INSTRUCTION: Using the following format, prepare a Teaching portfolio for any one of the courses taught. A core course with a large number of students is preferred. Retain the **blue** coloured headings as it is and enter your details in **black** coloured texts.

Teaching Portfolio

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Email: chandrasekhar@iitbbs.ac.in

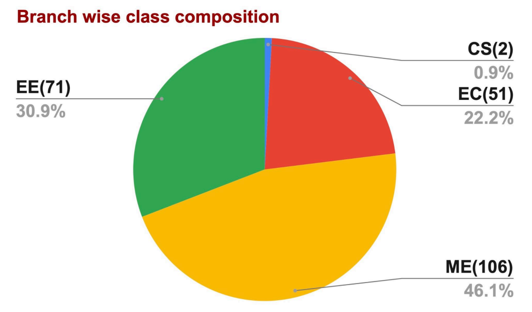
1) Course Details:

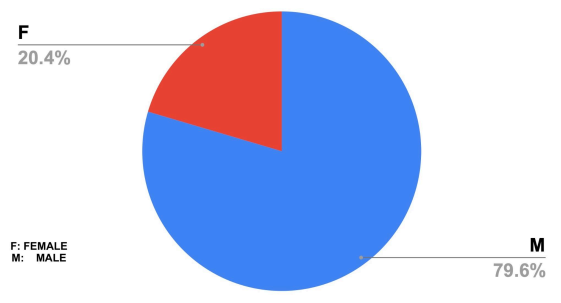
Name: Physics **Code:** PH1L001 (L-T-P-C: 3-1-0-4) **Semester:** Autumn- 2023

One Text / Reference Book:
Classical Dynamics of Particles and Systems – J Marion, S. Thornton, Brooks/Cole; 5th edition (7 July 2003)

Course Content (only key topics): Newtonian Mechanics; conservation laws; phase portraits; central forces; basics of special Relativity; Galilean and Lorentz transformations; mass-energy equivalence and derivation of $E = m c^2$.

Class composition: 204 students





2) Learning outcomes (mention up to 5 outcomes):

After completing the course, students will be able to:

- Explain the concepts of acceleration, force, energy, conservation of energy and angular momentum; Kepler's laws, orbital motion.
- Systematically draw the potential for one-dimensional cases, and compute the dependence of time-period on energy for periodic systems.
- Imagine and draw phase portraits for several examples, such as, simple and damped harmonic oscillator, simple pendulum, double-well potential, without solving equations of motion.
- Explain and interpret the concepts of simultaneity, invariant intervals, light-cone, relativistic energy and time-dilation
- Analyse, evaluate and solve practical problems in daily life based on the above examples towards the end of the course

3) Assessment format:

Assignments, Practice problem sets, Challenging problems and performance in tutorials (20 marks): Mid-sem (30 marks) – Closed book; End-sem (50 marks) – Closed book.

4) Attendance policy:

Attendance was taken by asking the students to sign a sheet which was circulated and the headcount was then taken. Students' presence in the class was closely monitored through random attendance checks. Students who were absent multiple times in surprise checks were given warnings. Repeat absence was noted and about 20 students were asked to submit an additional assignment to avoid deregistration, before the end of the course.

5) **Teaching-aids:** Chalkboards were used throughout the course. This provides enough time for the students to absorb the new material and think about the concepts being taught in a slow paced manner. As the lecture notes of each class were circulated immediately through email, the students never had to copy the material on the board hurriedly (unless they felt it helps them).

6) **Activities and fraction of class time spent on these** (Reference - bookend lecture model):

Details of classes conducted in Active Collaborative Learning (ACL) Classrooms

- ACL Classes were conducted from Spring 2024 onwards..

Details of activities in other classes

Lecture Class:

For an Introductory Lecture on a fresh topic:

- Handout of Syllabus and weekly breakup of the lectures with planning: 5-10 minutes
- Motivation through daily life examples: 5 minutes
- Ask simple questions to test how much is known about the subject: 5 minutes
- Introduce the subject, go deeper with maximum one/two new concepts: 20 minutes
- Probe students to make them talk, ask questions, doubt clearance: 5-10 minutes
- Attendance: 5-7 minutes

For follow up lectures, the first 20 minutes in point A above are different. First, I will revise the topics covered in the last class. Second, I ask questions and clear doubts and then go into the lecture. In Autumn 2025, I plan to make the classes more interactive (like division of students into groups, change pattern of questions to easy, difficult, puzzlers/very challenging to understand student understanding) compared to the last batch I taught and conduct classes in ACL classrooms. Results will be reported in the next teaching portfolio.

Tutorial Class: Problem sets were distributed beforehand by email. The problem sets contained few questions which were easy/moderately difficult and always there was one question which was quite challenging. Some questions were marked as difficult and to be attempted only if the student is interested in the subject (but will not come in the exam). Only 5% of the students attempted to solve such questions. There was a fresh handout given to students in each tutorial which they had to solve. Problems from the tutorial were not solved on the board and each student was made to workout the problems in their own copies. Due to the large number of students in each tutorial batch (about 40), it was not easy to ensure that each student actually did all the problems. But, it was ensured that every student worked out at least one problem from the problem set completely on their own. Some students of course worked out all problems within the given time frame. Tutorial sessions were always interactive and students were allowed/encouraged to discuss with each other or with the instructor on how to solve the problems. Once the student understood how to solve it, they then had to do it on their own.

7) **Concepts/principles taught with either analogies or multiple points of view**

The concept of “acceleration” though thought to be very easy to learn and of prime importance in Newtonian Physics, was explained to students through several different ways. This is because, it was found through probing questions that many students were unable to clearly explain the meaning of acceleration and related concepts in Newtonian physics. They were also found to have significant scientific misconceptions and poor problem-solving skills, and inability to apply what they learned in classical physics itself (not to mention intricate concepts introduced in quantum mechanics).

- <u>Concept - Acceleration</u> : Definition - Acceleration is the time rate of change of velocity
- <u>Question asked in the class</u>: Look at the figure below and answer whether the acceleration is zero at the dotted points.

$$\mathbf{a} = \frac{d\mathbf{v}}{dt}.$$

Someone able to interpret the concept acceleration should be able to identify the acceleration of a particle in various specific cases, such as those illustrated in Fig. 2. For instance, Fig. 2(a) shows a sled which moves up along a hill, passes the point A with decreasing speed, comes momentarily to rest at the point B, and then slides down again. Figure 2(b) shows a car passing the points A and B while moving with constant speed around a horizontal racetrack. Figure 2(c) shows an oscillating pendulum bob which is momentarily at rest at the extreme point A of its circular arc, passes the point B with increasing speed, reaches its maximum speed at its lowest point C where the string is vertical, continues past the point D, and is again momentarily at rest at the point E.

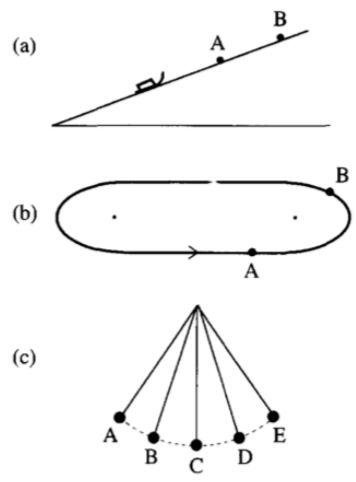
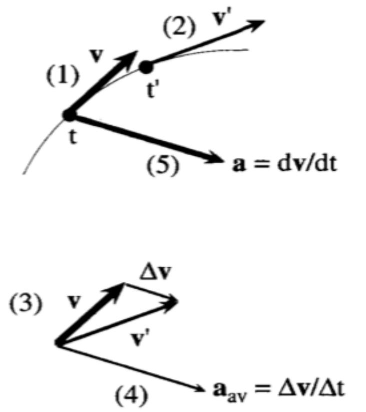


Fig. 2. Situations used for testing the interpretation of acceleration. (a) Sled sliding along a hill. (b) Car traveling around a horizontal racetrack. (c) Oscillating pendulum bob.

- Surprisingly, many students (about 50%) concluded that:
  a) Particle's acceleration is zero whenever velocity is zero !
  b) Acceleration in circular motion is always directed towards the center !
- Both the above statements (a) and (b) are not correct in general !!
- Reason for failure to answer the question correctly:
  a) The students remembered the definition of acceleration and also correctly recalled the definition from a mathematical equation, but misinterpreted it.
  b) Students also came to wrong conclusions drawn due to fragmented memory of the concept, whose validity they did not spend time checking in specific situations.

The concept of acceleration e.g., can be explained as follows (Reference: Frederick Reif, Millikan Lecture 1994: Understanding and teaching important scientific thought processes)



(1) *Original velocity* $\mathbf{v}$. Identify the velocity of the particle at the time t of interest.
(2) *New velocity* $\mathbf{v}'$. Identify the velocity of the particle at a slightly later time t'.
(3) *Change of velocity* $\Delta\mathbf{v}$. Find the velocity change $\Delta\mathbf{v} = \mathbf{v}' - \mathbf{v}$ of the particle during the small time interval $\Delta t = t' - t$.
(4) *Average acceleration* $\mathbf{a}_{av}$. Find the ratio $\Delta\mathbf{v}/\Delta t$, the "average acceleration" of the particle during the time Δt.
(5) *Acceleration* $\mathbf{a}$. Determine the limiting value approached by the average acceleration if the time t' is chosen very close to t (so that Δt becomes infinitesimally small and can be denoted by dt). The resultant ratio $d\mathbf{v}/dt$ is then called "the acceleration of the particle at the time t."

8) Up to 5 most significant questions asked by students (give Roll no. and name): Include questions which made you think, and you could not answer immediately.

I am generally in constant touch through Whatsapp with my students, to clarify their doubts as fast as possible. Some examples are given below.

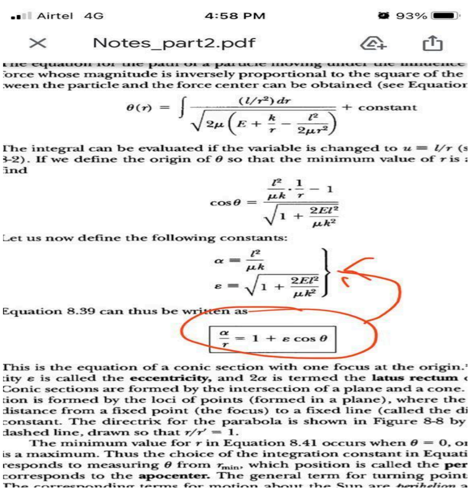
<table>
<tr><th>Question</th><th>Student name & Roll no</th></tr>
<tr><td>

1. Several questions asked by students (several whatsapp conversations are available, which are quite long) on motion of planets around the sun and Kepler orbits, one sample is given below.

a) [19/09/23, 7:19:53 AM] +91 94446 36319: If we write L for sun and Earth and ext force is acting, we must include 1/2 M V square + Uext(r,R) also sir?

b) [23/09/23, 9:01:10 AM] +91 94446 36319: r is increasing and U is increasing sir. So how it is related to theta sir?

[23/09/23, 9:30:05 AM] Chandrasekhar: Theta is a function of time and will change with time. You should remember that actual trajectory requires knowledge of both r(t) and theta(t). The effective potential approach does not say anything about theta. It only gives us information about r. If radius changes, with theta changing with time and if it is a bound trajectory, then it will be some sort of spiral.



Airtel 4G 4:58 PM 93%

Notes_part2.pdf

…orce whose magnitude is inversely proportional to the square of the …ween the particle and the force center can be obtained (see Equatio…

$$\theta(r) = \int \frac{(l/r^2)\,dr}{\sqrt{2\mu\left(E + \frac{k}{r} - \frac{l^2}{2\mu r^2}\right)}} + \text{constant}$$

…he integral can be evaluated if the variable is changed to $u \equiv l/r$ (s… …-2). If we define the origin of θ so that the minimum value of r is … …ind

$$\cos\theta = \frac{\frac{l^2}{\mu k}\cdot\frac{1}{r} - 1}{\sqrt{1 + \frac{2El^2}{\mu k^2}}}$$

…et us now define the following constants:

$$\alpha \equiv \frac{l^2}{\mu k}$$
$$\varepsilon \equiv \sqrt{1 + \frac{2El^2}{\mu k^2}}$$

Equation 8.39 can thus be written as

$$\frac{\alpha}{r} = 1 + \varepsilon\cos\theta$$

…his is the equation of a conic section with one focus at the origin. …ity ε is called the **eccentricity,** and 2α is termed the **latus rectum** … …onic sections are formed by the intersection of a plane and a cone. …ion is formed by the loci of points (formed in a plane), where the …distance from a fixed point (the focus) to a fixed line (called the di… …onstant. The directrix for the parabola is shown in Figure 8-8 by …ashed line, drawn so that $r/r' = 1$.

The minimum value for r in Equation 8.41 occurs when $\theta = 0$, o… is a maximum. Thus the choice of the integration constant in Equati… …esponds to measuring θ from r_{min}, which position is called the **per…** …orresponds to the **apocenter.** The general term for turning point…

c) How to derive the equation in red for the conic sections? can explain again in next class?

</td><td>

Sandeep K

23EC01041

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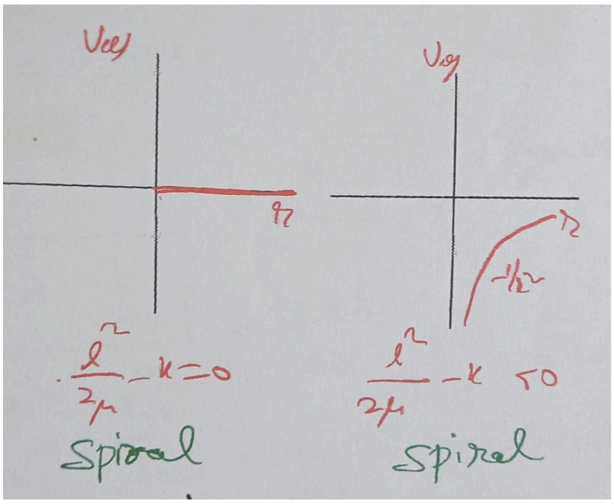
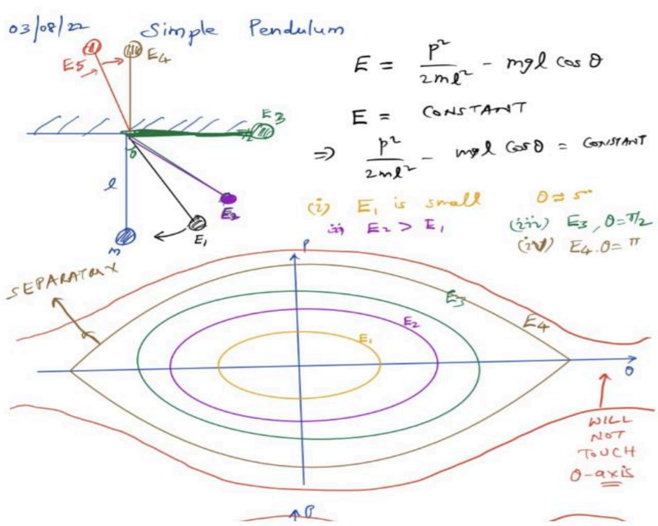
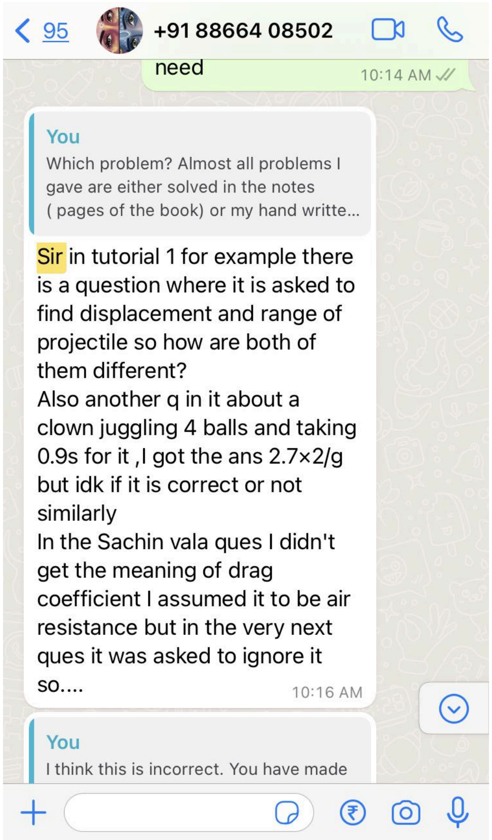
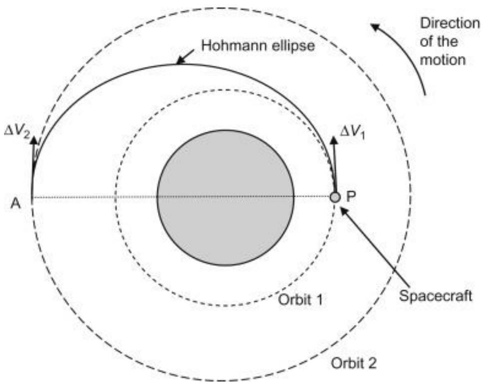
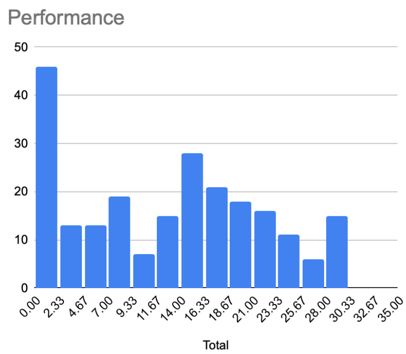
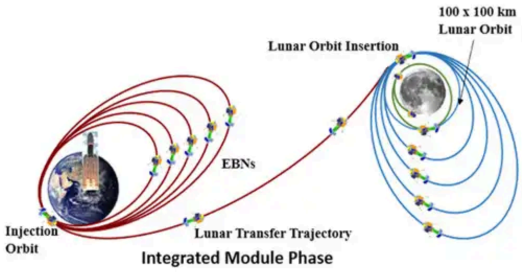
</table>

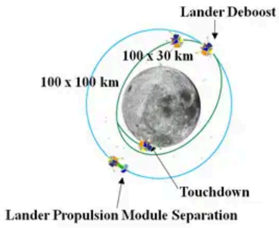
2.  Can you please explain the above orbits you discussed in the class Sir? which central forces are spiral? is angular momentum involved Sir? or only coming from energy conservation?	Aditya Raj 23ME01003
+91 99897 17845 26/09/23, 6:50 PM All Media  Good evening sir how can we say that the E5 graph does not touch the x axis? 3. Phase portrait of Simple Pendulum	L. Aneesh 23EC01005
4. I don't understand how to use chain rule here in deriving Newton's equations in polar coordinates. Can you re derive in class?	Anand Roy 23EE01004

5.		Aum Vyas 23EC01005

9) Up to 5 critical thinking level questions from assignments and examinations together with the marks, answering time and student performance:

Question	Time & Marks	Performance
<u>Following were open book (take home) assignment problems</u> Q1. A spacecraft is parked in a circular orbit 200 km above Earth's surface. We want to use a Hohmann transfer to send the spacecraft to the Moon's orbit.  A. What are the total transfer velocity and transfer time required? B. Why Hohmann transfer was not used directly in Chandrayaan-3 mission by ISRO ? Give proper arguments supported by data.	60-120 min 30 marks	





C. Using Hohmann transfer, calculate the minimum transfer velocity required to place a satellite (which is already in Earth's heliocentric orbit) into the orbit of Venus. Also, calculate the time of flight for such a trip.

Footnote for Q1:

The traditional way for a spacecraft transfer trajectory from Earth is by Hohmann transfer (refer to: Porkchop plots). This type of transfer uses only 2-body dynamics. It is constructed by determining a two-body Keplerian ellipse from an Earth parking orbit to the orbit of, say, the moon (see figure). The two bodies involved are the Earth and a spacecraft. Such a transfer requires a large V for the spacecraft to catch up and get captured by the moon. In 1991, the Japanese Hiten mission used a low energy transfer with a ballistic capture at the Moon which required less V than a standard Hohmann transfer (see figure). Chandrayaan-3 recently used a trans-lunar injection (TLI) from a Low Earth Orbit (LEO) with a series of propulsive maneuvers used to set a spacecraft on a trajectory that will cause it to arrive at the Moon.

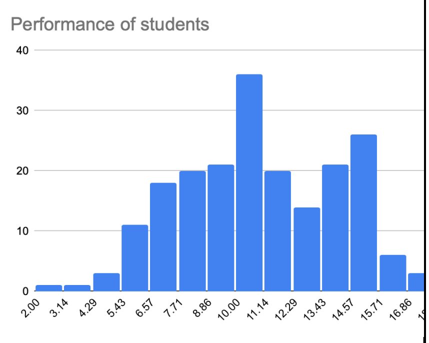
Q2: Sachin Tendulkar slashes Shoaib Akhtar's ball at a height of 0.7m above the ground. The ball leaves Sachin's bat at an elevation angle of 35 degrees and travels towards the third man boundary 60m away from the centre, where Wasim Akram of height about 2m, is waiting to catch the ball. Let the drag coefficient be c_w=0.5, the radius of the ball be 5 cm and the mass be 200g.

A. What must the initial speed of the ball be, to clear Wasim Akram at the boundary ? Ignore air resistance.

B. Include air resistance proportional to the square of the ball's speed now and find the initial speed needed to clear the fielder.

30 - 60 min

20 marks



<table>
<tr>
<td>C. For this speed (with air resistance), find the initial elevation angle that allows the ball to most easily clear the boundary. By how much does the ball now vertically clear the boundary?

Context: In the 2003 Cricket World Cup match between India and Pakistan at the Centurion, Sachin Tendulkar slashed Shoaib Akhtar for six en route to his iconic 98, that helped India beat Pakistan. The quality of that six was bettered by Kohli's six off Haris Rauf in the T20 world cup match at the Melbourne in 2022 (debatable over a coffee !).</td>
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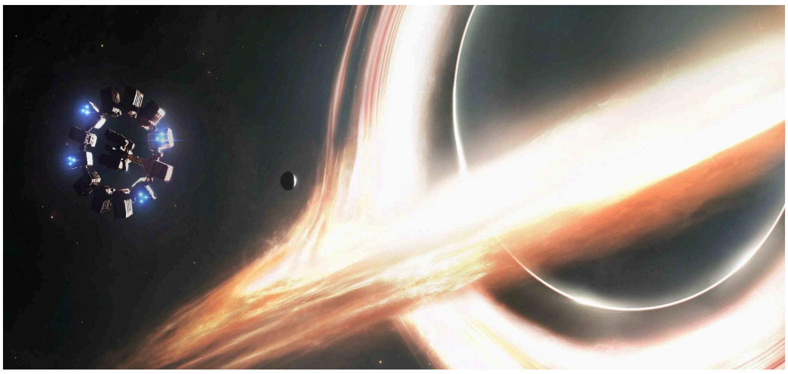
</tr>
<tr>
<td>Q3: The line element in special relativity to measure space-time distances is, ds^2 = - c^2 dt^2 + dx^2 (ignoring two other directions for brevity).

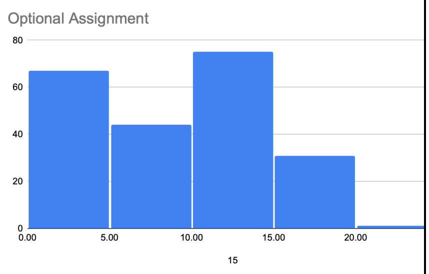
A. Use the above line element to define a light-cone. Draw a light-cone diagram and mark the time-like, space-like and light-like regions clearly.

B. Explain time-dilation by drawing a space-time diagram of observer O (at rest) and observer O' (moving with velocity v in positive x-direction).

C. Use space-time Minkowski diagrams to imagine and create a qualitative explanation of the Twin Paradox in the film Interstellar.

Context: Interstellar (Film, 2014) - The relevant concept used is gravitational time-dilation. Roughly speaking, it means, time runs slow for an observer close to a heavy gravitational object (e.g., black hole). The relevant formula is $T_r / T = (1- r_s/r)^{1/2}$. Here, T_r is the time of an observer close to a black hole, T is the time of an observer outside the influence of a black hole (far away), r is the distance of the observer from black hole and r_s is called the Schwarzschild Radius or size of the black hole, given as $r_s = 2 G M/c^2$. You can use these formulas to calculate the number of earth years spent by doing a short slingshot around Gargantua of mass M !

</td>
<td>30 - 120 min

25 marks</td>
<td>
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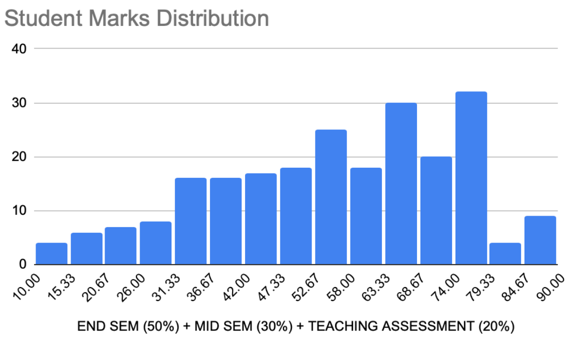
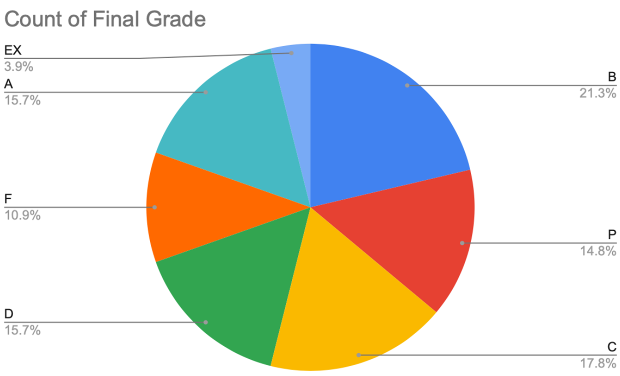
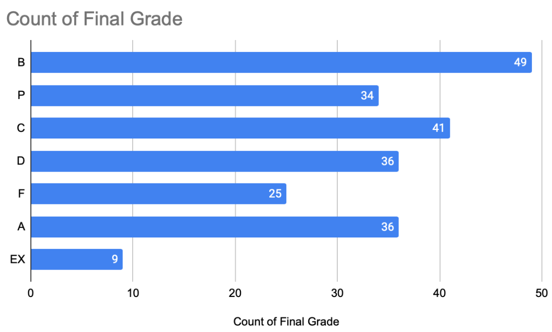
10) Overall student performance and grading policy:







11) Feedback provided to the students on their performance in the assignments, examinations and activities:

<u>Traditional Method:</u>

a) Assignments and examinations were evaluated.
b) Mistakes committed were pointed out in the answer paper for every student.
c) In the class, correct solutions were given including the steps, possible reasons for the mistakes were explained, and methods to avoid them in future were suggested.

<u>Possible New Method:</u>

In addition to the above, a new model to give feedback to students is currently under development. Few models have been tried already and the current model is given below. The model is quite clear, with following highlights..

a) The feedback shows problem wise performance of students with different colors signifying their understanding level.
b) Red Color: Shows that the students have not understood the problem/concept at all and they need to read from scratch. The solution they presented is unacceptable.
c) Yellow Color: The students have made some conceptual errors and they need to proceed with caution in these topics/concepts.
d) Blue Color: The understanding of the problem/concept is almost clear and with minor effort, they can master the topic
e) Green Color: The understanding of the topic/concept is as good as any!
f) There are other in-between colors for finer details.

A sample is given below for a core course for M.Sc. (a similar feedback model for B.Tech. is possible, but time consuming). For large classes, an automated method following the current model is being developed.

Problem wise feedback provided to students on their performance and understanding of concepts in assignments and examinations

CLASSICAL MECHANICS									Consolidated Semester Evaluation: 2022									
TOPICS			LAGRANGIAN MECHANICS				HAMILTONIAN		POISSON BRACKETS		CANONICAL TRANSFORMATIONS			CENTRAL FORCES		SPECIAL RELATIVITY		
Question Number			Q[1] (a)	Q[1] (b)	Q[2] (a)	Q[2] (b)	Q[3]	Q[4]	Q[5]	Q[6] (a)	Q[6](b)	Q[6] (c)	Q[6] (d)	Q[7]	Q[8]	Q[9]	Q[10]	Q[11]
S. No	Roll Number	Name/Marks	[5]	[5]	[10]	[10]	[7]	[8]	[15]	[5]	[5]	[10]	[10]	[5]	[5]	[5]	[10]	[10]
1	22PH05001	Colin Jacob	A	A	Ex	Ex	Ex	Ex	A	Ex	A	Ex	A	Ex	Ex	Ex	Ex	A
2	22PH05002	Adrinil Paul	A	B	A	Ex	Ex	A	A	A	A	Ex	B	Ex	C	A	B	C
3	22PH05003	Somnath	A	D	B	Ig	B	B	B	B	A	NA	B	A	B	A	B	B
4	22PH05004	Deepanshu	F	F	NA	C	F	F	A	A	C	B	NA	F	D	Ex	NA	F
5	22PH05005	Dhriti Mandal	Ex	A	A	A	B	Ex	A	Ex	Ex	B	B	Ex	C	Ex	NA	C
7	22PH05008	A Patidar	F	F	NA	Ex	F	D	A	F	A	B	NA	A	F	Ex	Ig	D
8	22PH05009	K Park	D	C	Ex	B	Ex	NA	NA	Ex	Ex	B	Ig	Ex	D	Ex	NA	B
9	22PH05010	B Joshi	D	F	Ex	NA	NA	F	A	F	F	A	A	Ex	F	Ex	NA	D
10	22PH05011	G Kulkarni	F	D	F	C	F	NA	NA	C	B	D	NA	Ex	B	F	NA	B
11	22PH05012	M Chowdhury	F	B	Ex	Ex	NA	B	F	B	C	Ex	F	NA	NA	NA	NA	F
12	22PH05013	Pranit	NA	NA	NA	NA	NA	C	A	NA	NA	D	F	F	B	F	NA	F
13	22PH05014	Rohit	NA	B	B	B	NA	C	A	B	A	D	F	Ex	F	F	NA	C
14	22PH05015	Suraj	NA	NA	B	Ex	F	F	A	F	A	D	NA	NA	NA	NA	NA	C
15	22PH05016	Devendra	A	B	B	A	B	B	B	B	B	Ex	A	F	B	F	NA	C
16	22PH05017	Prakash	B	F	F	B	B	NA	NA	A	B	Ex	NA	Ex	F	Ex	Ig	C
17	22PH05019	Golak	Ex	A	A	Ex	NA	Ex	A	Ex	A	D	F	A	A	Ex	B	NA
18	22PH05021	Chakali	B	F	B	F	B	F	B	Ig	Ig	B	F	F	D	F	NA	C
19	22PH05022	Dinesh	B	D	B	A	D	F	B	Ig	Ig	B	B	B	B	B	NA	C
20	22PH05023	Satyavati	C	C	C	D	C	NA	NA	F	B	D	Ig	D	D	F	NA	B
21	22PH05024	Rajkumar	F	C	B	A	C	NA	NA	B	B	D	Ig	D	F	D	NA	B
22	22PH05025	Suman	B	F	D	B	B	F	B	Ig	Ig	D	B	D	B	D	NA	C
23	22PH05026	goutam	NA	NA	B	D	F	NA	NA	F	F	D	NA	D	F	D	Ig	C
24	22PH05027	Satyajit	F	C	D	F	B	NA	NA	B	B	D	Ig	D	F	D	NA	B

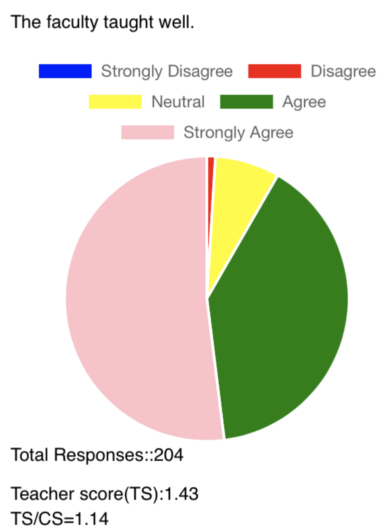
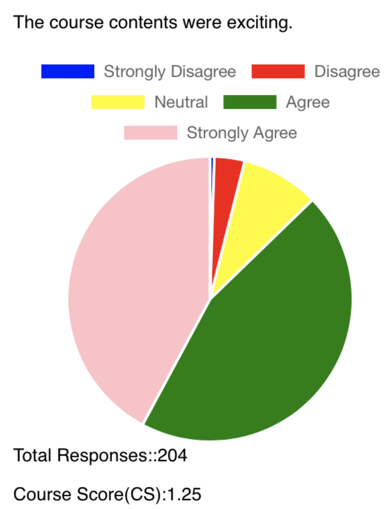
Categ	Credit	
Ex	100%	WoW
A	90%	Almost Correct
B	70.00%	Not Finished..
C	50.00%	Half way
D	30.00%	Some Positive points
F	No, Credit	Unacceptable
Ig, NA	Extra (ignored); Not Attempted	

12) Students' feedback on teaching:

Registration time perception: not available

Statement	The faculty handling the course teaches well.	The course contents are exciting.
Response	-	-

Perception at the end of the course:

Statement	The faculty handling the course taught well.	The course contents were exciting.
Response		

Descriptive comments at the end of the course (mention up to 5 significant comments):

Comments included here should be verbatim. A comment that reflects three or more comments with almost identical meanings should be included here.

Aspects of the course and the teacher that need improvement.

1. I felt that special relativity should be given more time, apart from that the course was taught exceedingly well
2. The only improvement is that he should be strict with attendence 😅 😅
3. course need much more time to understand and teacher do not any improvement
4. It was perfect, just perfect..... down to every last bit of it.
5. Due to the large curriculum, sir has to speed up at times, which became problematic sometimes

What I like most about the course and the teacher.

1. Best physics faculty I studied from,Other than the contents of the course(which itself were explained in detail) I got to learn alot of things from him. The best thing about him was the entire explaination and summary of the class provided via detailed class notes which was really helpful during exams. Relativity really blew my mind away.
2. Everything about this course excited me. The topics taught were intriguing and required a great deal of conceptual understanding . Chandrashekar sir taught the course in the best way possible. He is an excellent teacher who has a talent for simplifying complex topics
3. Lagrangian mechanics gave me a new lens to see most phenomena and is a phenomenal approach that lets us circumvent many layers of complexities. The sir presented the topic in

a marvelous way and was very engaging with the students. He has surely left a lasting impact on all his students.

4. I like him very well among all the 4 Physics sirs. He says extraordinary and phenomenal He elaborates everything and says clearly Very thankful to him
5. the way he shares all the assignments and class notes regularly reducing the burden and helped to pay attention in class only in concept building. also his discussions in the class makes the content more interesting. also his interactive nature even after the class with us helped us to be comfortable to share all our doubts and conceptual problems.

13) Identifying and dealing with students needing special attention

Students who were low in attendance (in surprise checks and random attendance) were identified and were made to solve extra problem sets. Extra classes were conducted specifically for students who had doubts. Many topics were repeated multiple times in extra doubts classes (date/times of the classes were widely circulated through email). Several such doubt clearing sessions and repeating of class topics were done and these extra classes were not mandatory. Nothing new was taught here, only to clear doubts. Students found it useful. Sometimes, only 5-10 students came, but the extra doubts classes were still running.

Following is common for some of the faculty teaching the batch: 5 backlog students (3 CE students, 1MM student, and 1 CS student of 21 batch) registered for this course and faced difficulty in attending classes due to overlap in time table. TAs and myself took extra sessions whenever necessary to help them understand various topics.

14) Anything else

A. Problem of Attendance: After entering the class, the first thing I like to do is to slowly drive the students to get interested in a physics concept (which takes about 10 minutes). After I am sure that I have their attention, that is when I introduce the most difficult concept for about 15 minutes, followed by examples to make it clear (about 15 minutes). I never introduce anything new in the last 10 minutes and leave it for questions/doubts or emphasizing what has already been taught. This has worked pretty well thus far. Taking attendance properly (in every class) is a challenge. It takes about 7-8 minutes to take attendance properly and that is a lot of time spent in a 50 minute class. Particularly, as mentioned above, the first 10-12 minutes are crucial to set the stage for discussing physics. I do not have a solution to the problem of taking attendance in a short time yet.

B. How to make a large class interactive, while at the same time covering the syllabus or going deeper into topics is also a challenge. The current teaching style of presentation of topics to students who are listening helps about 50-70% of the students (even this set of students will learn better in an interactive style of teaching). For remaining 30-50 % students, special attention is required (such as personalised teaching in small groups) and more time extra classes to make them solve slightly less difficult problems (but there is not much time available in the time-table to have such extra classes). As per the feedback I received, some of these need to be implemented and I will try my best in the future semesters to improve.

C. With the changes brought in by NEP 2020, there are changes to curriculum, with slightly lesser sections for Physics, in which case, there can be smaller sections or groups (say 60-70) to teach. I am hoping some of the issues mentioned above can be taken care of in the future.

If available

15) Peer / Experts' feedback on teaching

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16) Performance of students in the follow-on course

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17) Performance of students in real life