National Junior College Physics JC2
Additional Exercise 2004 (Term 2)

Current Electricity (18 – 24 Apr)

1(a) Two light bulbs are labeled 230V, 25 W and 230 V, 150 W, respectively. Calculate the resistance of each of the light bulbs under its normal operating condition.

(b) The two light bulbs referred to in part (a) are connected in series across a 230 V mains supply.

(i) Which of the two lamps will dissipate the greater power? Explain the reasoning behind your answer.

(ii) Without quoting specific values, state how the resistance of each of the light bulbs now compares with the value which you calculated in part (a). Explain the reasoning behind your answer.

2. A length of wire is cut in half and the two lengths are wrapped together side by side to make a thicker wire. How does the resistance of this new combination compare to the resistance of the original wire?

3. 220 V is applied to two different conductors made of the same material. One conductor is twice as long and twice as thick as the second. What is the ratio of the power transformed in the first relative to the second?

4. What is the internal resistance of a 12.0 V car battery whose terminal voltage drops to 8.8 V when the starter motor draws 60 A? What is the resistance of the starter motor?

5. The coiled filament of a 230 V light bulb is 0.25 m long, and is made of wire of cross-sectional area 1.2×10^{-8} m^2. The resistivity of the filament material at the normal working temperature of the bulb is 7.0×10^{-5} Ωm.

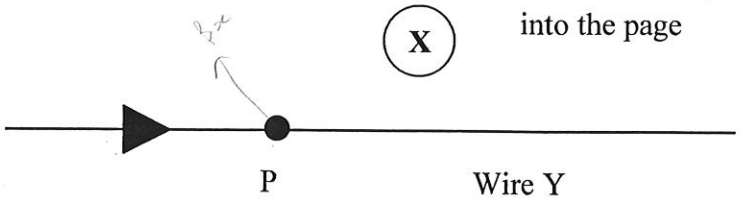
(a) Calculate the electrical power dissipated by the filament at its normal working temperature.

(b) The metal of the filament evaporates slowly from its surface while the bulb is lit, causing the filament to become thinner. Explain, without calculation, what effect this will have on

(i) the resistance of the filament;
(ii) the electrical power dissipated by the filament.

Electromagnetism (26 Apr – 1 May)

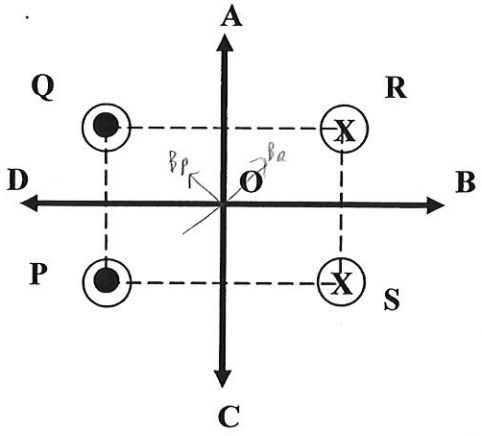
1. Two long straight current carrying wires, X and Y are placed perpendicular to each other as shown in the figure below:



Current flows into the page in wire X and from left to right in wire Y. What is the direction of the force acting on wire Y at point P due to the magnetic field produced by wire X?

A out of the page
B into the page
C towards wire X
D away from wire X

2. Four parallel conductors carrying equal currents pass vertically through four corners of a square PQRS. In conductor P and Q, the current are directed out of the page and in conductors R and S into the page. What is the direction of the resultant field at O?



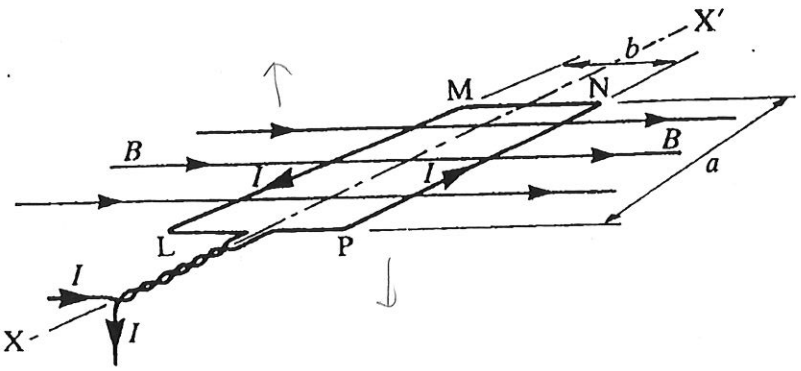
3. A rectangular loop LMNP carrying a current I is placed with its plane horizontal and parallel to a uniform magnetic field of flux density B. The loop is free to rotate about the axis XX'. The loop has length LM = PN = a. The directions of B and I are shown on the diagram. The turning force on the loop can be balanced by hanging a rider of mass

A $\frac{2BaI}{g}$ on LM

B $\frac{BaI}{g}$ on LM

C $\frac{2BaI}{g}$ on PN

D $\frac{BaI}{g}$ on PN

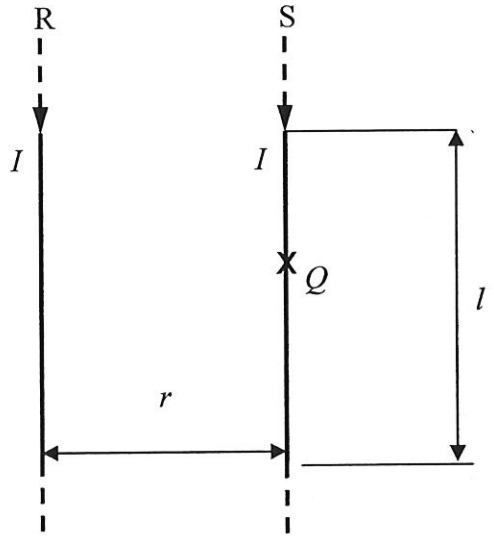


4. The equation $B = \frac{\mu_o I}{2\pi a}$ gives the magnetic flux density due to a current flowing in a long straight wire at a point distance a from the center of the wire.

[Permeability of free space $\mu_o = 4\pi \times 10^{-7}$ Hm^{-1}]

(a) Draw a diagram showing a vertical wire carrying a current and three lines of the resulting magnetic field in a horizontal plane due to this current. Show the directions of the current and field on your diagram.

(b) A second vertical wire is arranged parallel to the first wire at a distance r from it as show in the figure. A current I flows in each in the direction show.



Write down

(i) an equation for the magnetic flux density at Q due to the current in wire R.

(ii) an expression for the force on a length l of wire S due to this field.

(iii) the direction of this force.

(iv) the magnitude and direction of the force on a length l of wire R due to the field produced by wire S.

(c) Two long vertical wires, 15 mm apart, each carry a current of 5.0 A. The direction of the currents is as shown on the figure above.

(i) Calculate the force on a 3.0 m length of one of the wires.

(ii) What would be the effect on this force if the direction of **one** of the currents were to be reversed?

5(a) Distinguish between *magnetic flux density and magnetic flux.* [2]

(b) **Figure 5.1** below shows a simple current balance. A flat solenoid is connected to a horizontal rectangular copper loop *ABCD*, such that the same current can pass through them as shown. The loop is pivoted on the axis *XY* which is mid-way between *AB* and *CD*, with *CD* inside the solenoid and perpendicular to the axis of the solenoid. When a current, *I*, flows through the solenoid and the loop, a rider of mass 10^{-4} kg has to be placed on *AB* to restore equilibrium. The length of side *AD* and *DC* are 50 cm and 20 cm respectively.

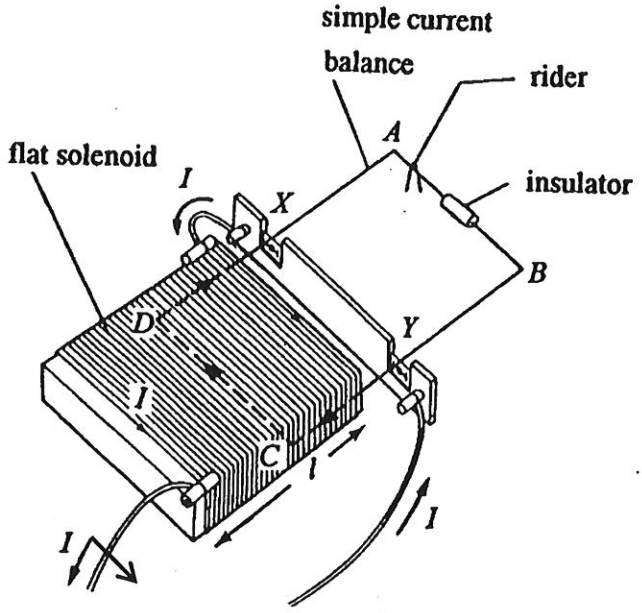


Figure 5.1

(i) State the direction of the magnetic field inside the solenoid. [1]

(ii) **1** If the magnetic flux density inside the solenoid is 1.5×10^{-3} *I*, find, in terms of *I*, the force acting on arm *CD*. [1]

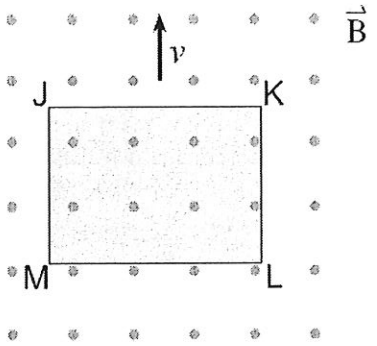
2 Hence deduce the value of *I*. [2]

(iii) Explain why the magnetic forces on sides *DX* and *CY* need not be considered when investigating the equilibrium of *ABCD*. [1]

(iv) Is this current balance useful for measuring a.c. as well? Explain briefly. [2]

EMI (3 May – 8 May)

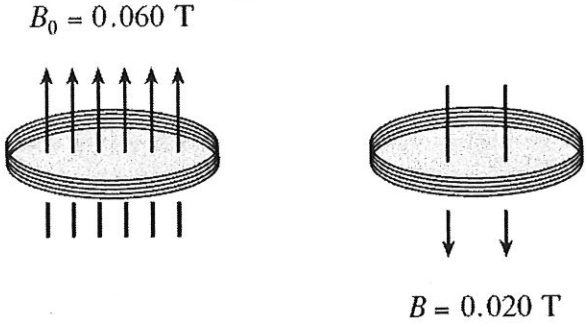
1. A metal block moves with a constant speed in a uniform magnetic field directed out of the plane of the paper as shown in the diagram.



Which side of the block is positive?

A JK B KL C LM D MJ

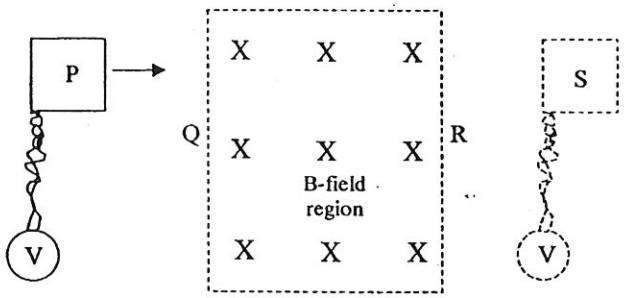
2. A 500-turn circular coil with an area of 1.54×10^{-2} m^2 is perpendicular to a 60 mT field. The magnetic field changes to 20 mT in the opposite direction in 0.12 s.



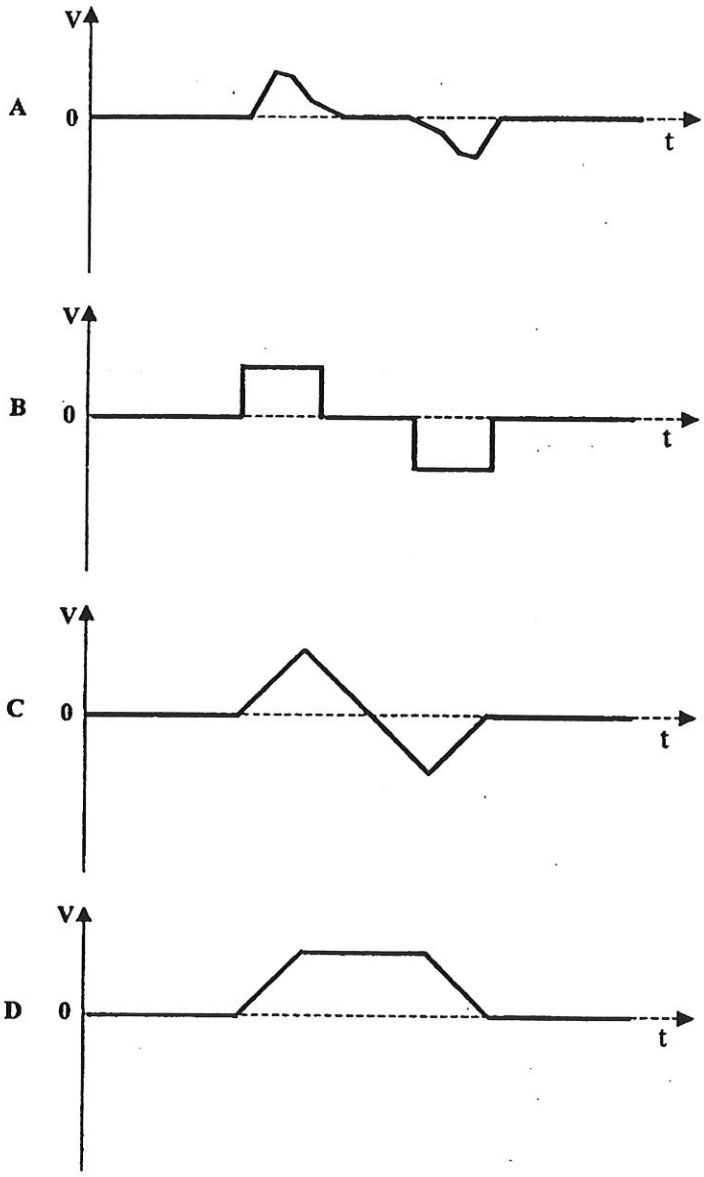
What is the average emf induced in the coil?

A 5.1 mV
B 10 mV
C 2.6 V
D 5.1 V

3. The ends of a square coil at P are connected to a voltmeter V. The coil is moved steadily from P to S through a region of uniform magnetic field, perpendicular to the plane of the coil between Q and R.

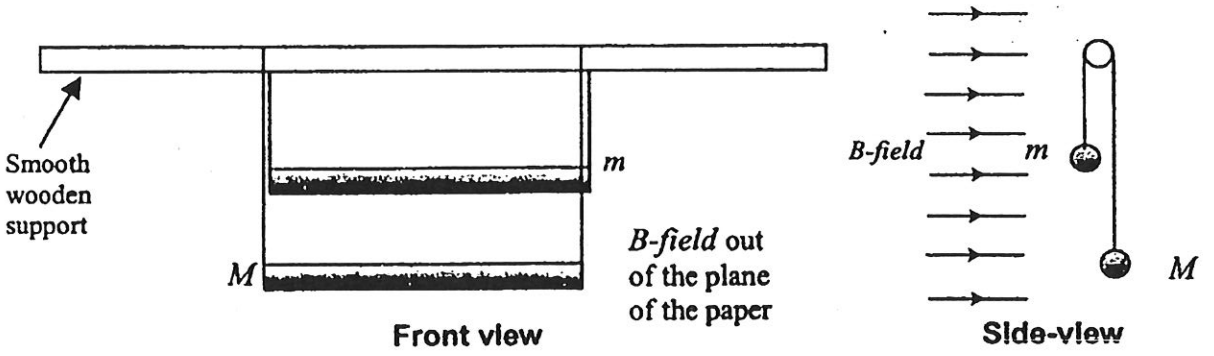


The graph which best represents the response V of the voltmeter plotted against time t, is



4.

A system consisting of two similar metal rods of the same length l but of different masses m and M, where m < M, are connected by conducting wires of negligible mass to form a closed circuit. It has a total resistance R. The system is hung over a smooth wooden support as shown in the figures below. A uniform magnetic field B is directed perpendicular to the rods and out of the plane of the paper.



The system is then released from rest. Ignore any viscous drag force.

(i) Draw a free body diagram for the above system using the side view as shown in Fig (b). Define clearly all symbols used.

(ii) Hence, by using the laws of electromagnetic induction, account for the magnitude and direction of the induced e.m.f. for each of the rods starting from the time the system is released. Copy Fig (a) and indicate clearly on it, the directions of the e.m.f. induced in each rod.

(iii) At a particular instant, mass M would be moving down at a speed of v and mass m moving up at the same speed. Find an expression in terms of the given symbols for the e.m.f. induced in each rod, as well as the net e.m.f. induced for the whole system at this particular instant.

(iv) Hence deduce the current induced for the whole system when the masses are at speed v.

(v) At the same instant, deduce the expression for the force generated on each rod.

(vi) If the wires are sufficiently long, the terminal velocity of the system can be reached. Show that the terminal velocity v_T is given by

$$v_T = \frac{(M-m)gR}{4B^2l^2}$$

Alternating Currents (AC) (24 – 29 May)

1. An alternating current I / A varies with time t / s according to the equation

$$I = 5\sin(100\,\pi t)$$

What is the mean power developed by the current in a resistive load of resistance 10 Ω?

A 62.5 W **B** 50W **C** 125 W **D** 250 W

2. When connected to a d.c. supply of voltage V, a resistor dissipates power P. In the same circuit but with an a.c. supply, what value of rms voltage will produce power $\frac{P}{2}$ in the resistor?

A. V

B. $\frac{V}{2}$

C. $\frac{V}{\sqrt{2}}$

D. $V\sqrt{2}$

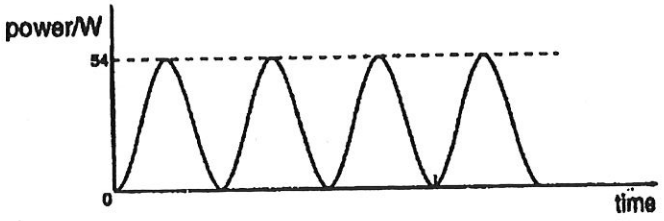
3. When a steady current I flows in a resistance R, the power dissipated is P. If an alternating current of r.m.s. value $I/2$ flows in a resistance $R/2$, what is the power dissipated?

A P **B** $P/2$ **C** $P/4$ **D** $P/8$

4. A factory requires a 1kV, 100kW electrical supply to be delivered to it through wires of total resistance 1000ohms. A step up and step down transformer are used to reduce the energy lost in the wires as heat. If the step down transformer at the factory has a turns ratio of 20:1, how much power is lost in the wires as heat?

A. 25kW
B. 50kW
C. 2.5kW
D. 5.0kW

5. A transformer has 60 turns on its primary winding and 1800 turns on its secondary. The sinusoidal input current has a value of 4.5 A r.m.s. and the power input to the transformer varies with time according to the graph below.



For the transformer, assumed to be ideal, calculate

(i) the r.m.s. value of the output current;
(ii) the mean output power; and
(iii) the r.m.s. value of the output voltage.

6. **(a)** Explain **briefly** why transformers have iron cores and are usually laminated? [2]

(b) A 50kW power plant with a source voltage of 120V may transmit power to a load over two cables, each of resistance 0.100 ohms, by two methods:

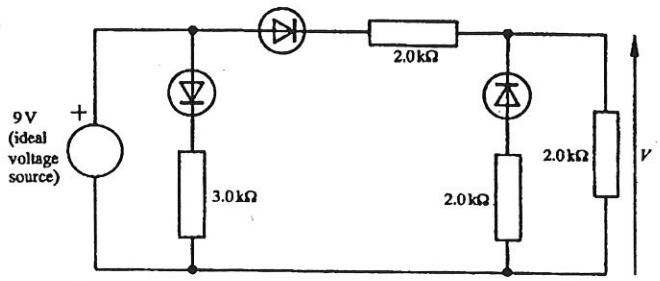
1. First stepped up the source voltage to 1200V and then down to 120V at the load.
2. Transmitted directly with a voltage of 120V.

Find the ratio of the power lost in the cables in Method 1 to Method 2. [3]

(c) A 24V accumulator battery may be charged from a 240V a.c. using a transformer and a diode. Explain whether the battery would be charged if the turn ratio is 12:1. [2]

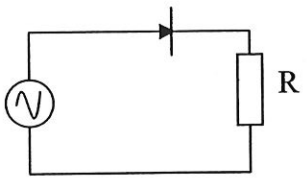
(d) State by how much would the time taken for the battery to be completely charged change if a full wave rectifier is used instead of diode.
[1]

7. In the circuit below, all the diodes are ideal. Which one of the following is the voltage V, in volts?



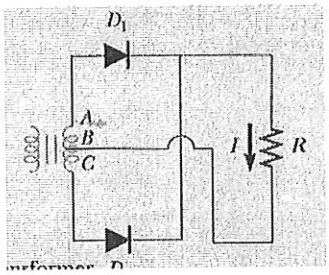
A 1.5 **B** 2.6 **C** 3.0 **D** 4.5

8a. A 240 V AC voltage is connected to a resistor, R via a diode in the diagram below.



Sketch a labelled graph showing how current flowing across R varies with time.
Comment on the resistance of the diodes.

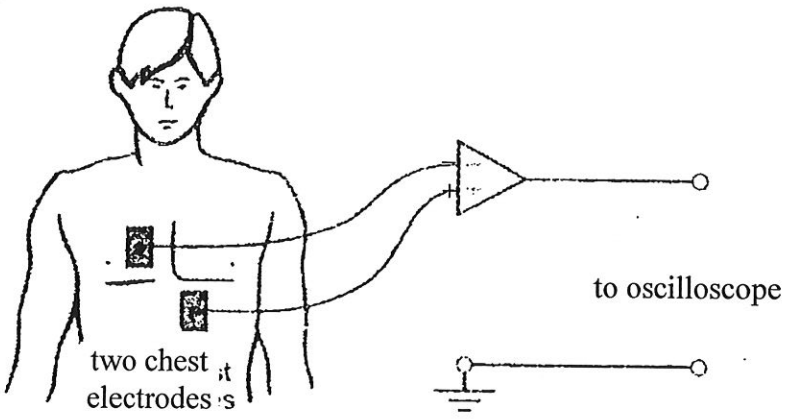
b. The 240 V AC voltage is reduced to 12 V with a step-down transformer and the output of the transformer is connected to the same resistor, R via 2 diodes in the diagram shown.



Sketch a labelled graph showing how current flowing across R varies with time.

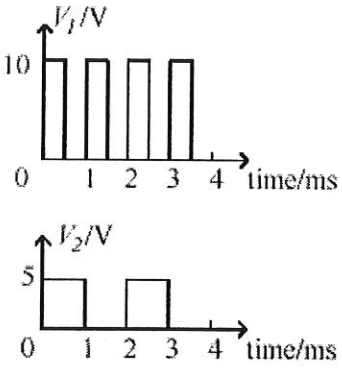
Analogue Electronics (31 May – 5 Jun)

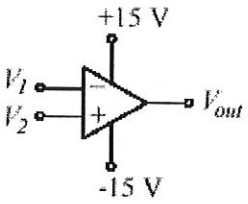
1. An electrocardiograph (e.c.g.) uses an operational amplifier as shown in the diagram. A signal proportional to the difference between the two chest electrodes is required but there is a large noise signal present in both electrodes. Which of the following is relevant in explaining why small e.c.g. signals produce regular visible oscilloscope pulses without the noise being displayed?



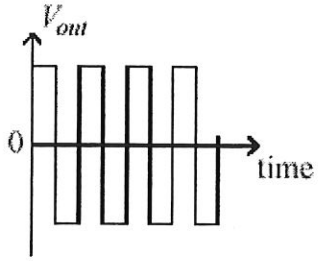
A The infinite impedance prevents the noise from being amplified
B The output signals are saturated when there is a slight difference at the inputs.
C The amplifier only amplifies voltage signals and not audio noise.
D The noise signal at the electrodes are channelled out of phase into the amplifier.

2. Two electrical signals V_1 and V_2 are fed into an optional amplifier. The variations of V_1 and V_2 with time are shown on the right. Which of the following graphs represent the variation of the output V_{out} with time?

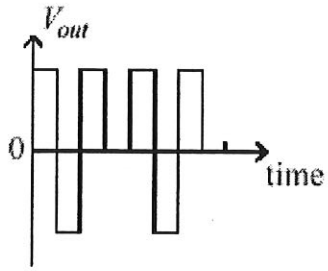




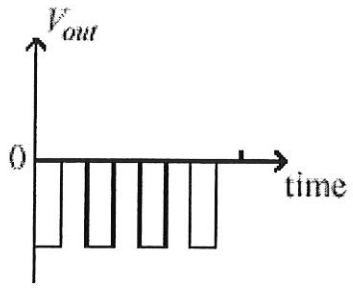
A



C



B



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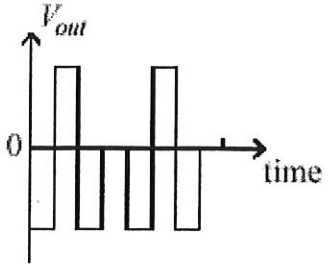
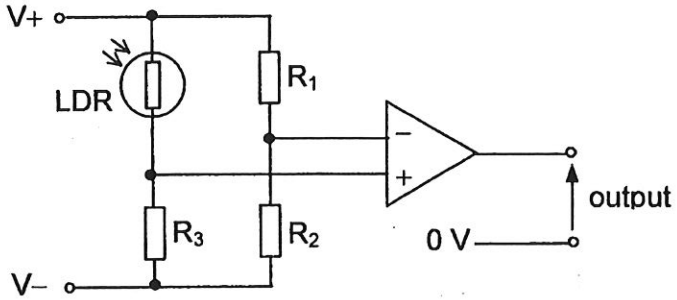


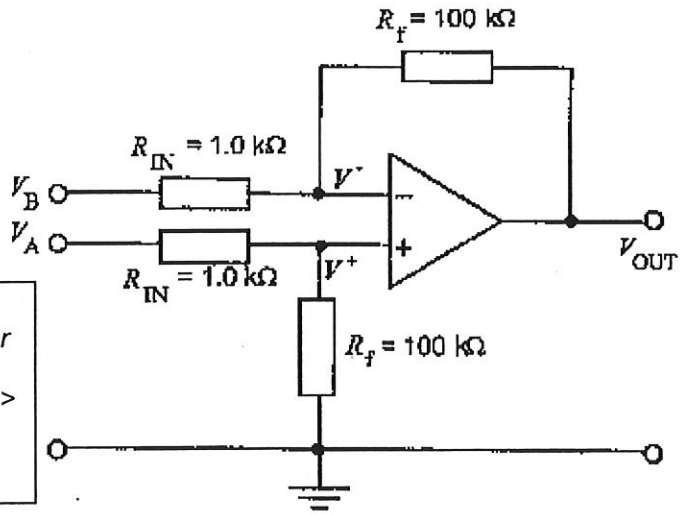
3. In the circuit shown below, R_1 and R_2 are equal, and the output voltage is positive. The resistance of the LDR decreases with an increase in light intensity.



Which one of the following changes may cause the output voltage to change sign?

A Increasing the value of R_3.
B Increasing the light intensity on the LDR.
C Increasing the value of R_1.
D Increasing the value of R_2.

3. This question is about using an op-amp as a differential amplifier. A circuit of this application is given below. You will analyse this circuit to see how it works.



Remember!
1. *No current enter the inputs*
2. *Not saturated => $V^- \approx V^+$*

Fig. 1

(a) Find an expression for V^+ in terms of V_A , R_{IN} and R_f . Explain your working.

(b) Find an expression for V^- in terms of V_B , R_{IN} , R_f and V_{OUT} .

(c) The amplifier is used in the linear mode, that is, it is not allowed to become saturated. Find an expression for V_{OUT} in terms of V_A , V_B , R_{IN} and R_f.

(d) One application of the circuit in Fig. 1 is to amplify the potential difference between two points across a pair of identical potential dividers. The values of the resistors are chosen so as to make the potential difference across A and B equal to zero when the strain gauges 1 and 2 are unstrained. Strain gauge 1 is then bonded onto a beam. When the beam bends as shown in Fig. 2, a potential difference of 1.5 mV develops across A and B.

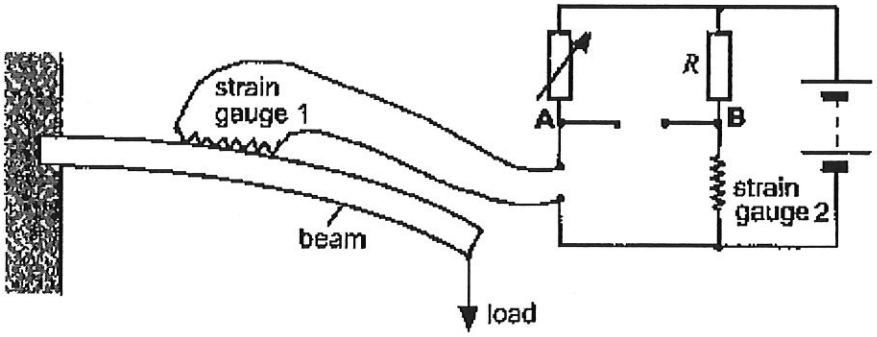


Fig. 2

(i) Is the difference in voltage ($V_A - V_B$) greater than or less than zero? Explain.

(ii) What is the output voltage of the amplifier when it is connected across A and B?

Physics Add Ec

Jen Zhi Yong 03S6H Current of Electricity

Subject: Date: 28-9-09

1(a) Resistance of 1st bulb $= \frac{V^2}{P}$

$= \frac{(230)^2}{25}$

$= 2120\ \Omega$ (3 s.f.)

Resistance of 2nd bulb $= \frac{V^2}{P}$

$= \frac{(230)^2}{150}$

$= 353\ \Omega$ (3 s.f.)

1(bi) The lamp with the ~~higher~~ lower resistance will dissipate greater power. ~~Since~~ It is designed to dissipate more power as it is rated 150W compared to the other bulb that is rated only 25W.

1(bii) They are the same as the calculated values as they are connected across a 230V supply, the same voltage used in the calculation of resistance.

2) $R = \frac{\rho l}{A}$

$R \propto \frac{l}{A}$

Let initial length of wire be l_i

Let initial radius of cross-section of wire be r_i

When wire is cut into half, $l_f = \frac{1}{2} l_i$

$r_f = 2r_i$

$\therefore A_f = \pi(2r_i)^2$

$= 4\pi r_i^2$

$= 4A_i$

$R_f = k\frac{\frac{1}{2}l_i}{4A_i}$

$= k\left(\frac{1}{8} \times \frac{l_i}{A_i}\right)$

$= \frac{1}{8}R_i$

$\therefore$ resistance of new combination is $\frac{1}{8}$ the resistance of the old combination

Subject: Date:

3) $P = \frac{V^2}{R}$

$= \frac{V^2}{\rho \frac{l}{A}}$

$= \frac{AV^2}{\rho l}$

~~$P \propto$~~ $= \frac{\pi r^2 V^2}{\rho l}$

$P \propto \frac{r^2}{l}$

Let length of 1st Conductor be l_1

Let radius of 1st Conductor be r_1

$l_2 = 2l_1$

$r_2 = 2r_1$

~~$A_2 = \pi(2r_1)^2$~~ $r_2^2 = 4r_1^2$

~~$= 4\pi r_1^2$~~

~~$= 4A_1$~~

$P_2 = k\frac{4r_1^2}{2l_1}$

$= k(2\frac{r_1^2}{l_1})$

$= 2P_1$

~~$P_2 : P_1 = 2 : 1$~~ $P_1 : P_2 = 1 : 2$

∴ ~~power~~ power transformed in the first wire is $\frac{1}{2}$ the power transformed in the second wire

4) $V_{ab} = E - Ir$

$8.8 = E - 60r$ ——— (1)

$12.0 = E$ ——— (2)

Subt (2) into (1): $8.8 = 12.0 - 60r$

$60r = 3.2$

$r = 0.0533\ \Omega$ (3s.f.)

Resistance of starter motor $= \frac{V}{I}$

$= \frac{12.0}{}$

Subject: Date:

5a) Power $= \frac{V^2}{R}$

$= \frac{V^2}{\rho \frac{l}{A}}$

$= \frac{(230)^2 (1.2 \times 10^{-3})}{(7.0 \times 10^{-5})(0.25)}$

$= 38.3\ W\ (3s.f)$

5bi) $R = \rho \frac{l}{A}$

$R \propto \frac{1}{A}$

When the filament becomes thinner, its cross-sectional area ~~becomes~~ decreases and its resistance increases.

5bii)

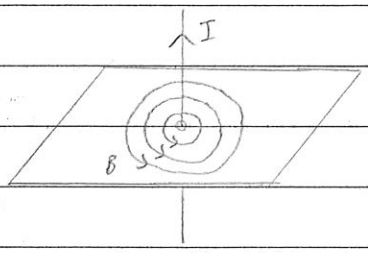
Electromagnetism

1) A

2) A

3) ~~B~~ B

4a)



4bi) $F = BIL$

$B = \frac{F}{IL}$

4bii) $F = BIl$

Subject: Date: