مسابقة في مادّة الفيزياء	**الاسم:**
المدّة: ساعتان ونصف	**الرّقم:**

يتكوّن هذا الامتحان من ستة تمارين، موزعة على ست صفحات. يجب اختيار **أربعة تمارين فقط**.
إقرأ الأسئلة كلّها بشكل عام وشامل، ومن ثمّ حدّد اختياراتك.
ملاحظة: في حال الإجابة عن أكثر من أربعة تمارين، عليك شطب الإجابات المتعلقة بالتمارين التي لم تعد من ضمن اختيارك، لأن التصحيح يقتصر على إجابات التمارين الاربع الاولى غير المشطوبة، بحسب ترتيبها على ورقة الاجابة.
يمكن الاستعانة بالآلة الحاسبة غير القابلة للبرمجة.

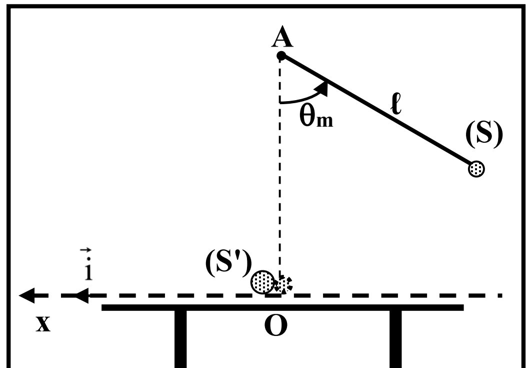
Exercise 1 (5 pts)

Energy and collision

The aim of this exercise is to determine the maximum height attained by a simple pendulum after a head-on elastic collision.

For this aim, consider a pendulum formed of a sphere (S), taken as a particle, of mass m = 100 g, suspended from the lower extremity of a light inextensible string of length ℓ = 40 cm. The upper extremity of the string is fixed, at A, to a support.

The pendulum is shifted, in the vertical plane by an angle $\theta_m = 60^o$ from its stable equilibrium position, the string remains taut, and then (S) is released from rest at instant $t_0 = 0$. Upon reaching the equilibrium position, at O, (S) has a velocity $\vec{V} = V\vec{i}$, where $\vec{i}$ is the unit vector along a horizontal x-axis passing through the equilibrium position of the pendulum. (Doc. 1).



Doc.1

Neglect all frictional forces.

Take:

- the horizontal plane passing through O as a reference level for gravitational potential energy;
- $g = 10\ m/s^2$.

1) Determine the value of the mechanical energy ME of the system (Pendulum – Earth).

2) Deduce that V = 2 m/s.

3) Determine the linear momentum $\vec{P}$ and the kinetic energy KE of (S) at point O.

4) When the pendulum passes through the equilibrium position, (S) enters a head-on elastic collision with another sphere (S'), taken as a particle, of mass m' initially at rest and placed on a horizontal table (Doc. 1). The velocities of (S) and (S') just after collision are collinear along the x-axis.

4.1) Name two physical quantities that remain conserved just before and just after this collision.

4.2) Determine in terms of m', the expressions of v'_1 and v'_2, the algebraic values of the velocities $\vec{v'_1}$ and $\vec{v'_2}$ of (S) and (S') respectively, just after collision.

4.3) Calculate m', such that just after collision (S) and (S') move in opposite directions, with the same speed $\|\vec{v'_1}\| = \|\vec{v'_2}\|$.

4.4) Calculate v'_1 and v'_2.

5) Determine the maximum height attained by the pendulum after this collision.

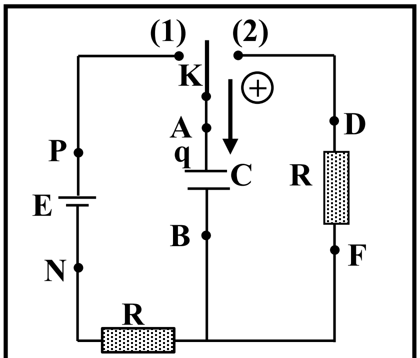
Exercise 2 (5 pts)

Charging and discharging of a capacitor

The aim of this exercise is to determine the capacitance C of a capacitor by two different methods.

For this aim, we set-up the circuit of document 2 that includes:

- a capacitor, initially uncharged, of capacitance C;
- two identical resistors each of resistance R = 1 kΩ;
- an ideal battery of e.m.f E;
- a double switch K.



Doc. 2

1) Charging the capacitor

At the instant $t_0 = 0$, K is placed in position (1) and the charging process of the capacitor starts. At an instant t, plate A of the capacitor carries a charge q and the circuit carries a current i.

1.1) Derive the differential equation that describes the variation of the voltage $u_{AB} = u_C$ across the capacitor.

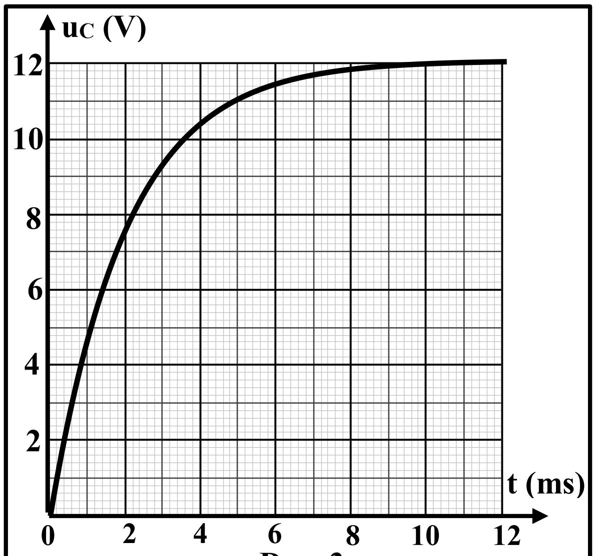
1.2) The solution of this differential equation has the form: $u_C = a - a\,e^{\frac{-t}{\tau}}$ where a and τ are constants. Determine the expressions of a and τ in terms of E, R and C.

1.3) Document 3 represents u_C as a function of time. Using document 3:

1.3.1) indicate the value of E;

1.3.2) determine the value of the time constant τ of the circuit.

1.4) Deduce the value of C.



Doc. 3

2) Discharging the capacitor

The capacitor is completely charged.

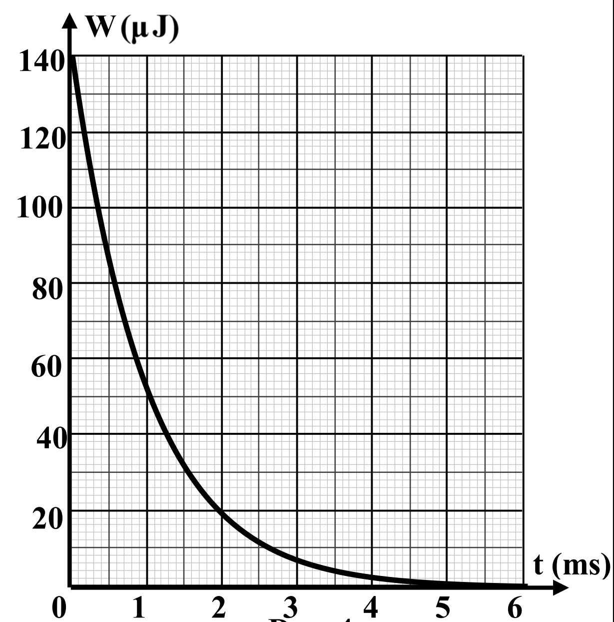
At an instant $t_0 = 0$, taken as an initial time, K is turned to position (2); the phenomenon of discharging of the capacitor thus starts. The voltage across the capacitor is:

$$u_{AB} = u_C = E\,e^{\frac{-t}{RC}}.$$

2.1) Show that the energy W stored in the capacitor, at an instant t, has the form: $W = W_0\,e^{\frac{-2t}{RC}}$, where W_0 is a constant to be determined in terms of C and E.

2.2) Show that for $t_1 = RC$ the energy is $W = 0.135\,W_0$.

2.3) Document 4 shows W as a function of time, during the discharging of the capacitor. Determine the value of C using document 4 and the result of part 2.2.



Doc. 4

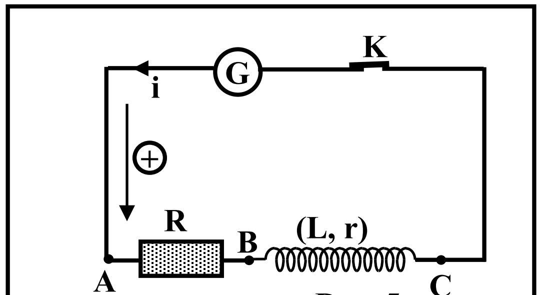
Exercise 3 (5 pts)

Self - induction

The aim of this exercise is to determine the characteristics of a coil and to specify its role in a circuit.

For this purpose, we set up the circuit of document 5 that includes in series:

- a generator (G);
- a resistor of resistance R = 18 Ω;
- a coil of inductance L and resistance r;
- a switch K.



Doc. 5

1) Characteristics of the coil

The generator (G) delivers a constant voltage E = 12 V.

At the instant $t_0 = 0$, K is closed. At an instant t the circuit carries a current i.

1.1) Derive the differential equation that describes the variation of the voltage $u_R = u_{AB}$ across the resistor R.

1.2) The solution of this differential equation has the form:

$u_R = a + b\,e^{\frac{-t}{\tau}}$ where a, b and τ are constants.

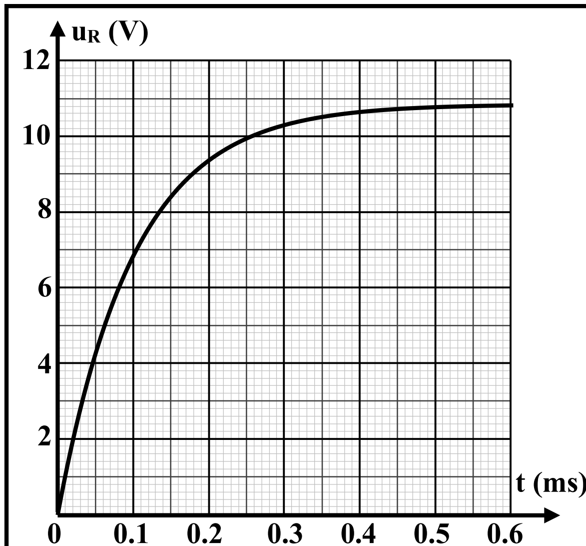
Determine the expressions of a, b and τ in terms of R, r, E and L.

1.3) Document 6 shows u_R as a function of time. Referring to document 6, indicate the maximum value of u_R.

1.4) Deduce the value of r.

1.5) Using document 6, determine the value of τ.

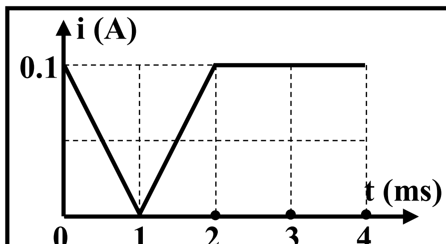
1.6) Deduce the value of L.



Doc. 6

2) Role of the coil

The generator (G) is adjusted to deliver a current « i » that varies between 0 and 4 ms as shown in document 7.



Doc. 7

2.1) Using document 7, copy and complete the table below:

Role of the coil	Time interval	Value of the self-induced e.m.f « e » in the coil
The coil acts as a resistor		
The coil acts as a generator		
The coil acts as a receiver		

2.2) Justify the role of the coil in each of the three above intervals of time.

Exercise 4 (5 pts)

Absorption spectrum

Given: Speed of light in vacuum: $c = 3\times10^8$ m/s; Planck's constant $h = 6.62\times10^{-34}$ J.s; 1 eV = 1.60×10^{-19} J.
All wavelengths in this exercise are taken in vacuum.

> The spectrum of the light emitted by the surface of a star is continuous. However, as it passes through the star's atmosphere (the chromosphere), this light is partially absorbed by the various chemical elements present, thus causing the appearance of dark lines in the spectrum relative to the star's chromosphere. This appears in an absorption spectrum; in which it is possible to identify series of missing lines by determining their wavelengths. These series of lines then constitute the "signature" of each element in the chromosphere of a star and thus allow us to determine its chemical composition.
>
> **Doc. 8**

1) Absorption spectrum

1.1) Indicate a difference between the absorption spectrum and the emission spectrum of an element.

1.2) Using document 8, indicate the reason for the presence of dark lines in the spectrum relative to a star's chromosphere.

1.3) Each chemical element, in the gaseous state, has a specific absorption spectrum. Extract from document 8 an expression that confirms this statement.

2) Balmer series

Balmer series is a series of spectral lines of the hydrogen atom. Each line in this series corresponds to a transition from a higher energy level E_n to energy level E_2.

The energy of level n of the hydrogen atom is given by the relation:

$$E_n = -\frac{E_0}{n^2}$$; with $E_0 = 13.6$ eV and n is non-zero natural number.

2.1) Express the wavelength of each line of Balmer series in terms of E_n, E_2, h and c.

2.2) Show that the wavelengths (λ in m) of the lines of this series are given by:

$$\lambda = \frac{91.2\times10^{-9}}{\left(\frac{1}{4}-\frac{1}{n^2}\right)}$$, where $n \geq 3$.

2.3) Calculate, in nm, the values of the wavelengths of the four lines of Balmer series of the hydrogen atom corresponding to n = 3, 4, 5 and 6.

3) Star Vega

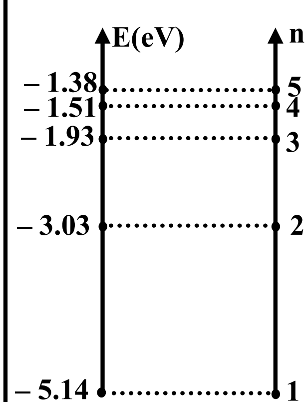
Star Vega is one of the brightest stars in the sky. The values of certain wavelengths of the most remarkable missing lines of the absorption spectrum relative to the chromosphere of this star are: $\lambda_1 = 393.3$ nm ; $\lambda_2 = 410.4$ nm ; $\lambda_3 = 434.2$ nm ; $\lambda_4 = 486.4$ nm ; $\lambda_5 = 588.2$ nm and $\lambda_6 = 656.6$ nm.

3.1) The chromosphere of the star Vega contains hydrogen. Justify.

3.2) Two of the mentioned wavelengths do not correspond to the absorption spectrum of the hydrogen atom.
Calculate, in eV, the energy of each photon which corresponds to each of these two lines.

3.3) Using document 9, specify which of these two lines corresponds to the sodium atom probably present in the chromosphere of this star.

Simplified diagram of the energy levels of sodium atom.



Doc. 9

Exercise 5 (5 pts)

Diffraction by a silk thread

The aim of this exercise is to determine the diameter of a silk thread and to choose the suitable thread to produce running outfits.

For this aim, consider a source (S) of monochromatic light of wavelength $\lambda = 650$ nm in air, that illuminates under normal incidence a horizontal narrow slit of width « a » cut in an opaque screen (P). The diffraction pattern is observed on a screen (E) placed perpendicularly to the incident beam of light at a distance D = 1 m from the slit.

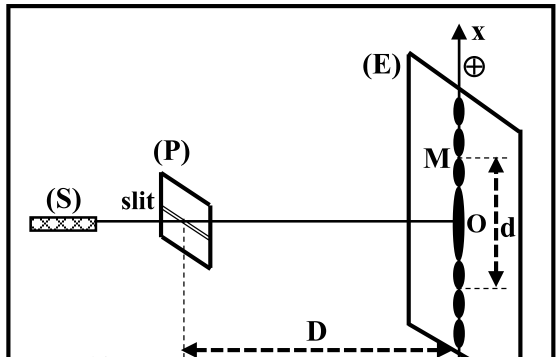
O is the center of the central bright fringe.

A point M, belongs to the obtained diffraction pattern, on the screen (E) is the center of a dark fringe of order n (n is a non-zero integer), and it has a position $x = \overline{OM}$.

Denote by « d » the distance that separates the centers of the dark fringes of order 2, located on either side of O (Doc. 10).

The diffraction angles in this exercise are small.

For small angles: $\sin\theta \approx \tan\theta \approx \theta$ (in radian).



Doc. 10

1) The phenomenon of diffraction of light shows evidence of an aspect of light. Name this aspect.
2) Write in terms of n, a and λ, the expression of the diffraction angle θ of M.
3) Show, providing a diagram, that $d = \frac{4\lambda D}{a}$.
4) A factory requests silk threads to produce running outfits. We use the same diffraction set-up of document 10, but we replace the slit by a silk thread of diameter « a ». The diffraction pattern is similar to that obtained by the thin slit.
   - **4.1)** To verify that the diameter of a silk thread is constant, we illuminate it at different positions. How does this method permit to verify that the diameter of the silk thread is constant?
   - **4.2)** Consider two silk threads each of constant diameter. The diameter of the first thread is « a_1 » and that of the second thread is « a_2 ». We notice that the distance « d » corresponding to the second thread is 7 cm longer than that of the first thread. Deduce that $a_1 > a_2$.
   - **4.3)** Knowing that d = 13 cm for the first thread, calculate a_1 and a_2.
   - **4.4)** The factory requests a silk thread of diameter between 10 µm and 15 µm. Deduce which of the two threads is convenient for the production of running suits.

Exercise 6 (5 pts)

Radon-222 nucleus

Given:

$1u = 931.5\ \frac{MeV}{c^2}$;

speed of light in vacuum $c = 3 \times 10^8$ m/s;

radius of a nucleon $r_0 = 1.2 \times 10^{-15}$ m;

mass of radon nucleus $^{222}_{86}Rn$: $m_{Rn} = 221.97028$ u;

mass of a proton: $m_p = 1.00727$ u;

mass of a neutron: $m_n = 1.00866$ u.

1) Dimension of the radon $^{222}_{86}Rn$ nucleus

1.1) Calculate the radius « r » of radon $^{222}_{86}Rn$ nucleus.

1.2) Knowing that the radius of the radon $^{222}_{86}Rn$ atom is approximately $R = 1.2 \times 10^{-10}$ m, choose with justification the correct answer.

a) The radius of the radon atom is approximately 160 times greater than that of the radon nucleus.
b) The radius of the radon atom is approximately 1600 times greater than that of the radon nucleus.
c) The radius of the radon atom is approximately 16000 times greater than that of the radon nucleus.
d) The radius of the radon atom is approximately 160000 times greater than that of the radon nucleus.

2) Stability of the radon $^{222}_{86}Rn$ nucleus

2.1) Indicate the composition of radon-222 nucleus.

2.2) Show that the mass of all nucleons, of radon-222 nucleus, taken separately is greater than that of the radon-222 nucleus.

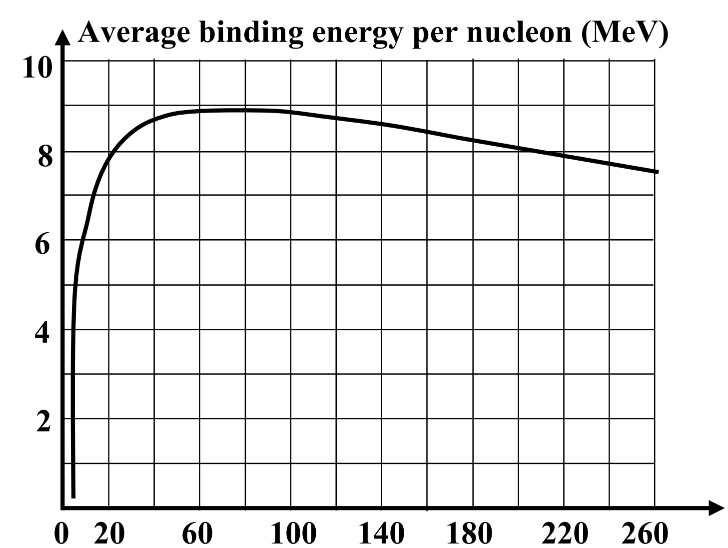
2.3) Deduce, in u, the mass defect Δm of the radon-222 nucleus.

2.4) This mass defect is converted into energy equivalent to the binding energy E_B of a nucleus. Define the binding energy of a nucleus.

2.5) Show that the binding energy of radon-222 nucleus is $E_{B(Rn)} = 1707.16$ MeV.

2.6) Show that uranium nucleus $^{238}_{92}U$ is less stable than radon nucleus $^{222}_{86}Rn$, although $E_{B(U)} = 1801.5$ MeV is greater than that of radon-222 nucleus.

2.7) Aston's curve of document 11 can be divided into three regions:
Region 1: 1 < A < 20;
Region 2: 20 < A < 190;
Region 3: A > 190.
Referring to Aston's curve, show that, even though radon-222 nucleus is more stable than uranium-238 nucleus, it does not belong to the region of the most stable nuclei.



Doc. 11

مسابقة الفيزياء
أسس التصحيح - إنكليزي

Exercise 1 (5pts) **Energy and collision**

Part	Answer	Mark
1	ME = GPE + KE , but GPE = mgh and $h = \ell(1 - \cos\theta_m)$ and KE = 0 So $ME = mg\,\ell(1 - \cos\theta_m) = 0.1\times10\times0.4\times(1 - 0.5)$, this implies: ME = 0.2 J	0.75
2	Sine there is no friction (or the sum of the work done by the non-conservative forces is zero) : $ME_i = ME_O$ $ME_i = \frac{1}{2}mV^2$, so $0.2 = \frac{1}{2}\times0.1\times V^2$; this implies: V = 2 m/s	0.25
3	$\vec{P} = m\vec{V}$ so $\vec{P} = 0.1\times 2\,\vec{i} = 0.2\,\vec{i}$ (kg.m/s) $KE = \frac{1}{2}mV^2$ so $KE = \frac{1}{2}\times 0.1\times 2^2 = 0.2$ J	0.5 0.5
4.1	Linear momentum of the system [(S) ; (S')] Kinetic energy of the system [(S) ; (S')]	0.25 0.25
4.2	**Conservation of linear momentum** $\vec{P}_{before} = \vec{P}_{after}$ $m\vec{V} = m\vec{v'_1} + m'\vec{v'_2}$. By taking the algebraic values: $mV = mv'_1 + m'v'_2$ This implies: $m(V - v'_1) = m'v'_2$ …. eq. (1) **Conservation of kinetic energy** $KE_{before} = KE_{after}$ So $\frac{1}{2}mV^2 = \frac{1}{2}m\,v'^2_1 + \frac{1}{2}m'\,v'^2_2$ $m(V^2 - v'^2_1) = m'\,v'^2_2$ … eq. (2) $\frac{eq.(2)}{eq.(1)}$: $V + v'_1 = v'_2$ … eq. (3) From eq. (3) & eq. (1), we get : $v'_2 = \frac{2mV}{m+m'}$ and $v'_1 = \frac{(m-m')V}{m+m'}$ We replace m = 0.1 kg and V = 2 m/s ; $v'_2 = \frac{0.4}{0.1+m'}$ and $v'_1 = \frac{(0.1-m')2}{0.1+m'}$	1.25
4.3	$\Vert\vec{v'_1}\Vert = \Vert\vec{v'_2}\Vert$ and opposite directions , so $-\frac{(0.1-m')2}{0.1+m'} = \frac{0.4}{0.1+m'}$ (0.1 – m') 2 = – 0.4 ; **m' = 0.3 kg**	0.5
4.4	$v'_1 = -1$ m/s and $v'_2 = 1$ m/s	0.25
5	$ME_O = ME_{max.\ height}$ $\frac{1}{2}m\,v'^2_2 = m\,g\,h_{max}$, thus $\frac{1}{2}\times0.1\times1 = 0.1\times10\times h_{max}$, this implies: $h_{max} = 0.05$ m = 5 cm	0.5

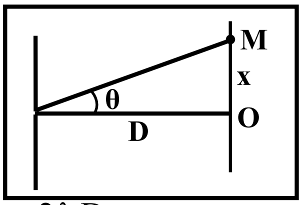
Exercise 2 (5pts)	Charging and discharging of a capacitor	
Part	**Answer**	**Mark**
1.1	$u_{PN} = u_{PA} + u_{AB} + u_{BN}$; $E = 0 + u_C + R\,i$ but $i = \frac{dq}{dt}$ and $q = C \times u_C$; then $i = C\frac{du_C}{dt}$ We obtain : $E = RC\frac{du_C}{dt} + u_C$	**1**
1.2	$u_C = a - a\,e^{\frac{-t}{\tau}}$; $\frac{du_C}{dt} = \frac{a}{\tau}\,e^{\frac{-t}{\tau}}$ We replace u_C and $\frac{du_C}{dt}$ in the differential equation : $E = RC\,\frac{a}{\tau}\,e^{\frac{-t}{\tau}} + a - a\,e^{\frac{-t}{\tau}}$; $a\,e^{\frac{-t}{\tau}}[\frac{RC}{\tau} - 1] + a = E$ This equality is verified for any t, by identification: $a\,e^{\frac{-t}{\tau}} \neq 0$ then $a = E$ and $+\frac{RC}{\tau} - 1 = 0$ so $\tau = R\,C$ then : $u_C = E\,(1 - e^{\frac{-t}{\tau}})$ with $\tau = RC$	**1**
1.3.1	$E = 12$ V	**0.25**
1.3.2	At τ: $u_C = 0.63\,E = 7.56$ V; from document 3: $u_C = 7.56$ V at $\tau = 2$ ms	**0.5**
1.4	$\tau = RC$ so $2\times10^{-3} = 1000\,C$, this implies: $C = 2\times10^{-6}$ F	**0.5**
2.1	$W = \frac{1}{2}C\,u_C^2 = \frac{1}{2}C\,u_C^2 = \frac{1}{2}C\left(E\,e^{\frac{-t}{RC}}\right)^2 = \frac{1}{2}C\,E^2 e^{\frac{-2t}{RC}} = W_0\,e^{\frac{-2t}{RC}}$, where $W_0 = \frac{1}{2}C\,E^2$	**0.5**
2.2	For $t_1 = R\,C$: $W = W_0\,e^{\frac{-2t_1}{RC}} = W_0\,e^{\frac{-2RC}{RC}} = W_0\,e^{-2} = 0.135\,W_0$	**0.25**
2.3	$W_0 = 140\ \mu J$ From document 4: for $W = 0.135\,W_0 = 0.135 \times 140 = 18.9\ \mu J$ we have $t_1 = 2$ ms $t_1 = R\,C$ so $2\times10^{-3} = 1000\,C$, this implies: $C = 2\times10^{-6}$ F	**1**

Exercise 3 (5pts)	Self - Induction	
Part	**Answer**	**Mark**
1.1	$u_G = u_R + u_{coil}$, $E = u_R + r\,i + L\frac{di}{dt}$, But $i = \frac{u_R}{R}$ so $\frac{di}{dt} = \frac{1}{R}\frac{du_R}{dt}$ This implies: $E = u_R + r\frac{u_R}{R} + \frac{L}{R}\frac{du_R}{dt}$ So $(R + r)\,u_R + L\frac{du_R}{dt} = R\,E$	**0.5**
1.2	$u_R = a + b\,e^{\frac{-t}{\tau}}$ then $\frac{du_R}{dt} = -\frac{b}{\tau}e^{\frac{-t}{\tau}}$, We replace in the differential equation: $(R + r)\,a + (R + r)\,b\,e^{\frac{-t}{\tau}} - L\frac{b}{\tau}e^{\frac{-t}{\tau}} = R\,E$ So $(R + r)\,a + [(R + r) - \frac{L}{\tau}]\,b\,e^{\frac{-t}{\tau}} = R\,E$ This is verified at any time t, then by identification $(R + r)\,a = R\,E$ and $[\frac{L}{\tau} - (R + r)] = 0$; since $I_m\,e^{\frac{-t}{\tau}} \neq 0$ Therefore $a = \frac{R\,E}{R + r}$ and $\tau = \frac{L}{R + r}$ At t = 0: $u_R = 0$, so $0 = a + b$, therefore $b = -a$. Thus $b = -\frac{R\,E}{R + r}$	**0.75**
1.3	$u_{R(max)} = 11$ V	**0.25**
1.4	$u_{R(max)} = a$, but $a = \frac{R\,E}{R + r}$ this implies $a = \frac{R\,E}{R + r} = 11$ V , so $\frac{18 \times 12}{18 + r} = 11$, thus r = 1.63 Ω	**0.5**
1.5	At $t = \tau$: $u_R = 0.63 \times 11 = 6.93$ V; from document 6: $\tau = 0.1$ ms	**0.5**
1.6	$\tau = \frac{L}{R + r}$, so $0.1 \times 10^{-3} = \frac{L}{18 + 1.63}$, thus $L = 1.96 \times 10^{-3}$ H	**0.25**
2.1	see table below	**0.5** **0.5** **0.5**

Role of the coil	Time interval	Value of the self induced e.m.f « e » in the coil
The coil acts as a resistor	Between 2 ms and 4 ms	$e = -L\frac{di}{dt}$; Since i = 0.1 A ; e = 0 V
The coil acts as a generator	Between 0 and 1 ms	$e = -L\frac{di}{dt}$; $e = -1.96 \times 10^{-3} \times (-100)$ e = 0,196 V
The coil acts as a receiver.	Between 1 ms and 2 ms	$e = -L\frac{di}{dt}$; $e = -1.96 \times 10^{-3} \times (100)$ e = –0,196 V

Part	Answer	Mark
2.2	• Between 2 ms and 4 ms : $u_{coil} = r\,i + L\frac{di}{dt} = ri$, The coil is acting as a resistor	**0.25**
	• Between 0 and 1 ms : Method 1: e > 0 ; and i > 0 then e.i > 0 ; therefore, acts as a generator Method 2: $W = \frac{1}{2}L\,i^2$; i decreases, then W decreases so acts as a generator Method 3: i decreases then the coil tends to oppose the decreasing of i so it acts as a generator (Lenz's law)	**0.25**
	• Between 1 ms and 2 ms: Method 1: e < 0 ; and i > 0 then e.i < 0 ; therefore, acts as a receiver Method 2: $W = \frac{1}{2}L\,i^2$; i increases, then W increases so acts as a receiver Method 3: i increases then the coil tends to oppose the increasing of i so it acts as a receiver (Lenz's law)	**0.25**

Exercise 4 (5 pts)	**Absorption spectrum**	
Part	**Answer**	**Mark**
1.1	Absorption spectrum is a continuous spectrum containing dark lines. Emission spectrum is formed of a series of bright lines	**0.5**
1.2	However, as it passes through the star's atmosphere (the chromosphere), this light is partially absorbed by the various chemical elements present, thus causing the appearance of dark lines in the star's spectrum.	**0.5**
1.3	These series of lines then constitute the "signature" of the different elements	**0.25**
2.1	$E_{photon} = E_n - E_2$; $\frac{hc}{\lambda} = E_n - E_2$; So $\lambda = \frac{hc}{E_n - E_2}$	**0.5**
2.2	$\lambda = \frac{hc}{E_n - E_2} = \frac{6.62\times10^{-34}\times3\times10^{8}}{13.6\times\left(\frac{1}{2^2}-\frac{1}{n^2}\right)\times1.6\times10^{-19}} = \frac{91.2\times10^{-9}}{\left(\frac{1}{4}-\frac{1}{n^2}\right)}$	**0.75**
2.3	$\lambda_{3\to2} = 656.6$ nm ; $\lambda_{4\to2} = 486.4$ nm ; $\lambda_{5\to2} = 434.2$ nm ; $\lambda_{6\to2} = 410.4$ nm	**1**
3.1	The majority of the values of the wavelengths of its absorption spectrum are: $\lambda_2 = 410.4$ nm ; $\lambda_3 = 434.2$ nm ; $\lambda_4 = 486.4$ nm ; and $\lambda_6 = 656.6$ nm Which corresponds to the Balmer series of the hydrogen atom.	**0.5**
3.2	$\lambda_1 = 393.3$ nm : $Eph_1 = \frac{hc}{\lambda_1} = 3.15$ eV $\lambda_5 = 588.2$ nm : $Eph_5 = \frac{hc}{\lambda_5} = 2.11$ eV	**0.25** **0.25**
3.3	$E_1 + Eph_5 = -5.14 + 2.11 = -3.03$ eV$= E_2$; So it's the radiation λ_5 .	**0.5**

Exercise 5 (5 pts)	**Diffraction by a silk thread**	
Part	**Answer**	**Mark**
1	Wave aspect of light	**0.25**
2	Dark fringe : $\sin\theta = n\frac{\lambda}{a}$, since θ is small, so $\sin\theta = \theta = n\frac{\lambda}{a}$	**0.75**
3	Consider the right angle triangle whose vertices are O, M and the center of the slit:  $\tan\theta \cong \theta = \frac{x}{D}$, and $\theta = n\frac{\lambda}{a}$ So $x = \theta D = \frac{n\lambda D}{a}$ For the second dark fringe on the positive side (above O) : $x = \frac{2\lambda D}{a}$ For the second dark fringe on the negative side (below O) : $x = \frac{-2\lambda D}{a}$ So $d = \frac{2\lambda D}{a} - (\frac{-2\lambda D}{a}) = \frac{4\lambda D}{a}$	**1.5**
4.1	The diffraction patterns stays the same **or** same linear width **or** d is constant …	**0.5**
4.2	$d = \frac{4\lambda D}{a}$; λD = constant, so d and a are inversely proportional. Since $d_2 > d_1$ then $a_2 < a_1$.	**0.5**
4.3	For the first thread, d = 13 cm. $d = \frac{4\lambda D}{a_1}$; $a_1 = \frac{4\times 650\times 10^{-9}\times 1}{13\times 10^{-2}} = 2\times 10^{-5}$ m = 20 μm For the second thread, d = 20 cm. $d = \frac{4\lambda D}{a_2}$; $a_2 = \frac{4\times 650\times 10^{-9}\times 1}{20\times 10^{-2}} = 1.3\times 10^{-5}$ m = 13 μm	**0.5** **0.5**
4.4	He must choose the second thread, since its diameter is between 10 μm and 15μm	**0.5**

Exercise 6 (5 pts)	Radon nucleus-222	
Part	**Answer**	**Mark**
1.1	The radius of the nucleus : $r = r_0 \times A^{1/3} = 1.2\times10^{-15}\times\sqrt[3]{222} \approx 7.26\times10^{-15}$ m.	**0.5**
1.2	**c)** The radius of the radon atom is approximately 16000 times greater than that of the radon nucleus. **Justification:** To compare the sizes, we calculate the ratio $\frac{R}{r} = \frac{1.2\times10^{-10}}{7.26\times10^{-15}} \cong 16528$, So this ratio shows that the radius of the radon atom is approximately 16000 times greater than that of the radon nucleus	**0.25** **0.5**
2.1	The nucleus of the radon $^{222}_{86}Rn$ is composed of: **Protons**: Z = 86 (atomic number of radon) **Neutrons** : N = A – Z = 222 – 86 =136	**0.25** **0.25**
2.2	Mass of the nucleons taken separately: $M_{nucleons} = Z\, m_p + N\, m_n = 86\, m_p + 136\, m_n$ $M_{nucleons} = 86\times1.00727 + 136\times1.00866 = 223.80298$ u Mass of radon nucleus = 221.97028 u So $M_{nucleons} > M_{nucleus}$ (223.80298 u > 221.97028 u)	**0.75**
2.3	$\Delta m = M_{nucleon} - M_{nucleus} = 1.8327$ u	**0.25**
2.4	The binding energy is the energy that should be given to the nucleus in order to break it up completely. **OR**: To completely break the nucleus into its constituent particles, one must supply the nucleus with a certain amount of energy. This amount of energy is called the binding energy of the nucleus. **OR**: Is the energy that the external environment must provide to separate (break – split) the nucleus which is at rest, into its free nucleons at rest.	**0.5**
2.5	$E_B = \Delta m \times c^2 = 1.8327 \times 931.5\ \frac{MeV}{c^2} \times c^2 = 1707.16$ MeV	**0.5**
2.6	To compare the stability of the nuclei, we calculate the binding energy per nucleon: For radon nucleus-222 : $\frac{E_B}{A} = \frac{1707.16}{222} = 7.68$ MeV/nucleon For uranium nucleus-238 : $\frac{E_B}{A} = \frac{1801.5}{238} = 7.56$ MeV/nucleon Since 7.68 > 7.56, so radon is more stable than uranium.	**0.5** **0.25**
2.7	Aston's curve shows that the most stable nuclei are those with the greatest binding energy per nucleon, therefore the region: 0 < A < 190. Radon nucleus-222 is more stable than uranium nucleus-238, even that it does not belong to the region (0 < A < 190) of the most stable nuclei.	**0.5**