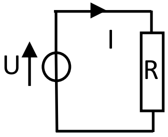
INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

Exam 1 – S1 – Physics Scan 1st 2023-2024

Exercise 1 : Ironing 8 pts +0.5pts bonus		
Elements of correction, expected items and grading scale		
1- Meaning o the different physical quantities 2000-2400W corresponds to the power used/received by the iron, noted P dim (P) = dim(Energie)T^{-1} and dim (Energie)= ML^2T^{-2} (kinetic energy for instance) dim(P) = ML^2T^{-3} 220-240V corresponds to the voltage difference accros the iron noted U dim (U) = dim(P)I^{-1} (P= UI law with I the electric current intensity through the iron) dim(U) = $ML^2T^{-3}\ I^{-1}$	0.5 pt for defining the quantities and their notation 0.5 pt for the dimension of P and U 0.5 pt for justifying the dimensions	/1.5
2- Physical and energy mechnisms at play The iron is made of a heating resistor (R). When plugged in, an electric current flows through the iron and energy is dissipated by Joule's effect.  An iron is a device that transforms **electric** energy into **thermal** energy	Expected words : Resistor/resistance, Joule's effect, electric energy, thermal energy *Bonus : 0.5 for a simplified eklectric scheme*	/1 *Bonus /0.5*
3- Electric current intensity $P = UI$ With the datasheet information: $P = \frac{P_{max}+P_{min}}{2}$ and $\Delta P = \frac{P_{max}-P_{min}}{2}$ P= 2.2 ± 0.2 kW $U = \frac{U_{max}+U_{min}}{2}$ and $\Delta U = \frac{U_{max}-U_{min}}{2}$ U= 230±10 V $I_{max} = \frac{P_{max}}{U_{min}} = \frac{2400}{220} = 10.909A$ $I_{min} = \frac{P_{min}}{U_{max}} = \frac{2000}{240} = 8.333A$ $I = \frac{I_{max}+I_{min}}{2} = 9.6212A \quad \Delta I = \frac{I_{max}-I_{min}}{2} = 1.2878A$ I= 9.6±1.3 A (give the points if correct result with differential method) R=U/I Rmax=Umax/Imin=28.801152 Ω Rmin=Umin/Imax=20.1668 Ω DR=4.31716 Ω R=24.48399 Ω R= 24±5 Ω	0.5 pt for literal expressions of P, ΔP, U, ΔU 0.5 pt for numerical values of P and U with their uncertainties. 0.5 pt for literal expressions of I_{max}, I_{min} , I and ΔI 0.5 pt for the result with correct formatting (digits and uncertainties)e 0.5 Ohm's law 0.5 final result (right unit, digits…)	/3
4- Consumed energy Consumed/received energy Ec = P*t with t the duration of use Hypothesis: no uncertainty on t or choose a realistic uncertainty, for instance $\Delta t = 1\ min$ $Ec_{max} = P_{max} * t_{max}$ and $Ec_{min} = P_{min} * t_{min}$ $If\ \Delta t = 60s$ $Ec_{max} = 5184000J\ and\ Ec_{min} = 4080000J$ => Ec = 4,63±0,56 MJ $if\ \Delta t = 0s$ $Ec_{max} = 5040000J\ and\ Ec_{min} = 4200000J$ => Ec = 4,62±0,42MJ	0.5 literal expression of Ec 0.5 hypothesis on the uncertainty on t 0.5 numerical value of Ec with uncertainty , in proper format (accept a result with 1 significant digit)	/1.5
5- Cost for a 35 min use Price 0.10€/kWh (2020 cost…) = 0.1/(1000*3600) €/J Cost $_{max}$ = 0.144€ Cost $_{max}$ = 0.111€ Cost = 0.13±0.02€	0.5 for unit conversion 0.5 for final result and uncertainty	/1

Exercise 2 : Diode	/ 27+6
1. Diode I-V curve in passive sign convention : see appendix for $u \leqslant e_S : I = 0$ for $u \geqslant e_S : I = -\frac{e_S}{r_d} + \frac{U}{r_d} = (-0.3\text{A}) + (0.2\Omega^{-1}) \times U$. Plot : one can use $(U = 0, I = 0)$, $(U = e_S = 1.5\text{V}, I = 0)$ and $(U = 1.75\text{V}, I = 5.10^{-2}\text{A})$ (accept other points, but -0.5 if 2 pts too close) Passive dipole, polarized, non linear (or piecewise linear)	0.5 convention 0.5 1 2 for plot with 3 well chosen points 1
2.a. Circuit scheme with all information (see. end of correction)	1
2.b. I-V curve of the generator : using two points with $U = E_g - R_g I$ in Active sign convention : for instance $(U_1 = 1.25\text{V}, I_1 = 3.5.10^{-2}\text{A})$ and $(U_2 = 1.75\text{V}, I_2 = 2.5.10^{-2}\text{A})$. Operating point : reading the intersection of the two curves $U_P = 1.60\text{V} + \frac{1.35\text{cm}}{18.8\text{cm}} \times 5.10^{-1}\text{V}$ and $I_P = 2.10^{-2}\text{A} + \frac{1.55\text{cm}}{10.1\text{cm}} \times 5.10^{-2}\text{A}$. Hence $P\left(U_P = 1.636\text{V}, I_P = 2.77.10^{-2}\text{A}\right)$ (accept any coherent value; significant digits decided after uncertainty calculation). Details about scale use expected, remove points otherwise	0.5 conv.+1 1.5 (with two points clearly shown) 1+1
Overall uncertainty (detailed redaction below) : $U = (1.636 \pm 0.009)\text{V}$ and $I = (2.8 \pm 0.2).10^{-2}\text{A}$	1 (formatting only)
Error sources and associated uncertainties : For instance (accept other organization if plausible; bonus for other relevant sources) - matter and medium : negligible - “man” (operator) : care while doing the projections and plots (line thickness, points positioning) : uncertainty on the intersection estimated as ±2 line widths. Perpendicularity of the axes projections : uncertainty estimated as ±2 line widths - means and method : 2 possible ways for reading (U,I) on the axes.	0.5 1 1
either direct reading with the axes graduation : half a graduation uncertainty so ($\Delta I = 0.25.10^{-2}$A and $\Delta U = 0.013$V - 2 significant digits max. Given the graduations (large zoom), this uncertainty accounts for all sources of uncertainties (including operator ones)	0.5 0.5+1(-0.5 if ΔU with 3 digits bonus 1
or reading using a 20cm ruler and using a scale : **in place of the 2.5+bonus1 above** : With the total error on the projected position of the operating point of ±4 line widths : We estimate 1 line width $\simeq$ 0.5mm which gives, using the intensity and voltage scales : 4 line widths $\simeq 4\frac{0.5\text{mm}}{18.8\text{cm}}0.5\text{V} \leqslant 6.10^{-3}\text{V}$, and 4 line widths $\simeq 4\frac{0.5\text{mm}}{10.1\text{cm}}5.10^{-2}\text{A} \leqslant 10^{-3}\text{A}$ We must add the half a graduation uncertainty per reading, that is 1 graduation (= 1mm) per distance measured : for each reading on the axis for the scale measure of each axis	0.5 1 0.5 bonus 0.5

We get the operating point as (accept any coherent value) : $U_{P,max} = 1.60\text{V} + \frac{1.45\text{cm}}{18.7\text{cm}} \times 0.5\text{V} + 6.10^{-3}\text{V} = 1.645\text{V}$ (literal relation no required) $U_{P,min} = 1.60\text{V} + \frac{1.25\text{cm}}{18.9\text{cm}} \times 0.5\text{V} - 6.10^{-3}\text{V} = 1.627\text{V}$ We get $\Delta U = \frac{U_{max} - U_{min}}{2} = 9.10^{-3}\text{V}$ $I_{P,max} = 2.10^{-2}\text{A} + \frac{1.65\text{cm}}{10.0\text{cm}} \times 5.10^{-2}\text{A} + 10^{-3}\text{A} = 2.925.10^{-2}\text{A}$ $I_{P,min} = 2.10^{-2}\text{A} + \frac{1,45\text{cm}}{10.2\text{cm}} \times 5.10^{-2}\text{A} - 10^{-3}\text{A} = 2,611.10^{-2}\text{A}$ and $\Delta I = \frac{I_{max} - I_{min}}{2} = 0.16.10^{-2}\text{A}$ Comment : The uncertainty due to the reading with a scale is 2 times smaller than with the line width	bonus 1 bonus 0.5 bonus 0.5 bonus 1 bonus 0.5 bonus 0.5 already graded bonus 0.5
2.c. Kirchhoff's voltage law $\Rightarrow I = \frac{E_g - e_s}{r_d + R_g}$ and $U = e_S + (E - e_S)\frac{r_d}{r_d + R_g} = \frac{e_S R_g + E r_d}{r_d + R_g}$. Numerical application : $U = 1.636\text{V}$ and $I = 2.7.10^{-2}\text{A}$. Remark : quantities E, e_s, R_g and r_d are known without uncertainty, so the number of significant digits is not defined. The values computed are in the uncertainty range obtained by graphical method.	1 2 0.5+0.5+ bonus 0.5 comment on digits 0.5
3. Using the I-V curve of the diode, we get $U(I = 10\text{mA}) = U_d = 1.55\text{V}$ Same uncertainty sources – accept results consistent with the previous question : half-graduation $\Delta U = 0.013\text{V}$ or ±4 line widths $\simeq \Delta U \leqslant 0.01\text{V}$ hence $U_d = 1.55 \pm 0.02\text{V}$ or $\pm 0.01\text{V}$ respectively (keeping only one digit for ΔU_d for instance)	0.5 0.5 0.5 oonly format
4. $E_g - U_d = (R_p + R_g) I_d \Leftrightarrow R_p = \frac{E_g - U_d}{I_d} - R_g$	2
$R_{p,max} = \frac{E_g - U_{d,min}}{I_d} - R_g$ $R_{p,min} = \frac{E_g - U_{d,max}}{I_d} - R_g$ $\Delta R_p = \frac{1}{2}\frac{U_{d,max} - U_{d,min}}{I_d} = \frac{\Delta U_d}{I_d} = \frac{0.01\text{V}}{10\text{mA}} = 1.\Omega$ and finally $R_P = (95 \pm 1)\Omega$	1 1 Num App+bonus0.5 literal expression with ΔU_d 0.5 only format
Remark : knowing all elements without uncertainty, we could deduce R_p directly : $R_p = \frac{E_g - e_s}{I_d} - r_d - R_g$. Does not follow the question (with "Deduce") and does not provide an uncertainty : give points on R_P only	

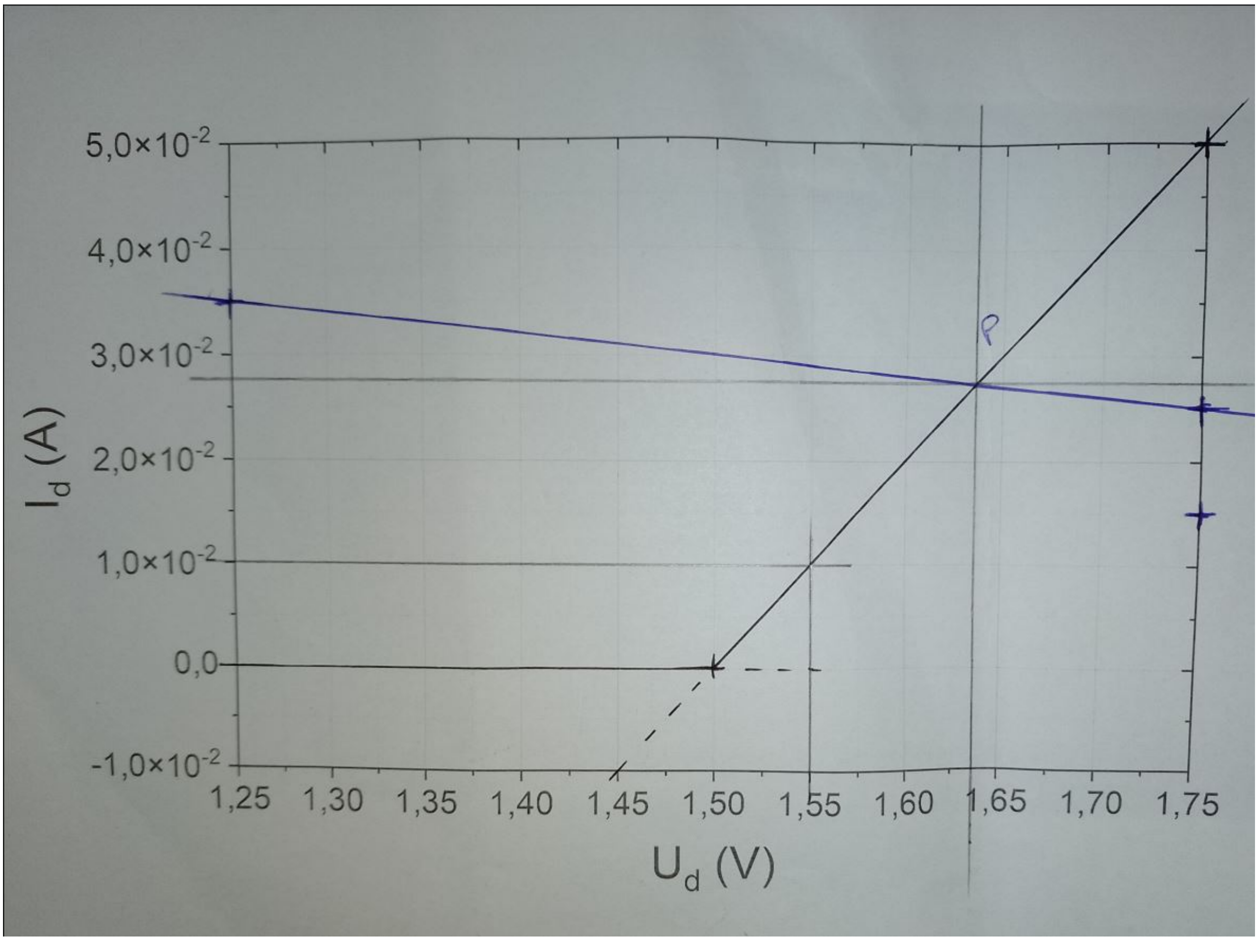
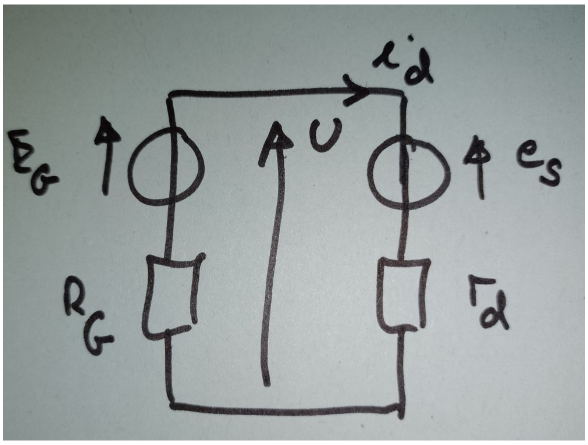
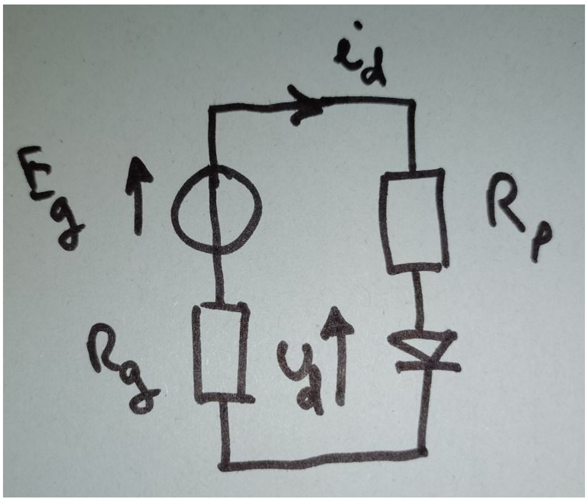


FIGURE 1 – Appendix 1



(a) Equivalent circuit for questions 1 and 2



(b) Equivalent circuit for questions 3 and 4