وزارة التّربية والتعليم العالي
المديريّة العامّة للتّربية
دائرة الامتحانات الرّسميّة

امتحانات الشهادة الثانويّة العامّة
فرع العلوم العامّة

دورة العام 2023 العاديّة
الثلاثاء 11 تموز 2023

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

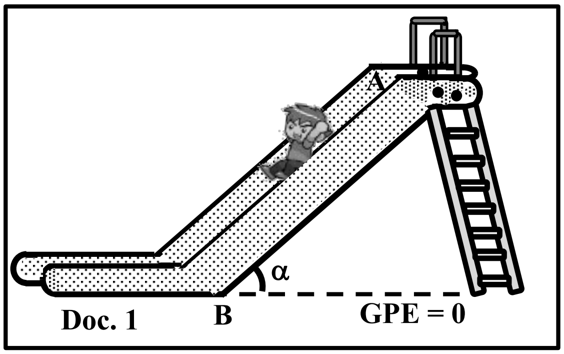
This exam is formed of four obligatory exercises in four pages.
The use of non-programmable calculator is recommended.

Exercise 1 (5 pts)

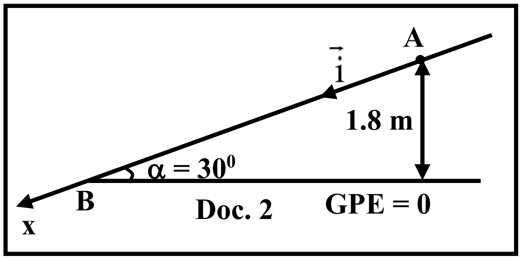
Motion on a slide

In a park, a child plays on a slide.
The child, considered as a particle, has a mass M = 20 kg.
He climbs to point A the top of the slide, and then slides down without initial velocity to point B at the bottom of the slide at the ground level (Doc. 1).
The part AB of the slide is straight and inclined by an angle $\alpha = 30^o$ with respect to the horizontal. The top A of the slide is situated at a height $h_A = 1.8$ m above the ground.
Point A is taken as the origin of the x-axis, passing through AB, and of unit vector $\vec{i}$ (Doc. 2).
The aim of this exercise is to determine the duration of motion of the child from A to B in two cases: without friction and with friction.
Take:

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



Doc. 1



Doc. 2

1) The child climbs from the ground to point A.
   1.1) Calculate the variation of the gravitational potential ΔGPE of the system (Child, Earth) between the ground and A.
   1.2) Calculate the work W done by the weight of the child, when he climbs from the ground to A, knowing that $W = M\,g\,(h_i - h_f)$ where h_i and h_f are the initial and final heights above the ground.
   1.3) Compare W and ΔGPE.
2) Suppose that the child slides without friction from A to B.
   2.1) Determine the speed V_B of the child when he reaches the ground at B.
   2.2) Show that the variation of the linear momentum of the child between A and B is $\Delta\vec{P} = 120\,\vec{i}$ (kg.m/s).
   2.3) Show that the sum of the external forces exerted on the child, during the downward motion from A to B is $\Sigma\vec{F}_{ext.} = 100\,\vec{i}$ (N).
   2.4) Deduce, by applying Newton's second law, the duration Δt_1 along AB, knowing that $\frac{\Delta\vec{P}}{\Delta t} = \frac{d\vec{P}}{dt}$.
3) In reality, the child is submitted to a force of friction $\vec{f}$, supposed constant and parallel to the displacement. During the motion from A to B, the system (Child, Slide, Earth, Atmosphere) loses 25% of its mechanical energy at A.
   3.1) Show that during the downward motion of the child from A to B, the variation in the internal energy of the system (Child, Slide, Earth, Atmosphere) is ΔU = 90 J.
   3.2) Deduce that the magnitude of the friction force $\vec{f}$ is f = 25 N.
   3.3) The variation of the linear momentum of the child between A and B, in this case, is $\Delta\vec{P} = 60\sqrt{3}\;\vec{i}$ (kg.m/s).
   Determine, by applying Newton's second law, the duration Δt_2 along AB, knowing that $\frac{\Delta\vec{P}}{\Delta t} = \frac{d\vec{P}}{dt}$.

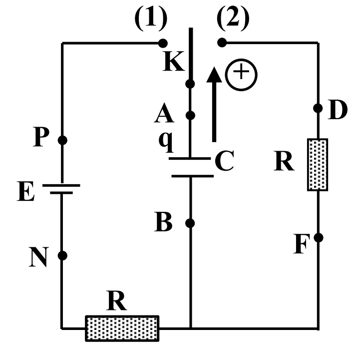
Exercise 2 (5.5 pts)

Effect of the capacitance on the duration of discharging of a capacitor

The aim of this exercise is to study the effect of the capacitance of a capacitor on the duration of discharging of a capacitor.

For this aim, we set-up the circuit of document 3 that includes:

- a capacitor, initially uncharged, of adjustable capacitance C;
- two identical resistors of resistance R = 100 Ω;
- an ideal battery of voltage $u_{PN} = E$;
- a double switch K.



Doc. 3

1) Charging the capacitor

At $t_0 = 0$, K is turned to position (1) and the charging process of the capacitor starts. At an instant t_1, the capacitor is completely charged.

1.1) Indicate the value of the current i carried by the circuit at t_1.

1.2) Write, at t_1, the charge Q in the capacitor in terms of E and C.

2) Discharging the capacitor

The capacitor is completely charged.

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

2.1) Show that the differential equation that describes the variation of the charge q of plate A of the capacitor is: $R\frac{dq}{dt} + \frac{q}{C} = 0$.

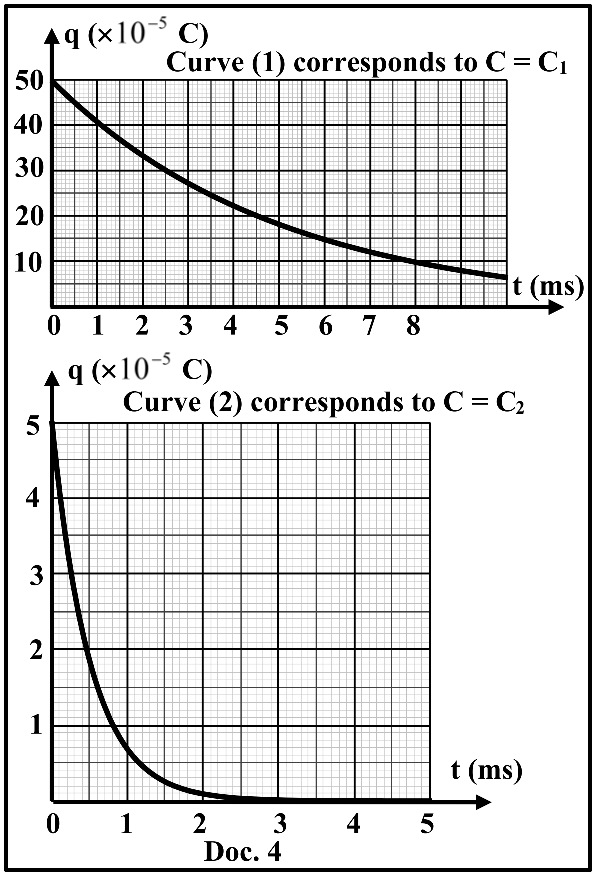
2.2) The solution of this differential equation is of the form: $q = Q\,e^{\frac{-t}{\tau}}$ where τ is a constant. Determine the expression of τ in terms of R and C.

2.3) Calculate the ratio $\frac{q}{Q}$ at $t = \tau$.

2.4) Verify that the capacitor is practically completely discharged at $t_2 = 5\,\tau$.

3) Duration of discharging a capacitor

We repeat the charging and the discharging of the capacitor by giving C two different values C_1 and C_2. The curves of document 4 show the charge q during the discharging process of the capacitor for each value of C as funcrions of time.



Doc. 4

3.1) Using document 4, copy and complete the below table:

	The charge Q (in C) at $t_0 = 0$	The time constant τ (in ms)
Curve (1) corresponds to $C = C_1$	$Q_1 =$	$\tau_1 =$
Curve (2) corresponds to $C = C_2$	$Q_2 =$	$\tau_2 =$

3.2) Calculate the values C_1 and C_2.

3.3) Deduce the effect of the capacitance of the capaitor on the duration of the discharging process.

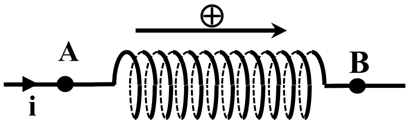
Exercise 3 (5.5 pts)

Inductance and resistance of a coil

Consider a coil of inductance L and internal resistance r.
The aim of this exercise is to determine L and r by two different methods.

1) First method

A portion of a circuit is formed of the coil, that carries a current « i ». The coil is oriented positively from A to B (Doc. 5).



Doc. 5

1.1) Write the expression of the self-induced electromotive force « e » in the coil in terms of L, i and time t.

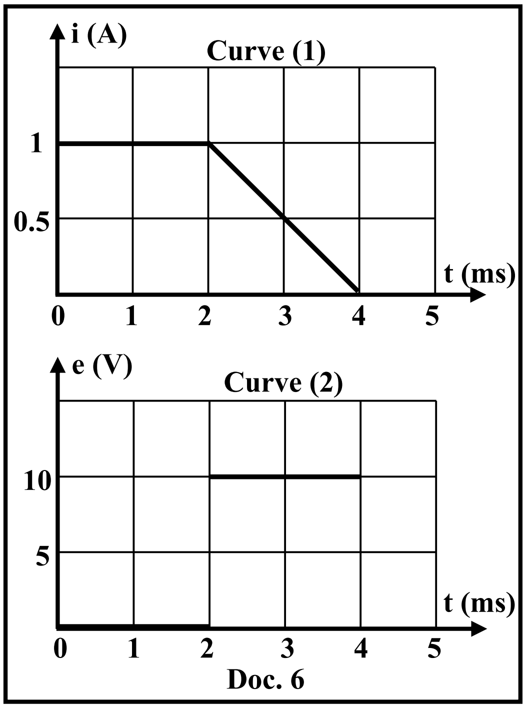
1.2) The curves (1) and (2) of document 6 show respectively « i » and « e » as functions of time, between 0 and 4 ms. Using document 6:

1.2.1) Justify each of the following statements:

- **Statement 1**: between 0 and 2 ms, the coil acts as a resistor of resistance r.
- **Statement 2**: between 2 ms and 4 ms, a phenomenon of self-induction takes place in the coil.
- **Statement 3**: between 2 ms and 4 ms the coil supplies the circuit with the stored magnetic energy.

1.2.2) Determine the value of L.

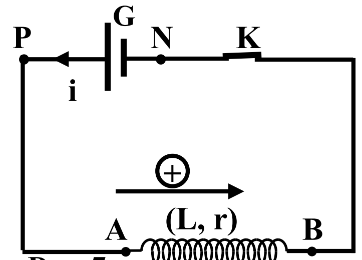
1.2.3) Determine the value of r, knowing that $u_{AB} = -5$ V at t = 3 ms.



Doc. 6

2) Second method

We connect the coil in series with an ideal battery (G) of electromotive force (e.m.f) E = 20 V (Doc.7).
At $t_0 = 0$, we close the switch K.
At an instant t, the circuit carries a current i.
Document 8 shows the current i as a function of time and the tangent (T) to the curve i(t) at $t_0 = 0$.



Doc. 7

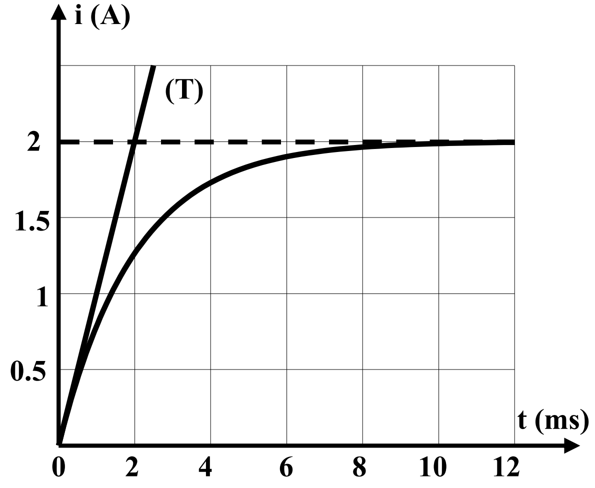
2.1) Establish the first order differential equation that describes the variation of the current i as a function of time.

2.2) Determine the expression of the maximum current I_m, at the steady state, in terms of E and r.

2.3) Calculate r using document 8.

2.4) Determine, using the differential equation, the expression of $\frac{di}{dt}$ at $t_0 = 0$ in terms of E and L.

2.5) Calculate the slope of the tangent (T). Deduce L.



Doc. 8

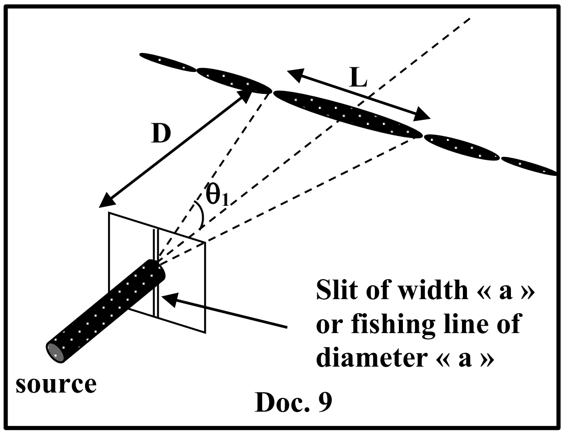
Exercise 4 (4 pts)

Diameter of a fishing line

The aim of this exercise is to determine whether the fishing line chosen by a fisherman is suitable to catch the trout fish of a specific size using the phenomenon of diffraction.

1) Set-up of diffraction

A monochromatic light, of wavelength λ, falls normally on a vertical narrow slit of width « a ». The diffraction pattern is observed on a screen placed perpendicularly to the incident light beam at a distance D from the slit.
Let «L» be the linear width of the central bright fringe (Doc. 9).
The diffraction angles in this exercise are small.
For small angle, take $\tan\theta \approx \sin\theta \approx \theta$ in radian.



Doc. 9

1.1) Describe the diffraction pattern observed on the screen.

1.2) Write, in terms of λ and « a », the expression of the angle of diffraction θ_1 corresponding to the center of the first dark fringe.

1.3) Show that $L = \frac{2\lambda D}{a}$.

2) Diameter of fishing line

A fisherman wants to catch a trout fish of size 50 cm to 55 cm. He bought a thin fishing line made up of 100% copolymer, but the strength of a fishing line also depends on its diameter « a ».
To find out if the chosen fishing line is suitable for such a type of fish, he uses the diffraction set-up of document 9 by replacing the slit of width « a » by the fishing line of diameter « a », so he obtains a diffraction pattern similar to that shown in document 9.
The screen is placed at a distance D from the fishing line, the linear width of the central bright fringe is L_1 = 13 mm. The screen is displaced by 50 cm away from the fishing line, the linear width of the central bright fringe becomes L_2 = 19.5 mm.

2.1) Show that D = 1 m.

2.2) Calculate the diameter « a » of the chosen fishing line, knowing that the wavelength of the used light is λ = 650 nm.

2.3) Referring to the table in document 10, specify if the chosen fishing line is suitable for fishing trout fish of size 50 to 55 cm.

Fishing line (100 % copolymer)	Diameter	Use
Fishing line (1)	0.10 mm	It is suitable to fishing a trout fish of size 35 cm to 40 cm.
Fishing line (2)	0.18 mm	It is suitable to fishing a trout fish of size 50 cm to 55 cm.
Fishing line (3)	0.25 mm	It is suitable to fishing a trout fish of size 65 cm to 70 cm.

https://www.truitesaquaponiques.com/

Doc. 10

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امتحانات الشهادة الثانوية العامة
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دورة العام 2023 العادية

مسابقة الفيزياء
أسس التصحيح

Exercise 1 (5 pts)	**Motion on a slide**	
Part	**Answer**	**Mark**
1.1	The gravitational potential energy of the system at B $GPE_{ground} = 0$ and at A, $GPE_A = M\,g\,h_A = 360$ J $\Delta GPE = GPE_A - GPE_B = 360 - 0 = 360$ J	**0.75**
1.2	The work done by the weight of the child, when he moves from the ground to the top A: $W = M\,g\,(h_i - h_f) = 20\times10\times(0 - 1.8) = -360$ J	**0.25**
1.3	$W_{weight} = -\Delta GPE$	**0.25**
2.1	$ME_A = GPE_A + KE_A = 360$ J ($KE_A = 0$ since $V_A = 0$) In the absence of friction, (or the work done by the nonconsevative forces is zero) the mechanical energy of the system is conserved, then $ME_B = ME_A = 360$ J But $ME_B = KE_B + GPE_B$; $GPE_B = 0$ (on reference) So $\frac{1}{2} M V_B^2 = 360$ therefore $V_B = 6$ m/s	**0.75**
2.2	$\Delta\vec{P} = \vec{P_B} - \vec{P_A}$; $\Delta\vec{P} = M\vec{V_B} - M\,\vec{V_A}$, therefore $\Delta\vec{P} = 20 \times 6\,\vec{i} - \vec{0}$, then $\Delta\vec{P} = 120\,\vec{i}$	**0.5**
2.3	$\Sigma\vec{F}_{ext} = M\vec{g} + \vec{N}$, along $\vec{i}$: $\Sigma\vec{F}_{ext} = Mg.\sin\alpha\,\vec{i} + \vec{0} = 100\,\vec{i}$	**0.5**
2.4	$\Delta\vec{P} = \Sigma\vec{F}_{Ext} \times \Delta t_1$, so $120\,\vec{i} = 100\,\vec{i} \times \Delta t_1$, then $\Delta t_1 = 1.2$ s	**0.25**
3.1	The system (Child, Slide, Earth, Atmosphere) is energetically isolated, So its total energy $E = ME + U = $ constant So, $\Delta U = -\Delta(ME)$ There is a loss of 25 % of ME; so $\Delta(ME) = -0.25\times ME_A = -0.25(360) = -90$ J: Hence, $\Delta U = 90$ J	**0.75**
3.2	The variation in mechanical energy equals the work of friction: $\Delta ME = W_{\vec{f}}$ so $\Delta(ME) = -90 = -f\times AB = -f\times\frac{h_A}{\sin(\alpha)}$ $-90 = -f\times3.6$, thus $f = 25$ N	**0.5**
3.3	$\Delta\vec{P} = \Sigma\vec{F}_{ext}\times\Delta t_2$, $\Sigma\vec{F}_{Ext} = (Mg.\sin\alpha - f)\,\vec{i} + \vec{0}$ so $60\sqrt{3}\,\vec{i} = (100 - 25)\,\vec{i} \times \Delta t_2$, then $\Delta t_2 = 1.385$ s	**0.5**

<table>
<tr><th colspan="3">Exercise 2 (5.5 pts) Effect of the capacitance on the discharging of a capacitor</th></tr>
<tr><th>Part</th><th>Answer</th><th>Mark</th></tr>
<tr><th>1.1</th><td>At instant t_1 : $i = 0$</td><th>0.25</th></tr>
<tr><th>1.2</th><td>$Q = C\,E$</td><th>0.25</th></tr>
<tr><th>2.1</th><td>$u_C = u_{DF} = u_R$; $\frac{q}{C} = R\,i$; But $i = -\frac{dq}{dt}$ so we get : $R\frac{dq}{dt} + \frac{q}{C} = 0$</td><th>0.5</th></tr>
<tr><th>2.2</th><td>$q = Q\,e^{\frac{-t}{\tau}}$; $\frac{dq}{dt} = -\frac{Q}{\tau}\,e^{\frac{-t}{\tau}}$ we substitute q and $\frac{dq}{dt}$ in the differential equation
$-R\frac{Q}{\tau}\,e^{\frac{-t}{\tau}} + \frac{Qe^{\frac{-t}{\tau}}}{C} = 0$; $Qe^{\frac{-t}{\tau}}\,[-\frac{R}{\tau} + \frac{1}{C}] = 0$;
But $Qe^{\frac{-t}{\tau}} \neq 0$; so $-\frac{R}{\tau} + \frac{1}{C} = 0$; therefore $\frac{R}{\tau} = \frac{1}{C}$
thus $\tau = RC$</td><th>1</th></tr>
<tr><th>2.3</th><td>the ratio: $\frac{q}{Q} = \frac{Qe^{\frac{-t}{\tau}}}{Q}$
at $t = \tau$: $\frac{q}{Q} = e^{-1} = 0.37$</td><th>0.5</th></tr>
<tr><th>2.4</th><td>$q = Q\,e^{\frac{-t}{\tau}}$; à $t_2 = 5$ RC: $q = Q\,e^{-5} = 0.006\,Q \approx 0$</td><th>0.5</th></tr>
<tr><th>3.1</th><td>Curve (1):
At $t_0 = 0$: $Q_1 = 50 \times 10^{-5}$ C
at $t = \tau_1$: $q = 0.37 \times 50 \times 10^{-5} = 18.5 \times 10^{-5}$ C.
From the graph: $q = 18.5 \times 10^{-5}$ C at t = 5 ms ; so $\tau_1 = 5$ ms

Curve (2):
at $t_0 = 0$: $Q_2 = 5 \times 10^{-5}$ C
at $t = \tau_2$: $q = 0.37 \times 5 \times 10^{-5} = 1.85 \times 10^{-5}$ C.
From the graph: $q = 1.85 \times 10^{-5}$ C at t = 0.5 ms ; so $\tau_1 = 0.5$ ms

<table>
<tr><th></th><th>Charge Q at $t_0 = 0$</th><th>The time constant τ</th></tr>
<tr><td>Curve (1) for $C = C_1$</td><td>$Q_1 = 50 \times 10^{-5}$ C</td><td>$\tau_1 = 5$ ms</td></tr>
<tr><td>Curve (2) for $C = C_2$</td><td>$Q_2 = 5 \times 10^{-5}$ C</td><td>$\tau_2 = 0.5$ ms</td></tr>
</table></td><th>1</th></tr>
<tr><th>3.2</th><td>$\tau_1 = R\,C_1$, so $C_1 = \frac{\tau_1}{R}$: $C_1 = \frac{5 \times 10^{-3}}{100}$ thus $C_1 = 5 \times 10^{-5}$ F = 50 μF
$\tau_2 = R\,C_2$, so $C_2 = \frac{\tau_2}{R}$; $C_2 = \frac{0.5 \times 10^{-3}}{100}$ thus $C_2 = 0.5 \times 10^{-5}$ F = 5 μF</td><th>1</th></tr>
<tr><th>3.3</th><td>As the capacitance increases , the duration of discharging increases</td><th>0.5</th></tr>
</table>

Exercise 3 (5.5 pts)	**Characteristics of a coil**	
Part	**Answer**	**Mark**
1.1	$e = -L\frac{di}{dt}$	**0.25**
1.2.1	• Statement 1 : During this interval i = constant, so $\frac{di}{dt} = 0$ thus e = 0, The voltage across the coil $u_{AB} = ri - e = ri$ The coil acts as a resistor of resistance r. • Statement 2 : i varies with time so $e \neq 0$ therefore e exists this implies that a phenomenon of self-induction appears in the circuit. • Statement 3 : i decreases, then $W_{mag} = \frac{1}{2}Li^2$ decreases Or $e.i > 0$, then it acts as a generator	**1.5**
1.2.2	Between 2 ms and 4 ms : e = 10 V $\frac{di}{dt} = \text{slope} = \frac{0-1}{4\times10^{-3}-2\times10^{-3}} = -500$ A/s $e = -L\frac{di}{dt}$ so : $10 = -L(-500)$, thus L = 0.02 H = 20 mH	**0.75**
1.2.3	$u_{AB} = ri - e$; at t = 3 ms : $-5 = r(0.5) - 10$ 0,5 r = 10 – 5 = 5 , then r = 10 Ω	**0.5**
2.1	$u_g = u_L$; $E = ri + L\frac{di}{dt}$;	**0.5**
2.2	in steady state : $i = I_m$; and $\frac{di}{dt} = 0$ so $E = r I_m$, thus $I_m = \frac{E}{r}$	**0.5**
2.3	$I_m = 2$ A ; $2 = \frac{20}{r}$, then r = 10 Ω	**0.25**
2.4	$E = r i + L\frac{di}{dt}$, then $\frac{di}{dt} = E - r i$; At $t_0 = 0$: $i = 0$ then $\left.\frac{di}{dt}\right)_{t_0=0} = \frac{E}{L}$	**0.5**
2.5	Slope of the tangent $= \frac{2}{2\times10^{-3}} = 1000$ A/s But, slop of the tangent $= \left.\frac{di}{dt}\right)_{t_0=0} = \frac{E}{L}$; So, $1000 = \frac{20}{L}$, then L = 0.02 H = 20 mH	**0.75**

Exercise 4 (4 pts)	**Diameter of a fishing line**	
Part	**Answer**	**Mark**
1.1	We observe on the screen: ✓ Alternating bright and dark fringes; ✓ 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**
1.2	$\sin\theta_1 \approx \theta_1 = \frac{\lambda}{a}$	**0.25**
1.3	$\tan\theta_1 = \frac{L/2}{D}$, then $\theta_1 = \frac{L}{2D}$; $\frac{\lambda}{a} = \frac{L}{2D}$; thus, $L = \frac{2\lambda D}{a}$	**1**
2.1	$\frac{\lambda}{a} = \frac{L_1}{2D_1} = \frac{L_2}{2D_2}$; $\frac{L_2}{L_1} = \frac{D_2}{D_1} = \frac{D+0.5}{D}$ $\frac{L_2}{L_1} = \frac{D+0.5}{D}$, so $\frac{19.5}{13} = \frac{D+0.5}{D}$ then 19.5 D = 13 D + 6.5 ; thus D = 1 m	**1**
2.2	$a = \frac{2\lambda D}{L_1}$ then $a = \frac{2\times 650\times 10^{-9}\times 1}{1.3\times 10^{-2}}$; a = 0.1 mm	**0.5**
2.3	The chosen line is not suitable to catch the trout fish of size 50 to 55 cm. Because the diameter of the line is less than 0.18 mm.	**0.5**