105 學年第二學期 普通物理 B 第二次期中考試題

Wolfson Ch 25-28 (第三版)；2017/05/02, ***8:20 am – 09:50 am***

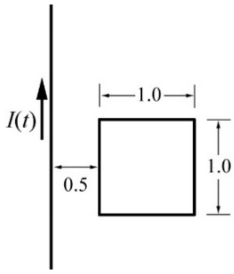
(i) 依空格號碼順序在第二張<u>正面</u>寫下所有填充題答案，不要寫計算過程。

(ii) 依計算題之順序在第二張<u>反面</u>以後寫下演算過程與答案，<u>**每題從新的一頁寫起**</u>。

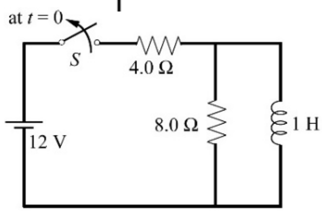
Constants: $\mu_o = 4\pi\times10^{-7}$ N/A^2, g = 9.8 m/s^2

Part I. Filling the blank (5 points per blank)

• Which of the following descriptions are NOT related to Faraday law? (more than one answer) (a)Back emf, (b)Diamagnetism, (c)Eddy current, (d)Ferromagnetism, (e)Levitation(浮升) of a superconductor in a **B** field, (f)Operation of a transformer, (g)Paramagnetism 【1】

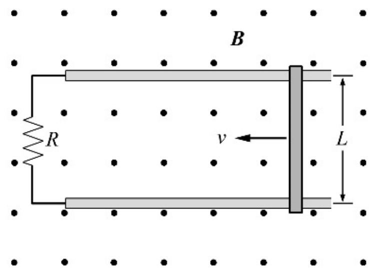


• A square conducting loop of side 1.0 m lies in a plane containing a long, straight wire as shown in right figure. The current in the long wire $I(t)$ comes from a charging *RC* circuit with a time constant 2.0 s, and at time t = 2.0 s, I = 4.0 A. The induced emf in the loop at time t = 4.0 s is 【2】V.

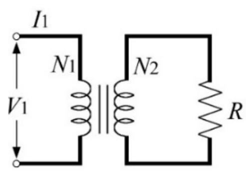


• The switch *S* in the circuit shown in right figure is closed for a long time. It is opened at time t = 0, the current through 8.0 Ω-resistor $I(t)$ = 【3】 A.

• A capacitor is connected across a 60-Hz, 110-V rms power line, and an rms current of 0.20 A flows. If the capacitor is replaced by an inductor, and the same current flows. The inductance is【4】H.

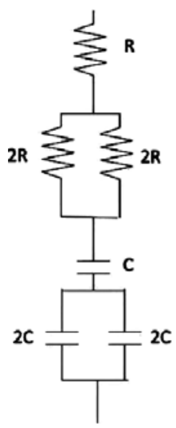


• A pair of parallel conducting rails, a resistor *R* across the rails, and a conducting bar of negligible resistance are arranged in a uniform field ***B*** as shown in right figure. The bar is pulled along the rails with velocity **v** to the left. Take L = 10 cm, B = 0.50 T, R = 2.0 Ω, and v = 2.0 m/s, the magnetic force on the bar is 【5】 N. (direction must be included).

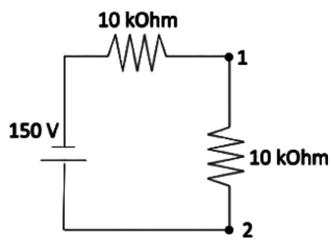


• A transformer consists of N_1-turn primary coil and N_2-turn secondary coil. The secondary circuit is completed by a resistor *R*, as shown in right figure. If the current and terminal voltage in the primary coil are I_1 and V_1, the ratio V_1 / I_1 = 【6】*R*.

• A series *RLC* circuit, has R = 18 kΩ, C = 14 μF, and L = 0.20 H, is connected across an AC power at 120 V rms and 60 Hz. The resonance frequency is 【7】 Hz. The average power delivered to the entire circuit is 【8】 W.



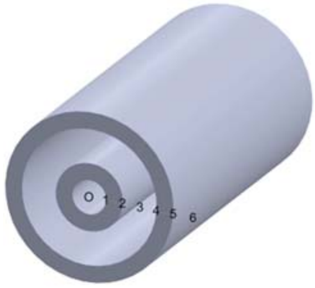
• The right diagram shows a network of resistances and capacitances. The total resistance is 【9a】 R and the total capacitance 【9b】C.



• The potential difference between the points 1 and 2 (see right image) is 【10a】 V. With a non-ideal voltmeter (internal resistance of 100 kOhm), you measure 【10b】V.

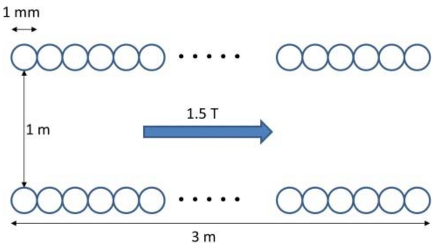
• The highvoltage powerline (resistance of 1 Ohm) between a power plant and the next town is operated at 110 kV and transports a power of 44 MW. (a) The power consumption of the powerline is 【11a】MW. If the line would be operated at 11 kV, the power consumption would be 【11b】MW. (Note: Ignore the reduced voltage due to the powerline).

• The right figure shows a double pipe system (Radius in units of r). Each tube carries a current I. If the two currents are flowing into the same direction, the magnetic field at point (0 r) is 【12a】, at point (3 r) 【12b】 and at point (6 r) 【12c】. If the two currents flow into opposite directions the respective values are 【12d】, 【12e】, and 【12f】

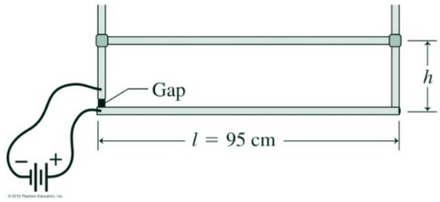


• A rectangular coil with sides a=5 cm and b=10 cm and carrying a current of 1 A is placed inside a magnetic field of 1 T. The maximum torques acting on the coil is: 【13】 Nm

• In a MRI Scanner, a coil generates a magnetic field of 1.5 T. The coil has a length of 3 m and a diameter of 1 m. The coil wire has a diameter of 1 mm and is densely packed. The required current to create the magnetic field is I = 【14】A.



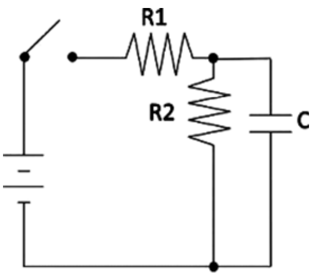
• A current of 70 A is driven through the shown structure. The upper bar (m = 30g) can vertically move. The equilibrium position h is 【15】 cm. Note: consider gravitational force and the magnetic interaction between the lower and upper bar.



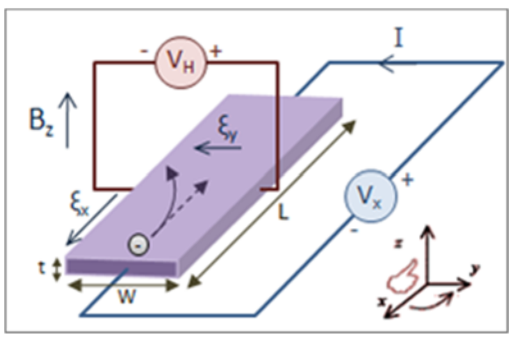
Part II Problems (10 points per problem)

1. A conducting disk with radius a, volume V, and resistivity ρ is inside a solenoid of circular cross section. The axis of disk coincides with that of the solenoid. The magnetic field in the solenoid is given by $B(t) = bt$, where b is a constant. Find (a) the magnitude of induced electric field $E(r)$ in the disk as a function of the distance r from the disk center. (b) the power dissipation in the entire disk.
(*Hint*: You may use the microscopic version of Ohm law $\boldsymbol{E} = \rho \boldsymbol{J}$, where $\boldsymbol{J}$ is the current density.)

2. (a) Evaluate the current I_C (as a function of time), which flows into the capacitor with time t after closing the switch. The battery has emf ε. (*Hint:* use Kirchhoff's Law to write down equations for loops and nodes, and solve for the charge Q in the capacitor using $I_C = dQ/dt$.)
(b) What is the time constant τ for charging the capacitor?



3. The right image shows the geometry of a Hall probe: a current I flows through a semiconductor (length L, width w, thickness t) and a magnetic field B is applied perpendicular to I. If the charge carrier in the semiconductor has density n (number/volume), and each carrier has charge q, what is the Hall Voltage V_H in terms of I, B, n and other given quantities?



Part I Answer (有效位數不扣分)

A【1】	(d) (g) (多選一個或少一個給三分)	= B【6】	B【1】	$(N_1/N_2)^2$
A【2】	$\mu_o \cdot e^{-1} \cdot \ln 3/\pi = 1.6\times10^{-7}$	= B【12】	B【2】	2.5×10^{-3} N, toward right(方向沒寫扣一分)
A【3】	$3.0e^{-8.0t}$, (3 給分，題目似乎是問 at t = 0)	= B【10】	B【3】	95 Hz (寫 598 扣一分，因當成ω)
A【4】	$110/(24\pi) = 1.46$	= B【13】	B【4】	0.8
A【5】	2.5×10^{-3} N, toward right (方向沒寫扣一分)	= B【2】	B【5】	(a): 2R (b): 4/5C (各 2.5 分)
A【6】	$(N_1/N_2)^2$	= B【1】	B【6】	(d) (g) (多選一個或少一個給三分)
A【7】	95 Hz (寫 598 扣一分，因當成ω)	= B【3】	B【7】	(a): 75 V (b): 71.4 V (各 2. 5 分)
A【8】	0.8	= B【4】	B【8】	0.005
A【9】	(a): 2R (b): 4/5C (各 2.5 分)	= B【5】	B【9】	1200 (or 1194)
A【10】	(a): 75 V (b): 71.4 V(各 2.5 分)	= B【7】	B【10】	$3.0e^{-8.0t}$, (3 給分，題目似乎是問 at t = 0)
A【11】	(a) 0.16 MW (b) 16 MW(各 2.5 分)	= B【14】	B【11】	0.32
A【12】	a = d = f = 0 b = c = e = $\mu_0 I / (6\pi r)$ (錯一個扣一分，扣到五分完為止)	= B【15】	B【12】	$\mu_o \cdot e^{-1} \cdot \ln 3/\pi = 1.6\times10^{-7}$
A【13】	0.005	= B【8】	B【13】	$110/(24\pi) = 1.46$
A【14】	1200 (or 1194)	= B【9】	B【14】	(a) 0.16 MW (b) 16 MW(各 2.5 分)
A【15】	0.32	= B【11】	B【15】	a = d = f = 0 b = c = e = $\mu_0 I / (6\pi r)$ (錯一個扣一分，扣到五分完為止)

Part II Answer

【A1 = B2 】

(a) 五分，(b) 五分。(b)部分視情況部份給分。

(a) In the loop of radius r,

$$|\mathcal{E}(r)| = \left|-\frac{d\Phi_B}{dt}\right| = \left|-\frac{d}{dt}(\pi r^2 \cdot bt)\right| = \pi b r^2 = \left|\oint \vec{E}(r)\cdot d\vec{r}\right| = E(r)\cdot 2\pi r$$

Therefore, $E(r) = br/2$.

(b) The current density in the loop of radius r is $J(r) = E(r)/\rho = br/2\rho$.

The power dissipated in this loop is

$dP = J(r)\cdot dA(\mathrm{r})\cdot|\mathcal{E}(r)| = \frac{b}{2\rho} r\cdot h dr\cdot \pi b r^2 = \frac{\pi h b^2}{2\rho} r^3 dr$, where h is the height of disk.

The total power dissipation in the disk $P = \int_0^a dP = \frac{\pi h a^4 b^2}{8\rho} = \frac{a^2 b^2}{8\rho} V.$

【A2 = B3 】

式子正確列出得五分，解出 Ic(t)得三分，正確寫出 time constant 得二分。

$\varepsilon - I_1R_1 - I_2R_2 = 0$ ---(1)

$Q/C + I_2R_2 = 0$----(2)

$I_1 = I_2 + I_C$-----(3)

Eliminate I_2 by $I_2 = I_1 - I_C$, into (1) and (2), you get $\varepsilon - I_1 - (I_1 - I_C) = 0$---(4) and $Q/C + (I_1 - I_C)R_2 = 0$-----(5)

From (4) (5), eliminate I_1, get $\varepsilon - I_CR_1 = (R_1R_2/R_2C)Q$ ------(6)

Differentiate both side of (6) and use $I_C = dQ/dt$, find $\frac{dI_C}{dt} = -\frac{R_1+R_2}{R_1R_2C} I_C$, this is a differential equation for I_C, and

the solution is $I_C = I_0 e^{-\frac{R_1+R_2}{R_1R_2C}t}$, at t = 0, $I_C = \varepsilon/R_1 = I_0$, and the time constant $\tau = R_1 R_2 C / (R_1+R_2)$

【A3 = B1 】

$qE = qvB$; $V_H = E*w \Rightarrow V_H = wvB$ ------(1)

$I = qnvA = qnv\, w*t$ --------(2)

(1) + (2) => $V_H = IB / (qnt)$