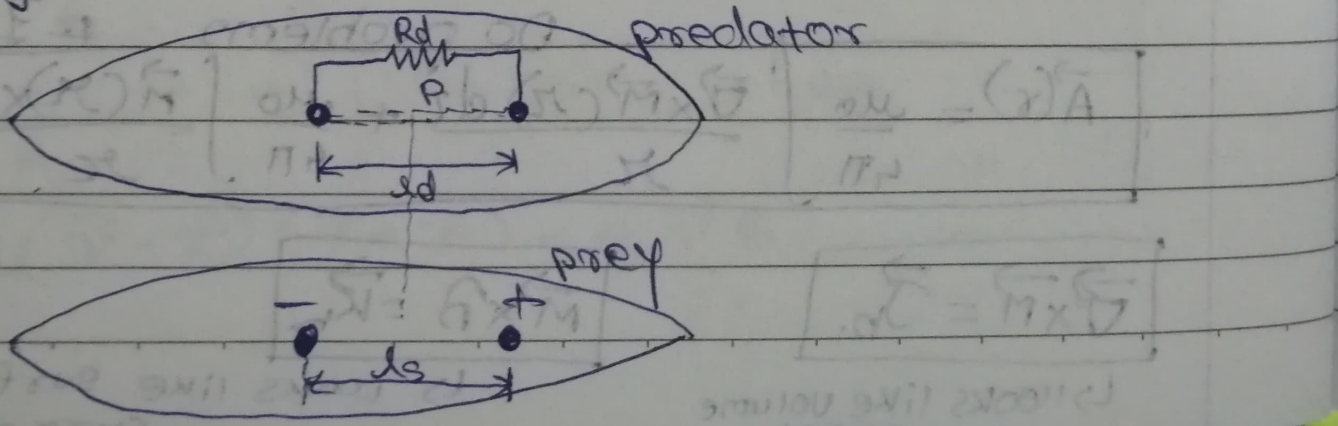
Physics Presentation.
Prey and Predators

→ Some seawater animals have the ability to detect other creatures at some distance away due to electric currents produced by the creatures during the breathing process or other processes involving muscular contraction.

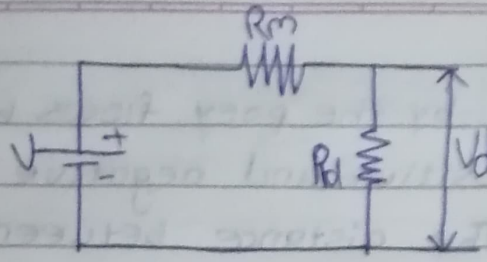
→ The physical mechanism underlying the current generation at prey and its detection at predator can be modeled as described by the given figure.



→ The current generated by the prey flows between two spheres with positive and negative potential in the prey's body. The distance between the centres of the two spheres is d_s, each having radius of r_s, which is much smaller than d_s. The sea water resistivity is ρ. Assume that the resistivity of the prey's body is the same as that of surrounding water.

→ In order to describe the detection of electric power by the predator coming from the prey, the detector is modeled similarly by two spheres on the predator's body and in contact with the surrounding water, lying parallel to the pair in the prey's body. They are seperated by a distance of d_d, each having a radius of r_d. which is much smaller than d_d.

→ In this case, the centre of the detector is located at a distance y right above the source and the line connecting the two spheres is parallel to the electric field as shown in Figure II-1. Both d_s and d_d are also much smaller than y. The electric field strength along the line connecting the two spheres is assumed to be constant.
Therefore, the detector forms a closed circuit system connecting the prey, the surrounding water and the predator.



The equivalent closed circuit system involving the sensing predator, the prey and the surrounding seawater.

→ In the figure V is the voltage difference between the detector's spheres due to the electric field induced by the prey, Rm is the inner resistance due to the surrounding sea water. Further, Vd and Rd are respectively the voltage difference between the detecting spheres and the resistance of the detecting element within the predator.

⇒ <u>Questions:</u>

1) Determine the current density vector $\vec{j}$ (current per unit area) caused by a point current source Is at a distance r in an infinite medium.

2) Based on the law $\vec{E} = \rho\vec{j}$, determine the electric field strength $\vec{E}_p$ at the middle of the detecting spheres (at point P) for a given current Is that flows between two spheres in the prey's body.

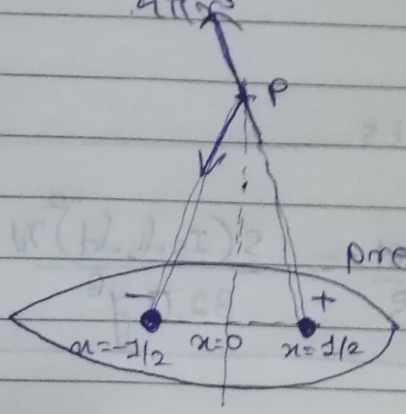
3) Determine the optimum value of Rd leading to maximum detected power and determine also the maximum power.

Answers:-

1] When a point current source I_s is in infinite isotropic medium, the current density vector at a distance r from the point is

$$\vec{j} = \frac{I_s}{4\pi r^3}\vec{r}$$

2]



Assuming that the resistivities of the prey body and that of the surrounding water are the same. It is a isotropic medium of resistivity ρ. When a small sphere produces current at a rate I_s.

$$\vec{j} = \frac{I_s}{4\pi r^3}\vec{r} \Rightarrow \vec{E}(\vec{r}) = \rho\vec{j} = \frac{\rho I_s}{4\pi r^3}\vec{r}$$

$$\vec{E_p} = \vec{E_+} + \vec{E_-}$$

$$= \frac{\rho I_s}{4\pi}\left[\frac{1}{\left(\left(\frac{ds}{2}\right)^2 + y^2\right)^{3/2}}\left(\frac{-ds}{2}i + yj\right) + \frac{1}{\left(\left(\frac{ds}{2}\right)^2 + y^2\right)^{3/2}}\left(\frac{-ds}{2}i - yj\right)\right]$$

$$= \frac{\rho I_s}{4\pi}\left[\frac{ds\,(-i)}{\left[\left(\frac{ds}{2}\right)^2 + y^2\right)^{3/2}}\right]$$

$$\vec{E_p} = \frac{\rho I_s I_s}{4\pi y^3}(-i) \quad \text{for } ds << y$$

3] P_d is maximum when

$$R_t = \frac{R_d}{\left[R_d + \frac{\rho}{2\pi r_d}\right]^2} = \frac{R_d}{(R_d + R_m)^2}$$ is maximum.

Therefore,

$$\frac{dR_t}{dR_d} = \frac{1(R_d+R_m)^2 - R_d\,2(R_d+R_m)}{(R_d+R_m)^4} = 0.$$

$$(R_d+R_m) - 2R_d = 0.$$

$$R_d^{optimum} = R_m = \frac{s}{2\pi r_d^2}$$

The maximum power is

$$P_d^{maximum} = \left(\frac{s\,I_s d_s l_d}{4\pi y^3}\right)^2 \frac{\pi r_d}{2s} = \frac{s(I_s d_s l_d)^2 r_d}{32\pi y^6}$$