PHYS1002 **Electricity Assignment** **Due:** 5pm Friday 11 April

Text: Randall D. Knight, Physics for Scientists and Engineers: A Strategic Approach
Hand in: BOTH staple your answers to this sheet and put in PHYS1002 slot outside rm. 6-320; and scan and upload to Blackboard.

I declare that this work is entirely my own, except where stated otherwise.

Name: _____ **Student Number:** _____ **Lab stream:** _____

This assignment is based on questions given in past exams. Each question will be marked by your tutor according to the below rubric, identical to the exam marking rubric. The overall mark will be the sum of the marks for each question.

Marking Rubric:

	Requirement	Q1 Unsat	Q1 Comp	Q1 Adv	Q2 Unsat	Q2 Comp	Q2 Adv
Model	Identifies correct physical principles						
	Introduces appropriate model						
	Explains main assumptions						
	Includes a useful diagram						
Solve	Uses a logical sequence of steps						
	Correct use of equations and mathematical techniques						
	Explains main steps						
	Handles units correctly						
Assess	Obtains correct or reasonable answer						
	Quotes answer with appropriate significant figures						
	Comments on reasonableness or consequences of answer						
	Clearly presented and easy to follow						

Q1 Grade and feedback

/7 Feedback:

Q2 Grade and feedback

/7 Feedback:

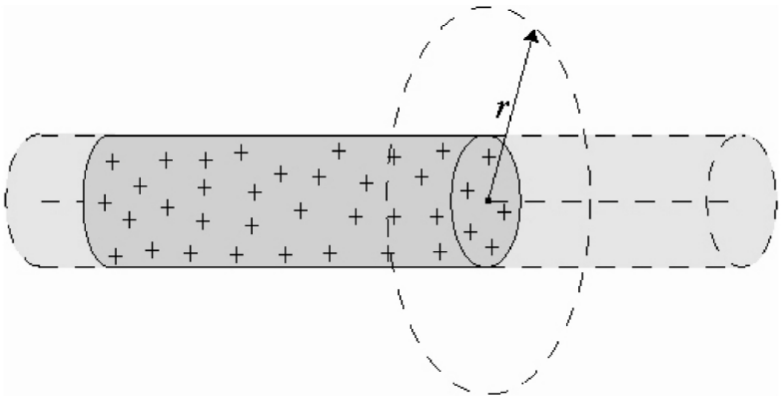
7: Demonstrates an advanced level for almost all requirements
6: Demonstrated competency in at least three requirements of each section but performs at an advanced level more than the level of competent
5: Demonstrated competency in at least three requirements of each section including at least one advanced level in most sections
4: Demonstrated competency in at least three requirements for most sections
3: Demonstrated competency in at least two requirements for most sections
2: Demonstrated competency in at least one requirement for most sections
1: Demonstrated minimal competency

Overall grade: **/14**

Signed: _____

Question 1.

Graded on a 1-7 scale



An infinitely long uniformly charged cylinder of radius R is shown.

(a) Using symmetry arguments, sketch the shape of the electric field of the cylinder.

(b) Use Gauss's Law to show that the electric field magnitude within the cylinder is

$$E(r) = \frac{\rho}{2\varepsilon_0} r, \qquad r \leq R,$$

where r is the distance from the centre of the cylinder and ρ is the volume charge density of the cylinder in units of C/m^3.

The electric field outside the cylinder is

$$E(r) = \frac{\rho R^2}{2\varepsilon_0} \frac{\hat{r}}{r}, \qquad r \geq R.$$

(c) Sketch the electric field magnitude as a function of position r.

A -50 nC point charge of mass 2.0 g is located outside the cylinder at a position $r_{\text{charge}} = 3$ mm.

(d) If $\rho = 1.0$ C/m^3 and $R = 2.0$ mm, calculate the electrostatic force exerted on the point charge by the cylinder.

(e) The point charge is propelled directly away from the cylinder with a velocity of 5.0 m/s. Due to the attractive force between the charge and the cylinder, the point charge decelerates, then stops, and finally moves back towards the cylinder. Calculate the maximum distance that the charge should reach from the centre line of the cylinder.

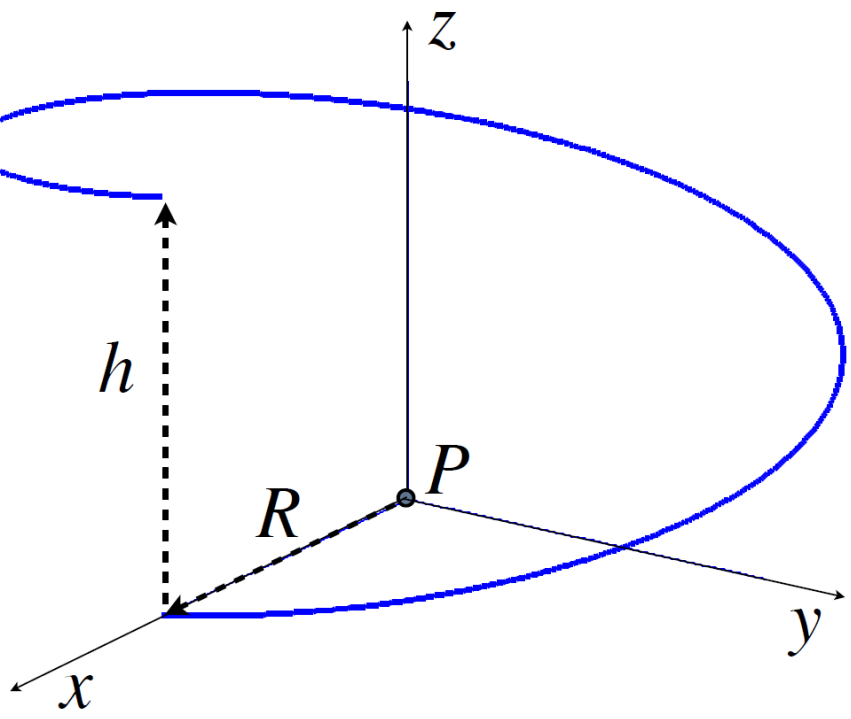
(f) An experimenter attempts to verify your predictions from part (e), and wishes to achieve an uncertainty of less than 0.1 mm in the maximum distance between point charge and cylinder. What level of uncertainty would be acceptable in the initial position? You may assume that the uncertainty in all other parameters is negligible.

The following expression may be useful: $\displaystyle\int_{x_i}^{x_f} \frac{1}{x} dx = \ln\left(\frac{x_f}{x_i}\right)$

Question 2.

Graded on a 1-7 scale

Consider a line of uniform charge Q that is bent into a 1-turn helix of radius R and height h. Suppose the helix is placed on an insulating surface and held such that the axis of the helix is vertical, as shown in the figure.



(a) Discuss how to calculate the electric field and potential generated by the helix. What are the main differences between calculating the electric field and the electric potential?

(b) Consider a point P that lies on the axis of the spiral where the axis intersects the horizontal surface. Show that the electric potential at point P is:

$$V = \frac{Q}{4\pi\epsilon_0 h} \ln\left(\frac{h}{R} + \sqrt{1 + \frac{h^2}{R^2}}\right)$$

(c) To what simpler result does this expression approach in the limit that the height of the spiral goes to zero $h \to 0$? In your answer include a mathematical justification, and explain whether this is what you expect based on physical arguments.

Useful mathematical results:

$$\begin{aligned}
\int \frac{dx}{\sqrt{x^2+a^2}} &= \ln\left(x + \sqrt{x^2+a^2}\right) \\
\ln(ab) &= \ln(a) + \ln(b) \\
\ln(a/b) &= \ln(a) - \ln(b) \\
\ln(1+x) &\simeq x \quad \text{if} \quad x \ll 1 \\
(1+x)^n &\simeq 1 + nx \quad \text{if} \quad x \ll 1
\end{aligned}$$