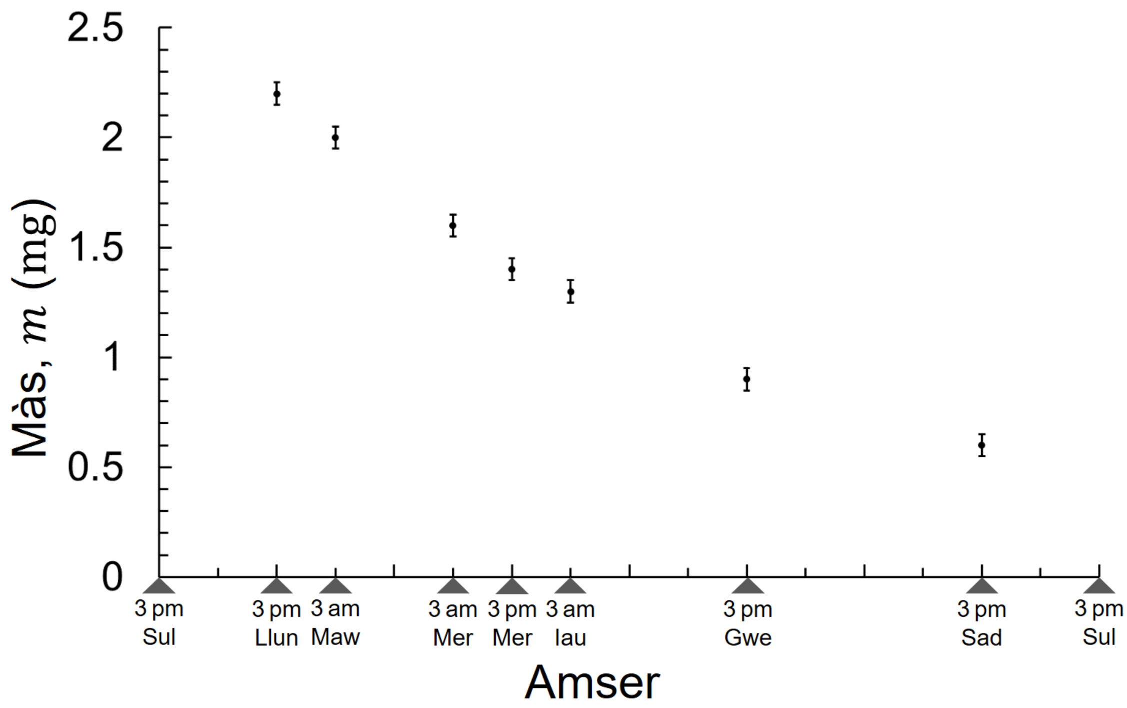
Friday 3 pm: $m_6 = 0.9\ \text{mg}$

Saturday 3 pm: $m_7 = 0.6\ \text{mg}$

The uncertainty of each measurement was: $e_m = \pm 50\ \mu\text{g}$



The above diagram with Welsh axes:



From the measured masses,

i) Find the half-life, $t_{1/2}$, of the gold isotope.

ii) Work out the mass, m_1, of the gold isotope in the dish on Sunday 3 pm, a day before the first measurement.

iii) Predict the mass, m_2, of the gold isotope in the dish on Sunday 3 pm, a day after the last measurement.

Question 1

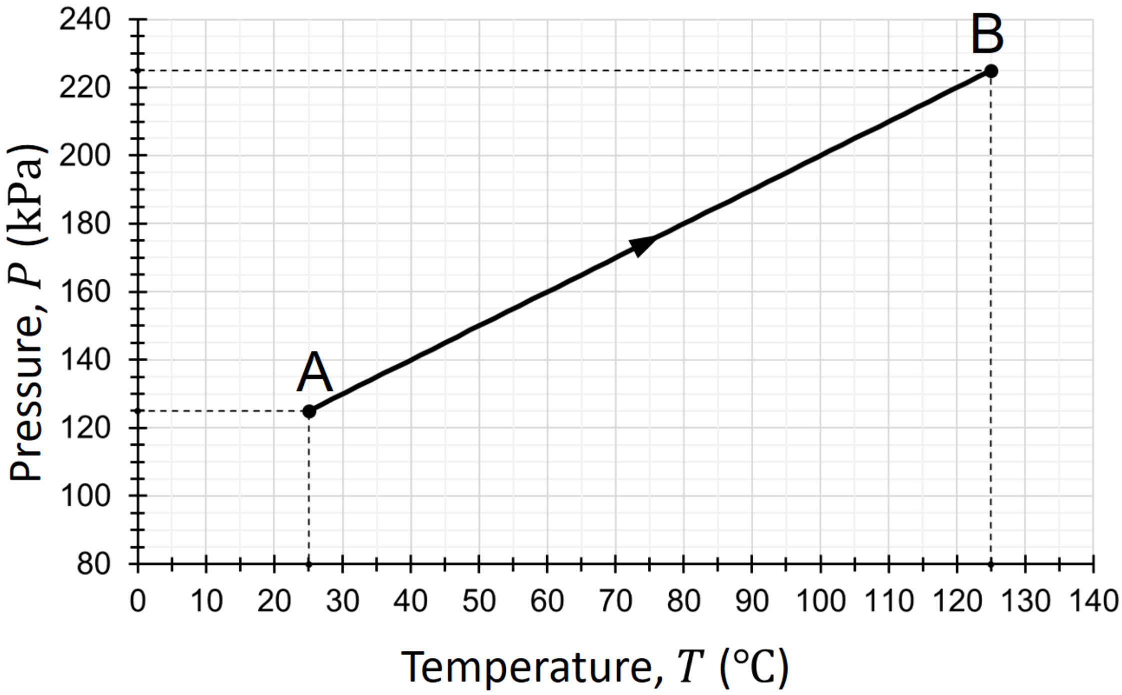
On a smooth horizontal surface, block A, of mass $m_{\mathrm{A}} = 0.5\ \mathrm{kg}$, is moving towards block B at speed u:

After elastic collision, the two blocks are moving in opposite directions at the same speed:

How heavy is block B?

Question 2

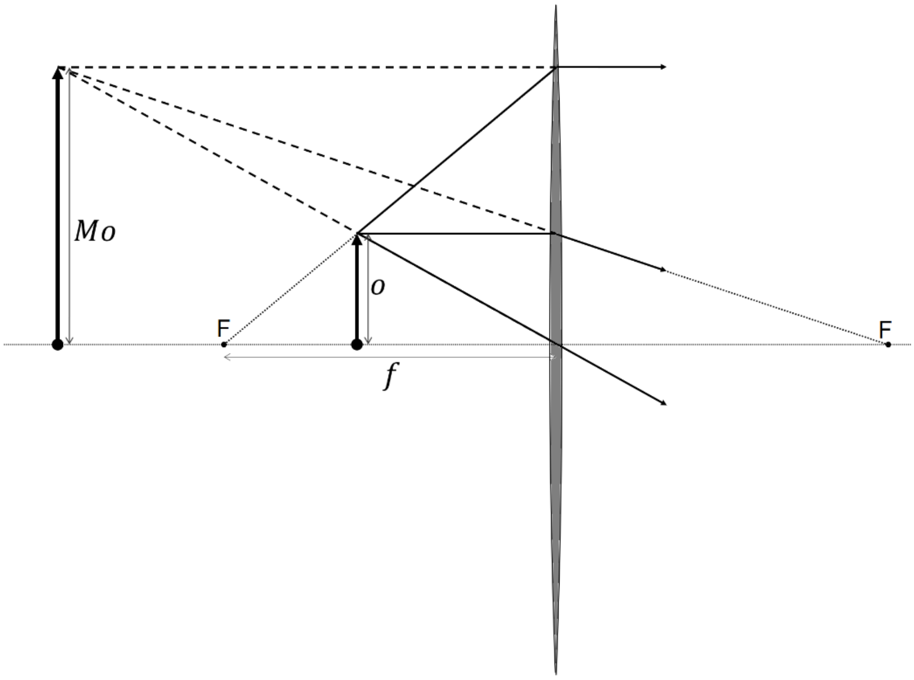
The diagram below shows the pressure of an ideal gas (perfect gas) of $n = 25 \text{ mol}$ against the gas temperature as it is going through a thermodynamic process from initial state A to final state B.



Make a simple sketch (no graph paper is needed) of the gas pressure, P, against the volume, V, of the gas from state A to B.

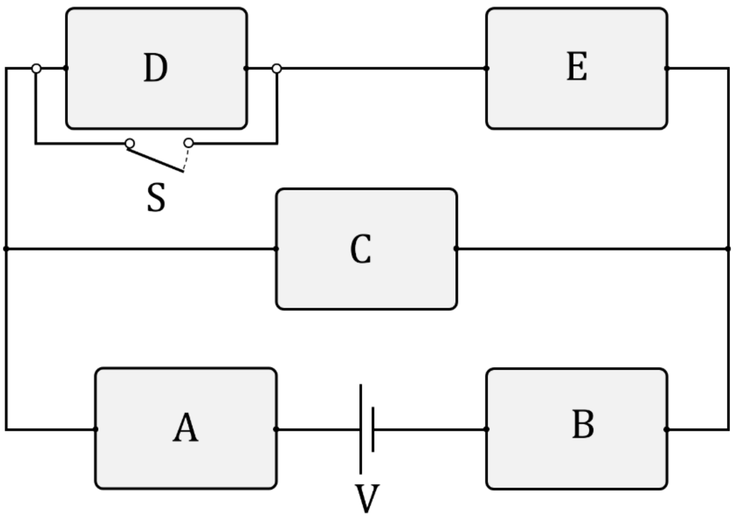
Question 3

How far is an object from a magnifying glass (a thin converging lens of focal distance $f = 3\ \mathrm{cm}$) if, when looking at the object through the glass, it appears $M = 2.5$ times larger than it is?



Question 4

The below schematic diagram shows a circuit with five identical appliances ($R_A = R_B = R_C = R_D = R_E$) connected to a power supply of fixed voltage, V. When all the five appliances are working, the current through the resistor of appliance C is $I_C = 5\ \mathrm{A}$.



Calculate I_C when appliance D is taken out of the circuit by turning on switch S.

Question 5

Ultraviolet light of wavelength $\lambda = 250\ \mathrm{nm}$ shines at a copper block.

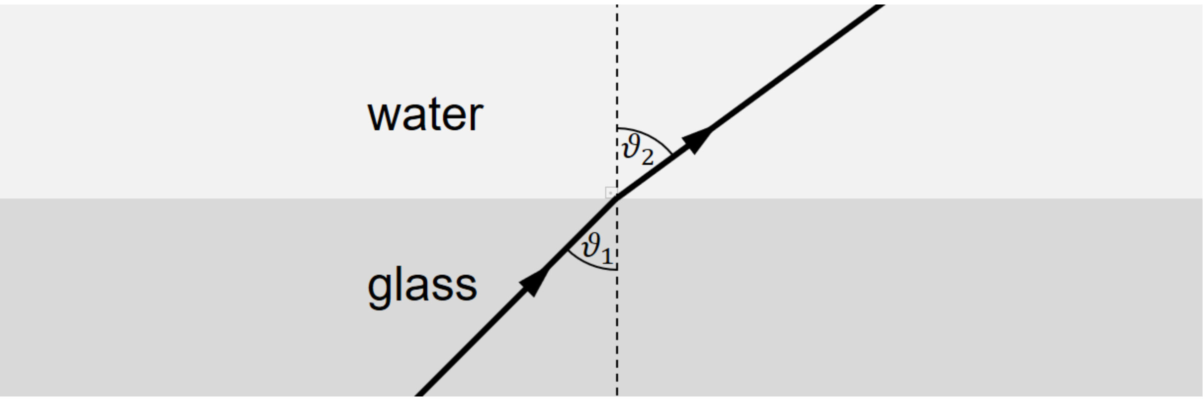
a) Show that, by the photoelectric effect, electrons can escape from the surface of the copper;

b) And find their possible speed at which they can leave the surface.

The work function of copper is: $W_{\mathrm{Cu}} = 4.9\ \mathrm{eV}$

Question 6

A light beam from a light source under a glass of water is propagating through the bottom of the glass at angle of incidence $\vartheta_1 = 45°$ and enters the water at angle of refraction $\vartheta_2 = 54°$.



Find out what happens to a light beam that enters the water from the glass at angle of incidence $\vartheta_3 = 60°$.