وزارة التربية والتعليم العالي
المديرية العامّة للتربية
دائرة الامتحانات الرسميّة

امتحانات الشهادة الثانويّـة العامّة
فرع علوم الحياة

دورة العام ٢٠٢٤ العاديّة
الأربعاء ٣ تموز ٢٠٢٤

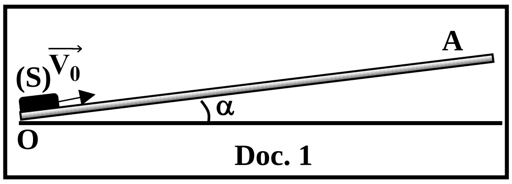
مسابقة في مادة الفيزياء	الاسم:
المدة: ساعة ونصف	الرقم:

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

Exercise 1 (6.5 pts)

Motion along an inclined plane

An object (S), considered as a particle of mass m = 0.2 kg, can move on a straight track OA, situated in a vertical plane and inclined by an angle α with the horizontal ($\sin\alpha = 0.1$).

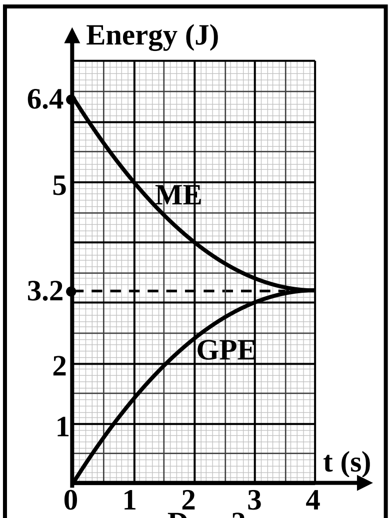


Doc. 1

At $t_0 = 0$, (S) is launched with a velocity $\vec{V_0}$ of magnitude V_0 (Doc.1).
Take:

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

The curves of document 2, represent the mechanical energy (ME) and the gravitational potential energy (GPE) of the system [(S) – Earth] as functions of time during the ascending motion of (S) on the inclined plane between 0 and 4 s.



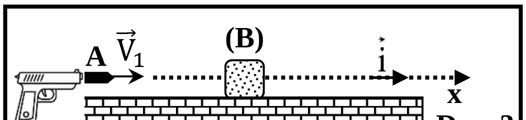
Doc. 2

1) Justify the existence of a force of friction $\vec{f}$ on (S) during its motion between 0 and 4 s.
2) Show that the kinetic energy of (S) at $t_0 = 0$ is $KE_0 = 6.4$ J.
3) Deduce the value of V_0.
4) At t = 4 s, (S) reaches point A. Justify that A is the highest point attained by (S) on the inclined plane.
5) Deduce that the maximum distance covered by (S) on the inclined plane during its ascending motion is OA = 16 m.
6) Determine the variation of the internal energy ΔU of the system (Object - Inclined plane – Earth - Atmosphere) between 0 and 4 s.
7) Deduce whether the internal energy of the system (Object - Inclined plane – Earth - Atmosphere), increases, decreases or remains the same between 0 and 4 s.
8) The force of friction $\vec{f}$ is constant and parallel to the displacement. Determine the magnitude f of $\vec{f}$.

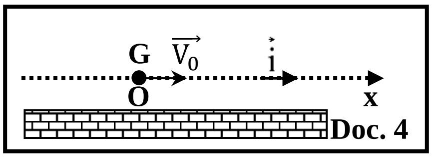
Exercise 2 (6.5 pts)

Motion of a block after collision

A gun shoots a bullet (A) of mass $m_1 = 20$ g towards a block (B), of mass $m_2 = 4$ kg, initially at rest, on a horizontal surface (Doc. 3). Bullet (A) enters a head on collision with block (B) with a horizontal velocity $\vec{V_1}$ of magnitude V_1 and becomes embedded in it. After the collision, the center of mass G, of the system [(A), (B)], starts at t = 0 s, from point O with a velocity $\vec{V_0} = V_0\,\vec{i}$ and moves along a horizontal x – axis of unit vector $\vec{i}$ (Doc. 4).



Doc. 3



Doc. 4

1) Choose the correct answer:
The collision between (A) and (B) is inelastic because:
a) the kinetic energy of (A) is different from that of (B) before the collision.
b) the kinetic energy of (A) is different from that of (B) after the collision.
c) part of the kinetic energy of the system [(A), (B)] before collision causes its deformation.
d) the kinetic energy of (B) is zero before the collision.

2) Show that $V_1 = \dfrac{(m_1 + m_2)V_0}{m_1}$.

3) After the collision, G moves along the x-axis with a velocity $\vec{v} = v\,\vec{i}$.
The table below shows different values of v, at different instants of time t, after the collision.

t (s)	0.2	0.4	0.8	1.4
v (m/s)	1.8	1.6	1.2	0.6

3.1) Trace, on the graph paper, the curve that represents v as a function of t.
Take the scale:
- On the abscissa axis: 1 cm $\leftrightarrow$ 0.2 s ;
- On the ordinate axis: 1 cm $\leftrightarrow$ 0.2 m/s.

3.2) Referring to the obtained curve, show that: $v = -t + 2$ (SI).
3.3) Deduce the value of V_0.

4) Calculate V_1.

5) Write, in terms of t, the expression of the linear momentum $\vec{P}$ of the system [(A), (B)] after the collision.

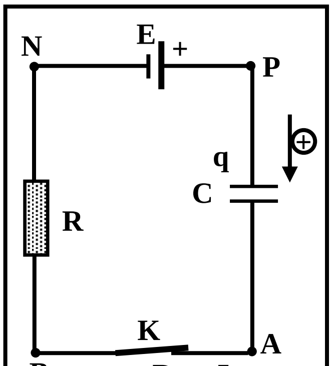
6) After collision, the system [(A), (B)] is subjected to a force of friction $\vec{f}$, parallel to $\vec{i}$, in the opposite direction of the displacement , of constant magnitude f.
Determine f, knowing that $\dfrac{d\vec{P}}{dt} = \Sigma \vec{F}_{ext}$ where $\Sigma \vec{F}_{ext}$ is the sum of the external forces exerted on the system [(A), (B)] after the collision.

Exercise 3 (6.5 pts)

Temperature sensor

The aim of this exercise is to identify the water temperature sensor used in a washing machine.
One of the circuits in this sensor is simplified by the series circuit of document 5, that includes:

- an ideal battery of electromotive force E;
- a resistor of resistance R that varies with temperature;
- a capacitor, initially uncharged, of capacitance C = 1 μF;
- a switch K.



Doc. 5

1) Theoretical study

At the instant $t_0 = 0$, K is closed and the charging process of the capacitor starts.
At an instant t, plate P of the capacitor carries a charge q and the circuit carries a current i.

1.1) Redraw the circuit of document 5 showing on it the direction of the current i.
1.2) Show that the differential equation that describes the variation of the voltage $u_{PA} = u_C$, across the capacitor is : $E = RC\dfrac{du_C}{dt} + u_C$.
1.3) The solution of the obtained 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.

2) Type of the sensor

In a washing machine, a sensor of temperature is used. When water is heated to 40°C, R takes a value R_1, and the variation of the voltage u_C with respect to time is represented by curve (a) (Doc. 6).
When water is heated to 60°C, R takes a value R_2, and the variation of u_C with respect to time is represented by curve (b) (Doc. 6).

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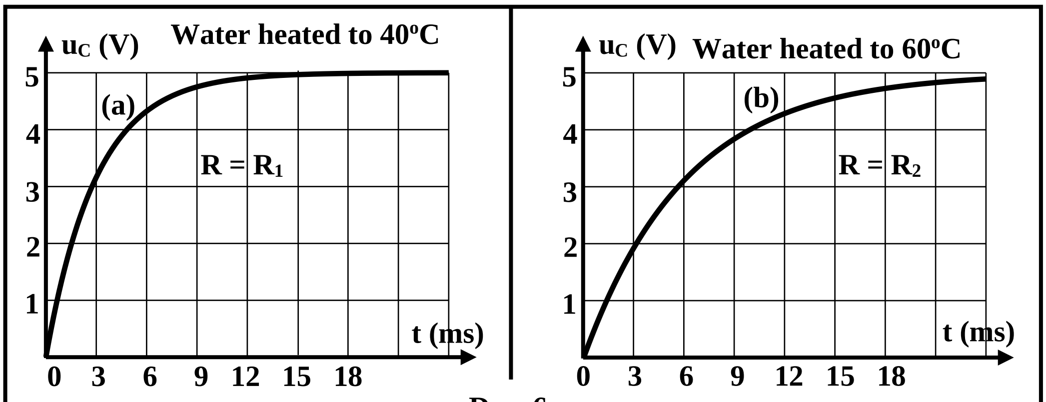


Doc. 6

2.1) Using document 6:

2.1.1) indicate the value of E;

2.1.2) determine the values of the time constants τ_1 and τ_2 corresponding to the curves (a) and (b) respectively.

2.2) Deduce the values of R_1 and R_2.

2.3) Consider two types of temperature sensors: one called "PTC" whose resistance increases with increasing temperature, and the other called "NTC" whose resistance decreases with increasing temperature.
Specify the type of sensor used in this washing machine.

Exercise 4 (6.5 pts)

Diffraction of light

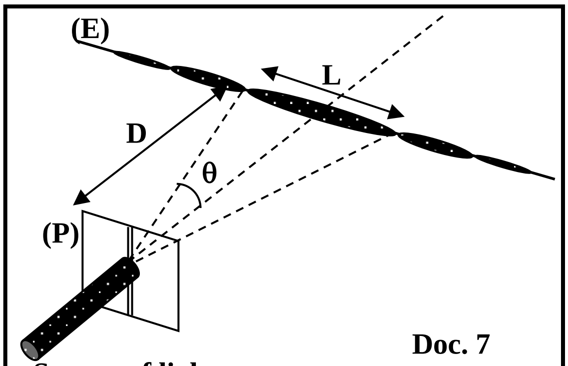
The aim of this exercise is to determine the percentage of concentration of carbon dioxide in air using the phenomenon of diffraction of light.

For this aim, consider a source of monochromatic light of wavelength « λ » in vacuum that illuminates under normal incidence a vertical 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 at a distance D from the slit.

Let «L» be the linear width of the central bright fringe (Doc. 7).

The diffraction angles in this exercise are small.

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



Doc. 7

1) The phenomenon of diffraction of light shows evidence of an aspect of light. Name this aspect.

2) Describe the diffraction pattern observed on (E).

3) The whole set up of document 7 is placed in vacuum.
We obtain a central bright fringe of linear width L_1.
Determine the expression of L_1 in terms of λ, D and a.

4) The whole set up of document 7 is placed in a research laboratory rich in carbon dioxide CO_2.
The wavelength of the light in this medium is $\lambda' = \frac{\lambda}{n}$, where n is the index of refraction of this medium.
We obtain a central bright fringe of linear width L_2.

4.1) Write the expression of L_2 in terms of λ', D and a.

4.2) Show that n = 1.000294, knowing that $L_1 = 1.000294 \times L_2$.

5) At room temperature, normal atmospheric pressure and humidity 20%, the index of refraction of air rich in CO_2 is given by: $n = 1.000293 + 1.57\times10^{-6}\,P$ where P is percentage of concentration of the carbon dioxide in air.

5.1) A researcher works in this laboratory, under the above mentioned conditions. Calculate P.

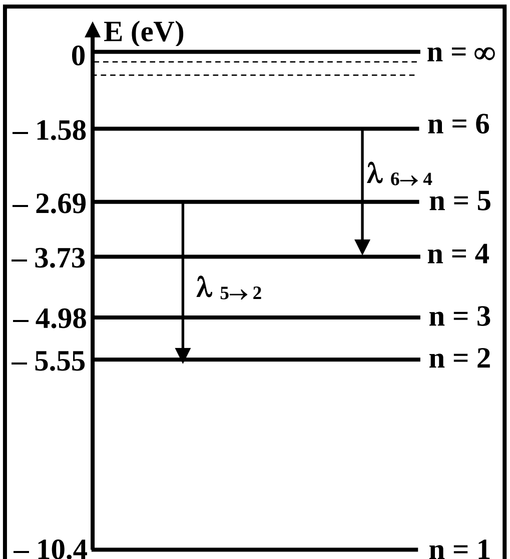
5.2) According to World Health Organization, the limit of exposure is 8 hours continuously when the concentration of the CO_2 reaches 0.5 %. Specify whether this researcher can continue working for more than 8 hours under these conditions.

Exercise 5 (6.5 pts)

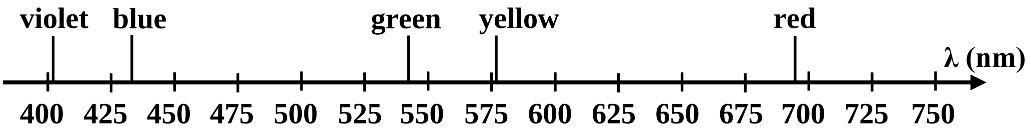
Mercury vapor lamp and photoelectric effect

The aim of this exercise is to study some lines of the emission spectrum of the mercury atom and to use one emitted radiation to produce photoelectric effect.
Document 8 shows a simplified energy level diagram of the mercury atom.
Document 9 shows some lines of the emission spectrum of a mercury vapor lamp in air.
Given:

- Planck's constant: $h = 6.63 \times 10^{-34}$ J·s;
- 1 eV = 1.60×10^{-19} J ;
- speed of light in air: $c = 3 \times 10^{8}$ m/s;
- 1 nm = 10^{-9} m;



Doc. 8



Doc. 9

1) The mercury atom, considered in the third excited state (n = 4), absorbs a photon with energy E. It then passes to the fifth excited state (n = 6).

1.1) Calculate E.

1.2) Calculate the wavelength λ of this photon in air.

1.3) Deduce, without calculation, the value of $\lambda_{6\to4}$, in air, associated to the transition $6 \to 4$ represented in document 8.

1.4) Indicate, using document 9, the color of this emitted radiation.

2) A filter placed in front of the mercury vapor lamp, allows the radiation of blue color to pass. Show that the radiation of wavelength $\lambda_{5\to2}$, associated to the transition $5 \to 2$, passes through this filter.

3) This lamp equipped with this filter, illuminates separately two metallic plates, one made of cesium and the other made of zinc.
Given: W_0 (work function) of cesium = 1.89 eV; W_0 of zinc = 4.31 eV.

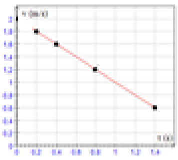
3.1) Define the « threshold wavelength» of a pure metal.

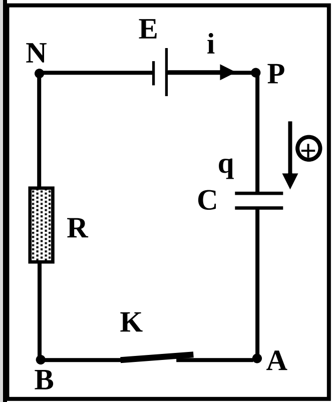
3.2) Calculate the threshold wavelength of each of these two metals.

3.3) The photoelectric effect takes place in one metal. Deduce which one.

مسابقة في مادة الفيزياء
أسس التصحيح - إنكليزي

Exercise 1 (6.5 points)	**Motion along an inclined plane**	
Part	**Answer**	**grade**
1	Since ME decrease, so friction exists	**0.5**
2	$ME_0 = KE_0 + GPE_0$; $KE_0 = 6.4 – 0 = 6.4$ J	**1**
3	$\frac{1}{2}$ m $V_0^2 = 6.4$ then $V_0^2 = 64$ therefore $V_0 =$ 8 m/s	**1**
4	At t = 4 s ; ME = GPE then KE = 0 J, therefore the speed of the object is zero, this is then the highest point reached on the inclined plane	**0.5**
5	At t = 4 s: GPE = 3.2 J m×g×h = 3.2 but h = OA × sinα Therefore : m×g×OA×sinα = 3.2 , 0.2×10×0.1×OA = 3.2 then OA = 16 m	**1**
6	The system (object, inclined plane, Earth, Atmosphere) is energetically isolated, So its total energy E = ME + U = constant ; ΔE = ΔME + ΔU = 0 then : ΔU = – Δ(ME) between 0 s and 4 s we have : Δ(ME) = 3.2 – 6.4 = – 3.2 J then ΔU = – Δ(ME) = 3.2 J	**1**
7	Increases since ΔU > 0	**0.5**
8	The variation in mechanical energy equals the work of friction: $\Delta ME = W_{\vec{f}}$ so Δ(ME) = – 3.2 = – f × OA – 3.2 = – f ×16 , then f = 0.2 N	**1**

Exercise 2 (6.5 pts)	Motion of a block after collision	
Part	**Answer**	**Grade**
1	c) part of kinetic energy of the system [(A), (B)] causes its deformation.	**0.5**
2	$\vec{P}_{\text{before the collision}} = \vec{P}_{\text{after the collision}}$ $m_1 \vec{V_1} = (m_1+m_2)\vec{V_0}$ Then : $V_1 = \frac{(m_1+m_2)\,V_0}{m_1}$	**0.75**
3.1		**0.5**
3.2	The shape of the curve is a decreasing straight line that does not pass through the origin. Its equation is of the form: $v = a \times t + b$ $a = \frac{v_f - v_i}{t_f - t_i} = -1.007 \cong -1\ m/s^2$ At t = 0.2 s ; v = 1.8 m/s ; so b = 2 , then $v = -t + 2$ (S.I.)	**0.75**
3.3	For t = 0 ; $V_0 = 2$ m/s.	**0.5**
4	Since $V_1 = \frac{(m_1+m_2)\,V_0}{m_1}$; then $V_1 = 402$ m/s	**1**
5	$\vec{P} = (m_1 + m_2)\vec{v}$; $\vec{P} = 4.02\,(-t + 2)\,\vec{i}$; $\vec{P} = -4.02\,t\,\vec{i} + 8.04\,\vec{i}$ (P in kg.m/s and t in s)	**0.25** **0.75**
6	$\Sigma\vec{F}_{ext} = (m_1 + m_2)\vec{g} + \vec{N} + \vec{f}$; Component along $\overrightarrow{Ox}$: $\Sigma\vec{F}_{ext} = -f\,\vec{i}$ **Or** : $\Sigma\vec{F}_{ext} = m\vec{g} + \vec{N} + \vec{f}$ but $m\vec{g} + \vec{N} = \vec{0}$ then $\Sigma\vec{F}_{ext} = -f\,\vec{i}$ $\frac{d\vec{P}}{dt} = -4.02\ \vec{i}$; since $\frac{d\vec{P}}{dt} = \Sigma\vec{F}_{ext}$; then $-4.02\ \vec{i} = = -f\,\vec{i}$ Therefore, f = 4.02 N	**0.75** **0.75**

Exercise 3 (6.5 pts)	Temperature Sensor	
Part	**Answer**	**grade**
1.1	 **Doc. 1**	**0.5**
1.2	$u_{PN} = u_{PA} + u_{AB} + u_{BN}$; $E = u_C + 0 + R\,i$ 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**
1.3	$u_C = a - a\,e^{\frac{-t}{\tau}}$; $\frac{du_C}{dt} = \frac{a}{\tau}\,e^{\frac{-t}{\tau}}$ 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 $\tau = RC$ then : $u_C = E(1 - e^{\frac{-t}{\tau}})$ with $\tau = RC$	**1.5**
2.1.1	$E = 5$ V	**0.5**
2.1.2	At $t = \tau$: $u_C = E(1 - e^{-1}) = 0.63\,E = 3.15$ V graphically this value of E corresponds to τ Graph (a) : $\tau_1 = 3$ ms Graph (b) : $\tau_2 = 6$ ms	**0.25** **0.5** **0.5**
2.2	$\tau_1 = 3$ ms and $\tau_1 = R_1 \times C$; $R_1 = \frac{\tau_1}{C} = \frac{3\times10^{-3}}{1\times10^{-6}} = 3000\ \Omega = 3\ k\Omega$ $\tau_2 = 6$ ms and $\tau_2 = R_2 \times C$; $R_2 = \frac{\tau_2}{C} = \frac{6\times10^{-3}}{1\times10^{-6}} = 6000\ \Omega = 6\ k\Omega$	**0.5** **0.5**
2.3	Since $R_2 > R_1$; Therefore, the resistance increases with increasing temperature, so it is an "PTC" type temperature sensor.	**0.75**

Exercise 4 (6.5 points) Diffraction of light		
Part	**Answer**	**Grade**
1	Wave Aspect of light	**0.5**
2	We observe on the screen: ▪ Alternating bright and dark fringes on both sides of the central bright fringe; ▪ The central bright fringe is the most intense and has a width double that of the other bright fringes; ▪ The direction of the fringes is perpendicular to the direction of the slit.	**0.75**
3	For dark fringes: $\sin\theta = n\frac{\lambda}{a}$, since θ small then $\sin\theta = \theta$ for first dark fringe: n = 1 ; $\theta_1 = \frac{\lambda}{a}$ $\tan\theta_1 = \frac{\frac{L_1}{2}}{D}$; $\theta_1 = \frac{L_1}{2D}$, and $\theta_1 = \frac{\lambda}{a}$ Then $\frac{L_1}{2D} = \frac{\lambda}{a}$; therefore $L_1 = \frac{2\lambda D}{a}$	**0.5** **0.5** **0.5**
4.1	$L_2 = \frac{2\lambda' D}{a}$	**0.5**
4.2	$L_1 = 1.000294 \times L_2$ So $\frac{2\lambda D}{a} = 1.000294\frac{2\lambda' D}{a}$; but $\lambda' = \frac{\lambda}{n}$ Then: $n\lambda' = 1.000294\lambda'$ thus n = 1.000294	**1.25**
5.1	$n = 1.000293 + 1.57 \times 10^{-6} P$; $1.000294 = 1.000293 + 1.57 \times 10^{-6} P$ then P = 0.63 %	**1**
5.2	No, since 0.63 % > 0.5 %	**1**

Exercise 5 (6.5 pts) **Mercury vapor lamp and photoelectric effect**		
Part	**Answer**	**grade**
1.1	Transition from third excited state E_4 to the fifth excited state E_6, then: $E_{photon} = E = E_6 - E_4 = 2.15$ eV	**0.75**
1.2	$E = \frac{hc}{\lambda}$ then $\lambda = \frac{hc}{E}$ $\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{2.15\times1.6\times10^{-19}} = 5.78\times10^{-7}$ m = 578 nm	**0.75**
1.3	$\lambda_{6\to4}$ emitted following the transition 6 → 4 is equal to the wavelength of the photon absorbed to excite the atom from level 4 to level 6. Therefore $\lambda_{6\to4}$ = 578 nm	**0.5**
1.4	From document, this radiation corresponds to the yellow color.	**0.25**
2	$E_5 - E_2 = 2.86$ eV ; $\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{2.86\times1.6\times10^{-19}} = 434\times10^{-7}$ m = 434 nm So the color is blue	**1.5**
3.1	« Threshold wavelength » of a pure metal, is the maximum wavelength of the incident radiation which is capable of extracting electron from the surface of this metal.	**0.5**
3.2	$W_0 = \frac{hc}{\lambda_0}$ then $\lambda_0 = \frac{hc}{W_0}$ For cesium : $\lambda_0 = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.89\times1.6\times10^{-19}} = 6.57\times10^{-7}\,m = 657\,nm$ For zinc : $\lambda_0 = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.31\times1.6\times10^{-19}} = 2.88\times10^{-7}$m = 288 nm	**0.25** **0.5** **0.5**
3.3	$\lambda < \lambda_0$ of cesium So, the photoelectric effect will occur with cesium.	**1**