# Using an MRI scanner to generate heat at a milli-robot

### How much energy needed to raise a 1mm capsule of water 2?

A 1-millimeter sphere of water contains approximately 0.5 g of water. To raise this 2 degrees Celsius requires about 4 Joules of energy. Assuming no heat loss, with 7mW of power, we’d need to wait 4/0.007 seconds, or almost 10 minutes. With 3.5mW of power, we’d need 20 minutes.

But a sphere in quiescent fluid conducts heat into the fluid.

is the heat transfer rate in J/S.

the conduction shape factor in m () [1]

the change in temperature

the thermal conductivity in W/m· °C

We require at least 7mW to maintain a 2 °C temperature difference.

### Method 1: Voltage induced by magnetic gradients switching

Faraday’s law of induction for a current-carrying loop (<http://hyperphysics.phy-astr.gsu.edu/hbase/electric/farlaw.html>):

N= number of turns

=change in magnetic field

A = area of loop

Typical slew rate (<http://www.mr-tip.com/serv1.php?type=db1&dbs=Slew%20Rate>)

Slew rate = 150 T/m/sec. at 10 cm from the center: 15 T/sec.

For a 1mm diameter, 1 turn coil, placed at 10 cm from the center of the MRI, we have

To answer: How many amps? How much power can we produce?

For a 10 cm diameter, 1 turn coil, placed at 15 cm from the MRI center, we have:

### Method 2: Harvesting energy from the RF coil

With a huge coil (1 m2), researchers raised a probe tip 50 °C in a few minutes [2].

Assume the RF coil operates at 35 MHz = 3.5x107­, then the full wave length is 8.6 m.

What is the optimal antenna size and shape to harvest this energy?

Using an MR spectroscope, this article used a 72mm diameter coil with 5,000 turns to extract 7mW from the RF coils [3]. This would be enough to maintain a thermal difference of 2°C

### Method 3: Force induced by eddy current

To investigate…

# Bibliography

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