

# Unit 8 - Week 7

## Course outline

How does an NPTEL online course work?

Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

Week 7

- The method of images
- Induced charge
- Force and energy
- Another example of the method of images
- Electric dipoles
- Multipole expansion, continuous charge distribution, and assembly of point charges
- Electric field due to a dipole
- Introduction to electric polarization in matter
- Quiz : Assignment 7
- Week 7 Feedback : Electromagnetism

Week 8

Week 9

Week 10

Week 11

Week 12

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Lecture materials

## Assignment 7

The due date for submitting this assignment has passed.  
As per our records you have not submitted this assignment.

**Due on 2020-03-18, 23:59 IST.**

### Method of images with spherical conductor

Using the law of cosines, the potential outside a grounded spherical conductor may be expressed in spherical coordinates as

$$V(r, \theta) = \frac{1}{4\pi\epsilon_0} \left[ \frac{q}{\sqrt{r^2 + a^2 - 2racos\theta}} - \frac{q}{\sqrt{R^2 + (ra/R)^2 - 2racos\theta}} \right],$$

where  $r$  and  $\theta$  are the usual spherical polar coordinates, with the  $z$ -axis along the line through the point charge  $q$ .  $R$  is the radius of the conducting sphere and  $a$  is the distance of the point charge from the center of the sphere.  $V = 0$  on the sphere  $r = R$ .

1) What is the induced surface charge density on the surface of the sphere? 5 points

$$\sigma(\theta) = \frac{q}{4\pi R} (R^2 - a^2)(R^2 + a^2 - 2Ra \cos\theta)^{-3/2}$$

$$\sigma(\theta) = \frac{q}{4\pi R} (R^2 + a^2)(R^2 + a^2 - 2Ra \cos\theta)^{-1/2}$$

$$\sigma(\theta) = \frac{q}{4\pi a} (R^2 - a^2)(R^2 + a^2 + 2Ra \cos\theta)^{1/2}$$

$$\sigma(\theta) = \frac{q}{4\pi R} (R^2 + a^2)(R^2 + a^2 - 2Ra \sin\theta)^{-1/2}$$

No, the answer is incorrect.  
Score: 0

Accepted Answers:

$$\sigma(\theta) = \frac{q}{4\pi R} (R^2 - a^2)(R^2 + a^2 - 2Ra \cos\theta)^{-3/2}$$

2) What is the total amount of induced charge (integrate  $\sigma(\theta)$  to find this)? 5 points

$$qR / a$$

$$qa / R$$

$$-qR / a$$

$$-qa / R$$

No, the answer is incorrect.  
Score: 0

Accepted Answers:

$$-qR / a$$

3) How much work is done to bring the point charge  $q$  from infinity to distance  $a$  from the center of the sphere? 5 points

$$\text{Work done} = \frac{1}{4\pi\epsilon_0} \frac{qR}{(a^2 - R^2)}$$

$$\text{Work done} = -\frac{1}{4\pi\epsilon_0} \frac{qR}{2(a^2 + R^2)}$$

$$\text{Work done} = \frac{1}{4\pi\epsilon_0} \frac{qR}{2(a^2 - R^2)}$$

$$\text{Work done} = -\frac{1}{4\pi\epsilon_0} \frac{q^2 R}{2(a^2 - R^2)}$$

No, the answer is incorrect.  
Score: 0

Accepted Answers:

$$\text{Work done} = -\frac{1}{4\pi\epsilon_0} \frac{q^2 R}{2(a^2 - R^2)}$$

4) Potential of electric multipole 8 points

A sphere of radius  $R$ , centered at the origin, carries a charge density

$$\rho(r, \theta) = k \frac{R}{r^2} (R - 2r) \sin\theta$$

where  $k$  is a constant,  $r, \theta$  are the usual spherical coordinates. What is the approximate potential for points on the  $z$ -axis far from the sphere?

$$V(z) \cong \frac{1}{4\pi\epsilon_0} \frac{k\pi^2 R^4}{24z^3}$$

$$V(z) \cong \frac{1}{4\pi\epsilon_0} \frac{k\pi^2 R^5}{48z^3}$$

$$V(z) \cong -\frac{1}{4\pi\epsilon_0} \frac{k\pi^2 R^4}{24z^3}$$

$$V(z) \cong \frac{1}{4\pi\epsilon_0} \frac{k\pi^2 z^4}{84R^3}$$

No, the answer is incorrect.  
Score: 0

Accepted Answers:

$$V(z) \cong \frac{1}{4\pi\epsilon_0} \frac{k\pi^2 R^5}{48z^3}$$

5) First nonzero term in multipole expansion 7 points

A circular ring of radius  $R$ , centered at the origin on the  $xy$  plane carries a uniform line charge density  $\lambda$ . What is the first nonzero term in the multipole expansion for the potential  $V(r, \theta)$  ?

$$V_{\text{nonzero}}^{\text{first}} = -\frac{\lambda}{8\epsilon_0} \frac{R^3}{r^3} (3\cos^2\theta - 1)$$

$$V_{\text{nonzero}}^{\text{first}} = \frac{\lambda}{4\pi\epsilon_0} \frac{R^3}{r^3} (3\sin^2\theta - 1)$$

$$V_{\text{nonzero}}^{\text{first}} = -\frac{\lambda}{4\pi\epsilon_0} \frac{R^3}{r^2} (3\cos^2\theta - 1)$$

$$V_{\text{nonzero}}^{\text{first}} = -\frac{\lambda}{8\epsilon_0} \frac{R^3}{r^2} (3\sin^2\theta + 1)$$

No, the answer is incorrect.  
Score: 0

Accepted Answers:

$$V_{\text{nonzero}}^{\text{first}} = -\frac{\lambda}{8\epsilon_0} \frac{R^3}{r^3} (3\cos^2\theta - 1)$$