PHY102: Introduction to Physics II

Spring Semester 2025
Lecture 1

Department of Physics, School of Natural Sciences, Shiv Nadar Institution of Eminence, Delhi NCR

Instructors

Dr. Binson Babu (coordinator): ***(binson.babu@snu.edu.in)***
Prof. Sajal Kumar Ghosh: ***(sajal.ghosh@snu.edu.in)***
Prof. Aloke Kanjilal: ***(aloke.kanjilal@snu.edu.in)***
Dr. Ipsita Mandal: ***(ipsita.mandal@snu.edu.in)***
Dr. Bhaskar Kaviraj: ***(bhaskar.kaviraj@snu.edu.in)***

Course credits: 5

(3 lectures+1 tutorial +3 hrs lab)

"This is a continuation of PHY 101 meant for engineers and non-physics majors. The course will introduce students to **Electricity and Magnetism, Maxwell's equations, light as an electromagnetic wave, and wave optics**." (Physics-UG-Prospectus, SNU)

Prerequisites (a must): MAT101 (Calculus-1), PHY101 (Introduction to Physics-1)

Academic aims and learning outcomes

During the semester we aim:

• to teach a wide range of physics at a basic level, appropriate to the ***first year*** of a physics degree.

• to stimulate the interest of students in physics by exposing them to some of the issues at the frontiers of knowledge.

• to allow all students, independent of their entry attainments, to reach a similar level of understanding in physics, **with the necessary skills in mathematics** to solve simple problems in physics.

On completion of the course, students should be able to:

- recognize the fundamental physics in a wide range of physical processes.

- explain a wide range of physical processes from underlying basic principles.

- explain the interrelationship between some physical parameters.

- calculate or estimate solutions to some simple physical problems.

Organization and Communication

Course Instructors:

Dr. Binson Babu (coordinator)

Prof. Sajal Kumar Ghosh,

Prof. Aloke Kanjilal

Dr. Ipsita Mandal

Dr. Bhaskar Kaviraj

In addition, there would be several **group instructors** who would be conducting the **tutorial classes**. You are advised to keep their personal details on hand for consultations regarding tutorial problems, attendance matters in tutorial classes, conduct of examination and evaluations.

Email addresses for correspondence

Dr. Binson Babu (coordinator): *(binson.babu@snu.edu.in)*

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Course outline and syllabus

Vector Calculus:

Fundamental vector operations, Vector calculus: Gradient, Divergence, Curl and related fundamental theorems of vector calculus, Vector integration (line, surface and volume integrals), Divergence theorem and Stoke's theorem, Coordinate systems (Polar (2D), Spherical and Cylindrical (3D)).

Electrostatics

Electric field, divergence and curl of electric fields, electric potential, Work and Energy in electrostatics, conductors and capacitors, Laplace's equation of electrostatic potential in 1, 2 and 3 dimensions, Multipole expansion of electrostatic potential, monopole and dipole terms, field due to electric dipole, polarization in dielectrics, field of a polarized object, bound charges and its physical interpretation, electric displacement vector and Gauss's law in dielectrics, definitions of permittivity, susceptibility and dielectric constant

Magnetostatics

Magnetic forces and Lorentz force law, charged particle in an electromagnetic field, magnetic field due to steady current (Biot-Savart law), Divergence and Curl of **B**, Ampere's law (differential and integral form), magnetic dipole, forces and torque on a current carrying loop, magnetic field due to a magnetic dipole, magnetic vector potential, effect of magnetic field on atomic orbits, magnetzation, field of a magnetized object, bound currents and their physical interpretation, auxiliary field **H**, Ampere's law in magnetized materials

Electrodynamics

Electromotive force, Ohm's law, motional emf, Faraday's law of electromagnetic induction and induced electric field, self and mutual inductance, energy in magnetic fields, Maxwell's equations before and after Maxwell, displacement currents, work-energy theorem (Poynting's theorem) in electrodynamics, Poynting's vector, continuity equation, electromagnetic waves in vacuum, monochromatic plane electromagnetic waves and their representation

Wave Optics:

Interference of light waves: Young's double slit experiment, displacement of fringes, Interference in thin films.

Diffraction: Fresnel's and Fraunhofer's class of diffraction, diffraction from single, double & N- Slits, theory of diffraction grating.

Further details:

Course pre-requisite (flexible): MAT101, PHY101

Reasonably good Mathematical background (calculus, differential equations, algebra, geometry, graphical analysis, co-ordinate system, transformation of coordinate systems, vectors, vector calculus).

Text /reference books:

1. **Introduction to Electrodynamics, *D. J. Griffiths***
2. Physics for Scientists and Engineers with Modern Physics, *J. W. Jewett and R. A. Serway*
3. *The* Feynman Lectures on Physics 2 (2^{nd} Ed, 1985).
4. Electricity and Magnetism, *Edward Mills Purcell*

Course evaluation scheme:

- **One mid semester exam (descriptive) : 25%**
- **Two quizzes (MCQ type) (Total, 20%)**
- Lab: 15% (Lab classes) + 10% (Lab Exam.) **(Total 25%)**
- **End-semester examination (descriptive) : 30%**

Syllabus for exams:

For mid sems.: Topics covered before the scheduled examinations.

End sem (Final): T*opics covered during end-term* (75-80% questions can be expected)+ *Mid-sem syllabus (20-25%)*

All quizzes (60 minutes duration): Topics covered before the scheduled examinations.

Schedule for exams and quizzes:

Important Dates

- Quiz 1: 10th Feb .
- Mid-sem exam: 28th Feb– 5th Mar. (CoE will decide the date)
- Quiz 2: 7th April
- Lab. exam:
- End sem exam: 1st May– 9th May (CoE will decide the date)

All **notices** relating to the course will be displayed in Blackboard. You should check regularly for details of lectures, examination timetables, etc. Information concerning individual lectures would be added under the **‘Content’** section in the respective course in Blackboard.

Marks in term-examinations and quizzes would be uploaded immediately after the evaluated scripts have been shown to you. In case of alterations, proper communication must be established with the **respective tutorial instructor**.

If you are unable to view your paper on designated dates, get in touch with group instructor for the next available date. In any case, you **forfeit** the rights to view/alter the performances in a component **after** 7 days of upload of marks.

Grading Scheme

Relative Grading

Attendance requirements: **75% (minimum as per SNU's policy)**

- **Attendance will not be granted by the instructor under any circumstances unless you are present in class.**

- Absences due to illness, extracurricular activities such as sports, interviews, or club functions will be accounted for within the 25% attendance allowance.

- *Extended leave due to any reasons should be cleared through the Dean of Academics.*

Warning:

- Any attendance-related misconduct, such as leaving class after marking attendance, will be reported directly to the Dean's office without exception.

Meeting hours with the instructor

A student may contact his/her respective instructor for any academic issues during the following contact hours without prior notification:

Instructor:

Meeting hours:

Office:

Extn:

Email:

Vector and Scalar Field

Gradient of a scalar field

Field : A physical quantity which is a function of spatial coordinate.

Scalar field :

A Physical Quantity which is a function of spatial coordinates and by nature, it is scalar.

Here we associate only a number to each spatial point/location ?

Example: Density of atmosphere , Temperature of a metal disk kept on a stove

Vector field :

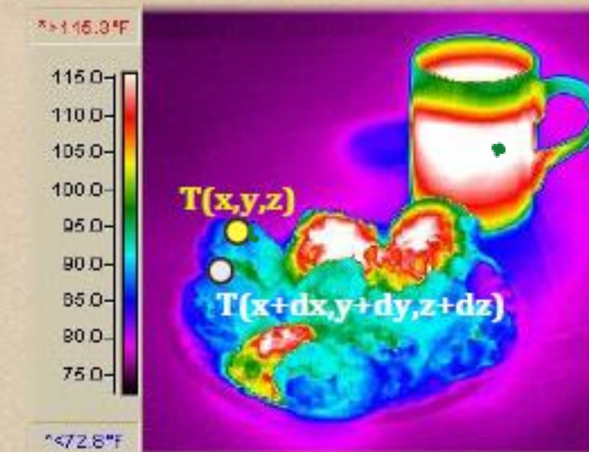
A Physical Quantity which is a function of spatial coordinates and by nature, it is a vector.

Here we associate not only a number to each spatial coordinate but the direction also.
Or we can say , we associate a vector to each spatial point/location ?

Example: velocity of the wind, water current,
Temperature gradient of a metal disk kept on a stove

Gradient

Consider a function of three variables, say temperature T as a function of the position (x,y,z).



Thermograph of a hot coffee mug and a plate of cookies.

$$T \equiv T(x, y, z)$$

We can pose the question: How does T vary as we move away from the point (x,y,z)?

For a one dimensional case ($T \equiv T(x)$) we know that it would be just the rate of change of T with respect to x, i.e., dT/dx.

Here we have three independent variables. How to proceed in such a case?

Image Source: http://www.irisinfrared.com/images/How%20It%20Works/mug.jpg

Gradient

We know that in three dimensional space we have three independent directions. Therefore no matter which direction we move in, we should be able to analyze the variation by figuring out the change in T due to change in these three independent coordinates.

It turns out that an infinitesimal variation in T is related to infinitesimal variations in x, y, z as

$$dT = \left(\frac{\partial T}{\partial x}\right) dx + \left(\frac{\partial T}{\partial y}\right) dy + \left(\frac{\partial T}{\partial z}\right) dz$$

where $\partial T/\partial x$ represents the partial derivative of T with respect to (wrt) x, i.e., the derivative of T wrt x only by treating other independent variables y, z as constants. Similarly we define $\partial T/\partial y$ and $\partial T/\partial z$.

Gradient of a scalar field.

Let $\boldsymbol{T(x,y,z)}$ ***be a scalar function of*** $\boldsymbol{(x,y,z)}$

Or $\boldsymbol{T(x,y,z)\ is\ a\ \ scalar\ field}$

$For\ Example:\ T = \ x^2 + y^2 + \ z^2\ or\ T = e^{x^2+y^2}\ or\ T = mgz$

If we move from $(x,y,z) \rightarrow (x+dx, y+dy, z+dz)\ ,\ \ T\ \ \rightarrow T + dT$

$$dT = \frac{\partial T}{\partial x}dx + \frac{\partial T}{\partial y}dy + \frac{\partial T}{\partial z}dz$$

Partial Derivative wrt $\boldsymbol{x}$

Partial Derivative wrt $\boldsymbol{y}$

Do you know what is $\frac{\partial T}{\partial x}$ or $\frac{\partial T}{\partial y}$ or $\frac{\partial T}{\partial z}$ ***?*** Partial Derivative wrt $\boldsymbol{z}$

If $T = \ x^2+y^2 + \ z^2$ ***then what is*** $\frac{\partial T}{\partial x}$ ***?***

$$\frac{\partial(x^2 + y^2 + \ z^2)}{\partial x} = 2x\ , \qquad \frac{\partial(x^2 + y^2 + \ z^2)}{\partial y} = ?\ \ , \qquad \frac{\partial(x^2 + y^2 + \ z^2)}{\partial z} = ?$$

$$\frac{\partial(x^2 + y^2 + \ z^2)}{\partial y} = 2\mathrm{y} \ , \qquad \frac{\partial(x^2 + y^2 + \ z^2)}{\partial z} = 2\mathrm{z} \ ,$$

$$\frac{\partial(e^{x^2+y^2})}{\partial x} = ? \qquad \frac{\partial(e^{x^2+y^2})}{\partial x} = 2xe^{x^2+y^2}$$

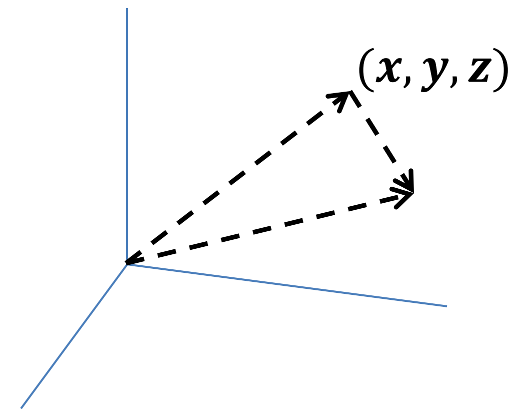
$$\frac{\partial(e^{x^2+y^2})}{\partial y} = ? \qquad \frac{\partial(e^{x^2+y^2})}{\partial y} = 2ye^{x^2+y^2}$$

$$\frac{\partial(mgz)}{\partial y} = ? \qquad \frac{\partial(mgz)}{\partial y} = 0$$

$$\frac{\partial(mgz)}{\partial z} = ? \qquad \frac{\partial(mgz)}{\partial z} = mg$$

Let $\boldsymbol{T(x, y, z)}$ ***be a scalar function of*** $\boldsymbol{(x, y, z)}$

$$For\ Example:\ T = x^2 + y^2 + z^2\ or\ T = e^{x^2+y^2}\ or\ T = mgz$$



$$dT = \frac{\partial T}{\partial x} dx + \frac{\partial T}{\partial y} dy + \frac{\partial T}{\partial z} dz$$

$$dT = \left(\hat{x} \frac{\partial T}{\partial x} + \hat{y} \frac{\partial T}{\partial y} + \hat{z} \frac{\partial T}{\partial z}\right) \cdot (\hat{x}\, dx + \hat{y}\, dy + \hat{z}\, dz)$$

$$dT = \left(\hat{x} \frac{\partial}{\partial x} + \hat{y} \frac{\partial}{\partial y} + \hat{z} \frac{\partial}{\partial z}\right) T \cdot \overrightarrow{\boldsymbol{dl}}$$

$$dT = \boldsymbol{\nabla} T \cdot \overrightarrow{\boldsymbol{dl}} = |\boldsymbol{\nabla} T||\overrightarrow{\boldsymbol{dl}}| \cos \boldsymbol{\theta}$$

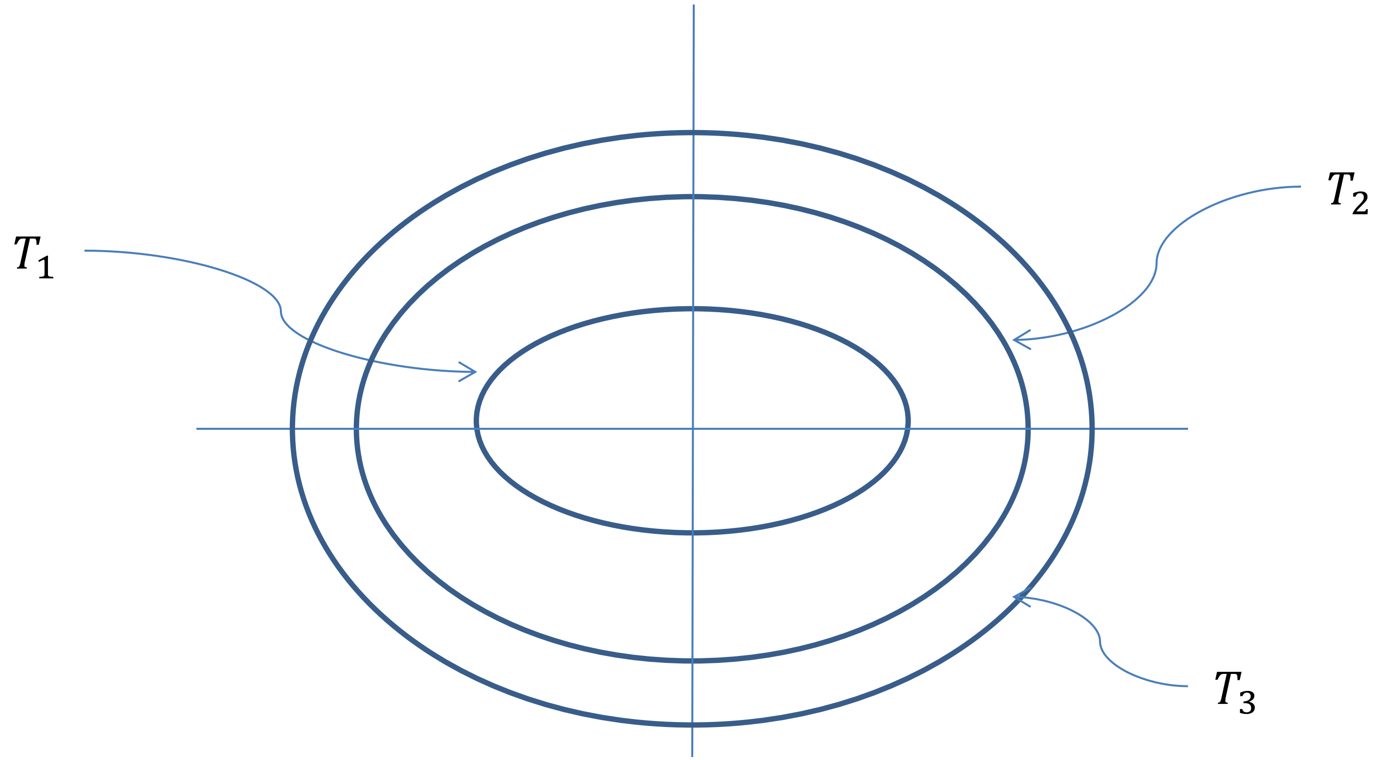
$\boldsymbol{\nabla} T$ is called Gradient of T

You can find some useful information on http://en.wikipedia.org/wiki/Del

Let $\boldsymbol{T} = 10\left(\frac{x^2}{9} + \frac{y^2}{4}\right)$

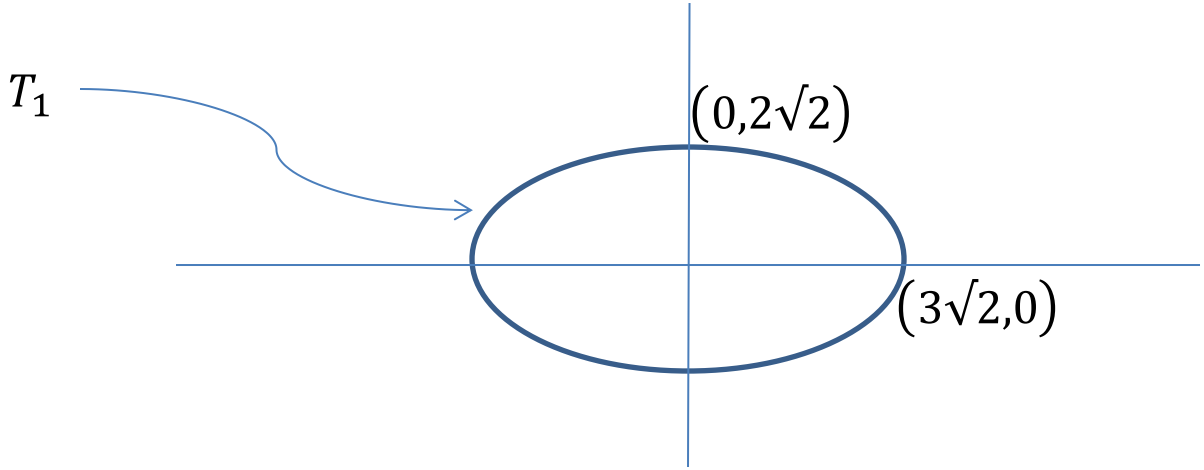
For one value of T this will form an ellipse. For example

$\boldsymbol{T} = \boldsymbol{T}_1$ $\boldsymbol{T} = \boldsymbol{T}_2$ $\boldsymbol{T} = \boldsymbol{T}_3$



$\boldsymbol{Let}\ \boldsymbol{T_1} = 20.$ What is the equation of ellipse on which $\boldsymbol{T_1} = 20$?

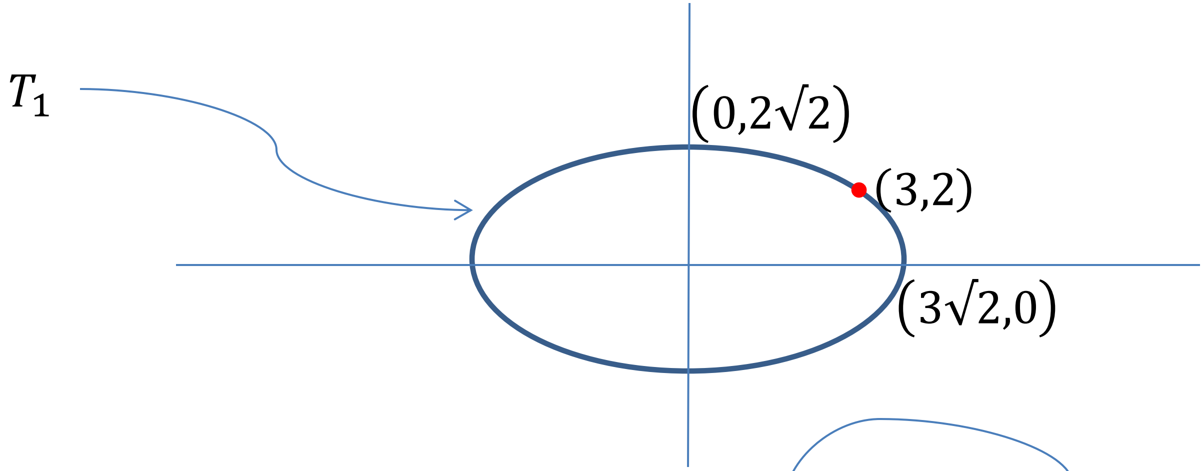
$$T = 10\left(\frac{x^2}{9} + \frac{y^2}{4}\right) \qquad \Rightarrow \qquad \left(\frac{x^2}{9} + \frac{y^2}{4}\right) = \mathbf{2}$$



What is $\boldsymbol{\nabla} T$?
$$\left(\hat{x}\frac{\partial}{\partial x} + \hat{y}\,\frac{\partial}{\partial y} + \hat{z}\frac{\partial}{\partial z}\right)T = 10\left(\frac{2x\hat{x}}{9} + \frac{2y\hat{y}}{4}\right)$$

$$\boldsymbol{\nabla}T = \frac{20x\hat{x}}{9} + \frac{20y\hat{y}}{4}$$

Let me chose three point on this ellipse $(0,2\sqrt{2})$, $(3\sqrt{2},0)$, $(3,2)$

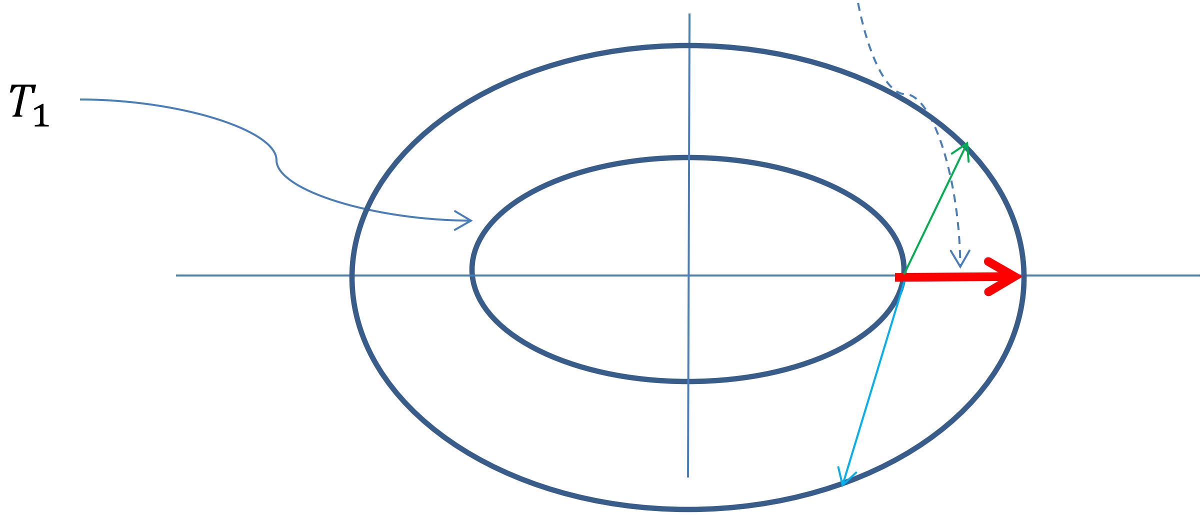


What is the gradient at $(3\sqrt{2},0)$?

$$\boldsymbol{\nabla}T = \frac{20x\hat{x}}{9} + \frac{20y\hat{y}}{4}$$

$$\Rightarrow \boldsymbol{\nabla}T = \frac{20\sqrt{2}\hat{x}}{3}$$

At $(x, y) = (3\sqrt{2}, 0)$ $\quad \boldsymbol{\nabla} T = \dfrac{20\sqrt{2}\hat{x}}{3}$



To go on the next ellipse at which $T > T_1$, ***from the point*** $(\mathbf{3\sqrt{2}, 0})$ by the Shortest route , What direction will you prefer ?

Along X axis . *i.e*. along the direction of $\boldsymbol{\nabla} T$

To reach on the same ellipse along any other direction , It has to cover longer distance.

So $\boldsymbol{\nabla T}$ $\boldsymbol{gives\ the\ rate\ of\ change\ of\ T\ with\ respect\ to\ position}$
$\boldsymbol{in\ the\ direction\ of\ maximum\ change\ or\ simply\ called\ gradient}$

Geometrical Interpretation of the Gradient

P2. Find the gradient of $r = \sqrt{x^2 + y^2 + z^2}$ (the magnitude of the position vector).

Solution

$$
\begin{aligned}
\nabla r &= \frac{\partial r}{\partial x}\,\hat{\mathbf{x}} + \frac{\partial r}{\partial y}\,\hat{\mathbf{y}} + \frac{\partial r}{\partial z}\,\hat{\mathbf{z}} \\
&= \frac{1}{2}\frac{2x}{\sqrt{x^2+y^2+z^2}}\,\hat{\mathbf{x}} + \frac{1}{2}\frac{2y}{\sqrt{x^2+y^2+z^2}}\,\hat{\mathbf{y}} + \frac{1}{2}\frac{2z}{\sqrt{x^2+y^2+z^2}}\,\hat{\mathbf{z}} \\
&= \frac{x\,\hat{\mathbf{x}} + y\,\hat{\mathbf{y}} + z\,\hat{\mathbf{z}}}{\sqrt{x^2+y^2+z^2}} = \frac{\mathbf{r}}{r} = \hat{\mathbf{r}}.
\end{aligned}
$$

The distance from the origin increases most rapidly in the radial direction, and that its rate of increase in that direction is **1.**

Look at these nice videos

https://www.youtube.com/watch?v=ynzRyIL2atU&feature=youtu.be