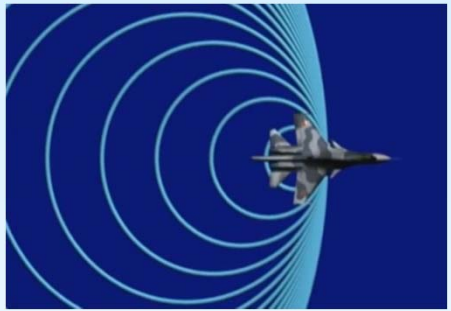
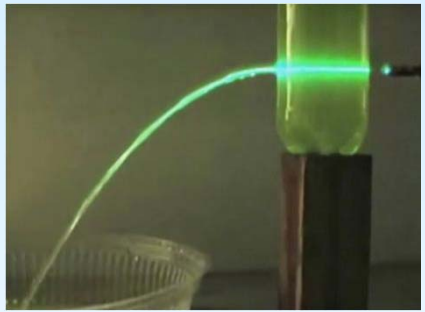
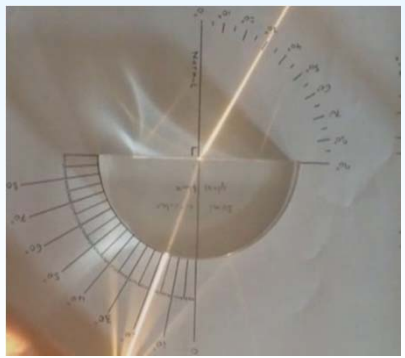
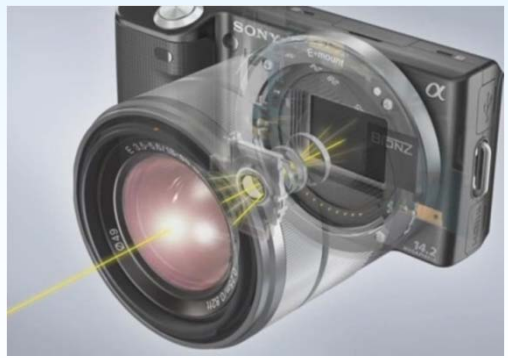
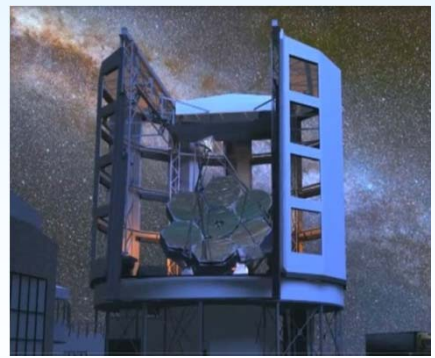
FYSA13: Waves, optics and quantum mechanics

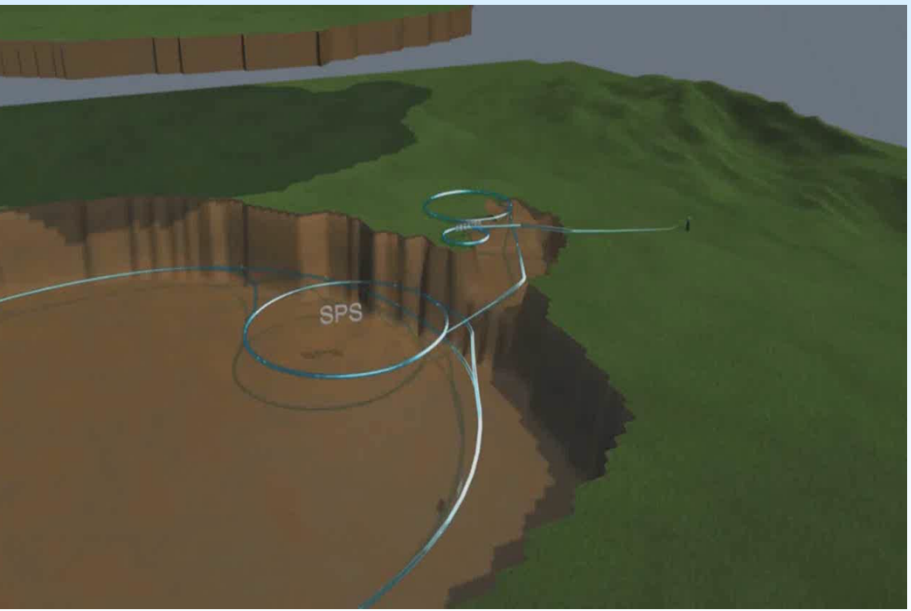





Introduction to the FYSA13 course in 2025

Course responsible



Particle physicist Vincent Hedberg
https://vincent-hedberg.web.cern.ch

FYSA13: Course structure

The course consists of three parts:

1. Wave mechanics: Lecturer Vincent Hedberg & Pablo Villanueva Perez
2. Geometrical optics: Lecturer Pablo Villanueva Perez
3. Quantum mechanics: Lecturers Joakim Bood

Each part has separate lectures, exercises, quizzes (online), exam (mandatory), lab (mandatory) and hand-in exercise.

The course has been given twice as an online course because of COVID but since then we given it on campus. Wave and optics lectures are therefore available on video.

The course has something called a syllabus in Canvas which is recommendations of the activities that you should do each day.

FYSA13: Course structure

The quizzes in Canvas contains knowledge questions which will help you check that you have understood the lectures and the text book.

After completing this course you should be able to solve numerical problems and this will be tested in the three exams. A minimum set of problems from the book has been selected to help you practice this. Exercise times with two tutors (Rezvan Tahouri and Daniel Holst) will be avilable and if you have problems with the quizzes or the numerical problems you can get help with them in these exercise sessions.

Hand-in problems based on old exam questions are provided on each of the three parts in the course. They are not mandatory but will give points that will be taken into account when the exams are corrected. You can work on the problems with other students but has to write your own report.

FYSA13: Course structure

Three mandatory labs will be given in two lab periods:

1. Wave mechanics: O5 Diffraction – half day,
   Supervisors: August Thomasson & Hajar Jalili

2. Geometrical optics: O4 Optics lab – half day,
   Supervisors: Julia Rogalinski & Runqing Yang

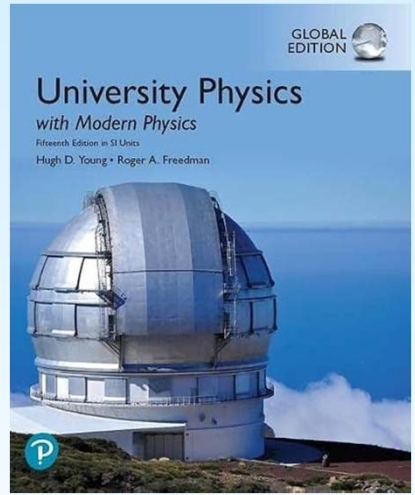
3. Quantum mechanics: K2 Quantum lab – half day,
   Supervisors: Sameer Devipur & Tommy Holmqvist

One mandatory lab introduction meetings will be given on March 27.

Three exams will take place on the 4th of June.

FYSA13: Textbook

University Physics by Young & Friedman



Wave mechanics

Oscillatory motion:	Chapter 14.1 – 14.4
Mechanical waves:	Chapter 15.1 – 15.8
Sound:	Chapter 16.1 – 16.3 and 16.8
Electromagnetic waves:	Chapter 32.1 - 32.3
Interference:	Chapter 35.1 – 35.5
Diffraction:	Chapter 36.1 - 36.5

FYSA13: Textbook

Optics

Nature and propagation of light:	Chapter 33.1 – 33.3
Geometrical optics:	Chapter 34.1 – 34.4, 34.6-34.8

Quantum physics

Photons:	Chapter 38.1 & 38.3 & 38.4
Matter waves:	Chapter 39.1 – 39.3 and 39.6
Quantum mechanics:	Chapter 40.1 – 40.6

Lectures & exercises in wave mechanics

There will be 9 lectures by Vincent Hedberg and Pablo Villanueva Perez and 3 exercise sessions during two weeks.

Week	Time	Mon 24-Mar	Tue 25-Mar	Wed 26-Mar	Thurs 27-Mar	Fri 28-Mar
13	08-10	Introduction to FYSA14	FYSA14-Chapter 17	FYSA14 - mandatory	8:15-9:00 Intro. to Exp. seminar 9:15-10:00 FYSA13-14: Lab Intro.	FYSA14-Chapter 18
	10-12	Introduction FYSA13 A-salen FYSA13 Lecture Ch14	FYSA13 Lecture Ch14 A-salen Ch14	FYSA13 Lecture Ch15 A-salen Ch15	FYSA13 Lecture Ch15 A-salen Ch16	FYSA13 Lecture Ch16 A-salen Ch16
	13-15	FYSA14 Lecture Introduction to popular science	FYSA14-Chapter 17	FYSA13 exercise Ch14 L217 & L218	FYSA14: Exercise C17	FYSA13 exercise Ch15,16 L217 & L218
	15-17					

Week	Time	Mon 31-Mar	Tue 01-Apr	Wed 02-Apr	Thurs 03-Apr	Fri 04-Apr
14	08-10	FYSA13 Lecture Ch32 A-salen Ch32		FYSA14: Climate lecture 1	FYSA14: Climate lecture 2	T1 lab gr 3,4
	10-12	FYSA14-Chapter 18	FYSA13 Lecture Ch35 D-salen Ch35	FYSA13 Lecture Ch35 A-salen Ch36	FYSA13 Lecture Ch36 A-salen Ch36	O5 gr 1 & 2 H323 H324
	13-15	FYSA14 Sustainability workshop	FYSA14: Exercise C18	FYSA13 Lecture CERN A-salen CERN	FYSA13 exercise Ch32,35,36 L217 & L218	
	15-17					

Labs in wave mechanics

In the O5 Diffraction lab you will study how light waves interacts and produce diffraction and interference effects.

Time	Fri 04-Apr
08-10	T1 lab gr 3,4
10-12	O5 gr 1 & 2 H323 H324
13-15	
15-17	

Mon 07-Apr	Tue 08-Apr	Wed 09-Apr
T1 lab gr 5,6	T1 lab gr 1,2	T1 lab spare
O5 gr 3 & 4 H323 H324	O5 gr 5 & 6 H323 H324	O5 spare H323

Lectures & exercises in optics

There will be 4 lectures by Pablo Villanueva Perez
and 1 exercise session during two weeks.

Time	Thurs 10-Apr	Fri 11-Apr	Mon 14-Apr	Tue 15-Apr	Wed 16-Apr
08-10		FYSA13 Lecture Ch34 A-salen Ch34	FYSA13 Lecture Ch34 A-salen Ch34	FYSA13 Lecture Ch34 A-salen Ch34	
10-12		FYSA14-Chapter 19	FYSA14: Exercise C19	FYSA14-Chapter 20	
13-15		FYSA14-Chapter 19		FYSA14-Chapter 20	
15-17	FYSA13 Lecture Ch33 A-salen Ch33				FYSA13 exercise Ch33, 34 L217 & L218

Lectures & exercises in quantum mechanics

There will be 6 lectures by Joakim Bood and 3 exercise sessions during two weeks.

Time	Wed 16-Apr	Thurs 17-Apr
08-10		FYSA13 Lecture Ch38 A-salen Ch39
10-12	FYSA13 Lecture Ch38. A-salen Ch38	
13-15	FYSA14: Exercise C20	
15-17	FYSA13 exercise Ch33, 34 L217 & L218	**FYSA13 Hand-in Waves**

Time	Tue 22-Apr	Wed 23-Apr	Thurs 24-Apr	Fri 25-Apr
08-10				
10-12	FYSA13 Lecture Ch39 A-salen Ch39	FYSA13 Lecture Ch40 A-salen Ch40	FYSA13 Lecture Ch40 A-salen Ch40	FYSA13 Lecture Ch40 A-salen Ch40
13-15	FYSA13 exercise Ch38-39 L217 & L218			FYSA13 exercise Ch40 L217 & L218
15-17				**FYSA13 Hand-in Optics**

Labs in optics & quantum mechanics

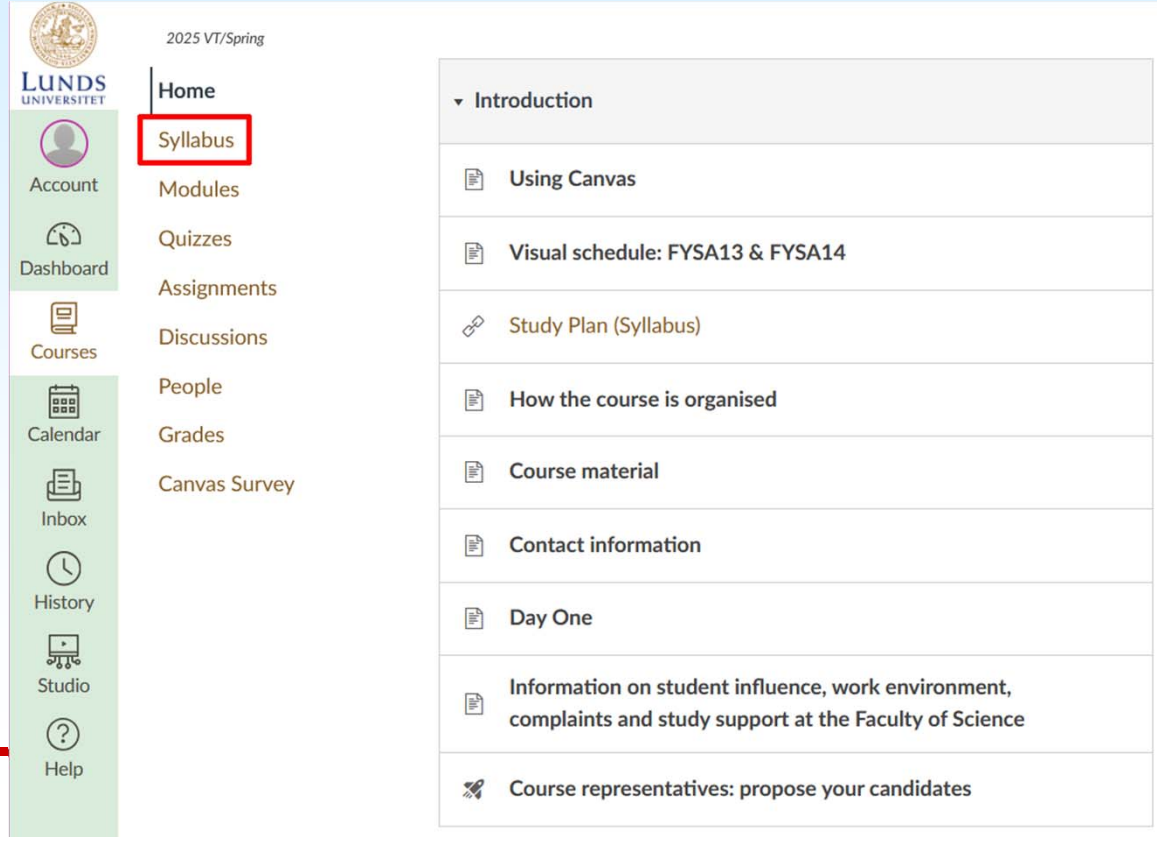
In the O4 Geometric Optics lab you will do measurements and explore the ray model of light that is used to study lenses and mirrors. In the K2 Quantum physics lab you will study the hydrogen spectrum and use a USB spectrometer.

Week	Time	Mon 28-Apr	Tue 29-Apr	Wed 30-Apr	Thurs 01-May	Fri 02-May
18	08-10	T2 lab **1.2** 10-12 13-15 15-17	O4 **gr 5 & 6** L224 L225	T2 lab **5.6** 10-12 13-15 15-17	O4 **gr 3 & 4** L224 L225	May day	**FYSA13 Hand-in Quantum**

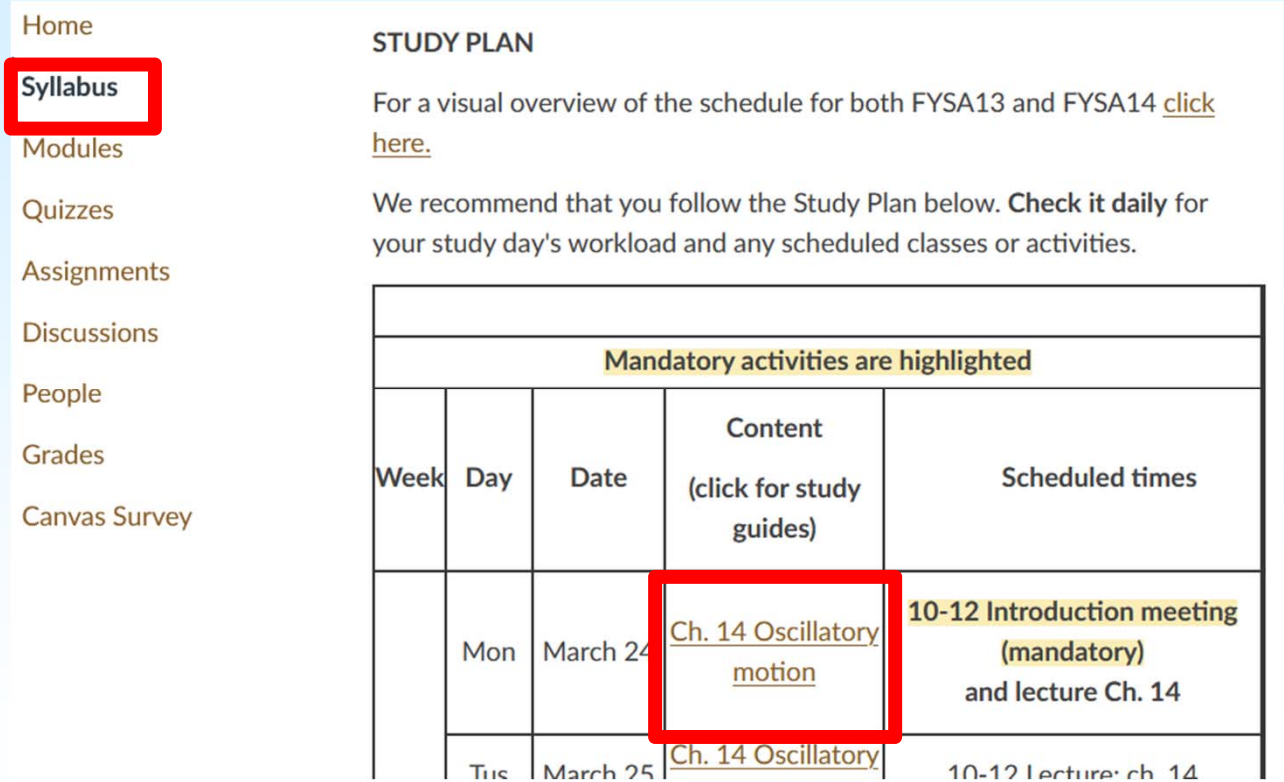
Week	Time	Mon 05-May	Tue 06-May	Wed 07-May	Thurs 08-May	Fri 09-May
19	08-10	T2 lab **3.4** 10-12 13-15 15-17	O4 **gr 1 & 2** L224 L225	T2 lab RESERVE	**K2 (5 hrs) gr 5 & 6** L224 L225	**K2 (5 hrs) gr 3 & 4** L224 L225	**K2 (5 hrs) gr 1 & 2** L224 L225	O4 **spare** L224	**K2 spare** L225

Web pages in Canvas

https://canvas.education.lu.se/courses/33871



Web pages in Canvas



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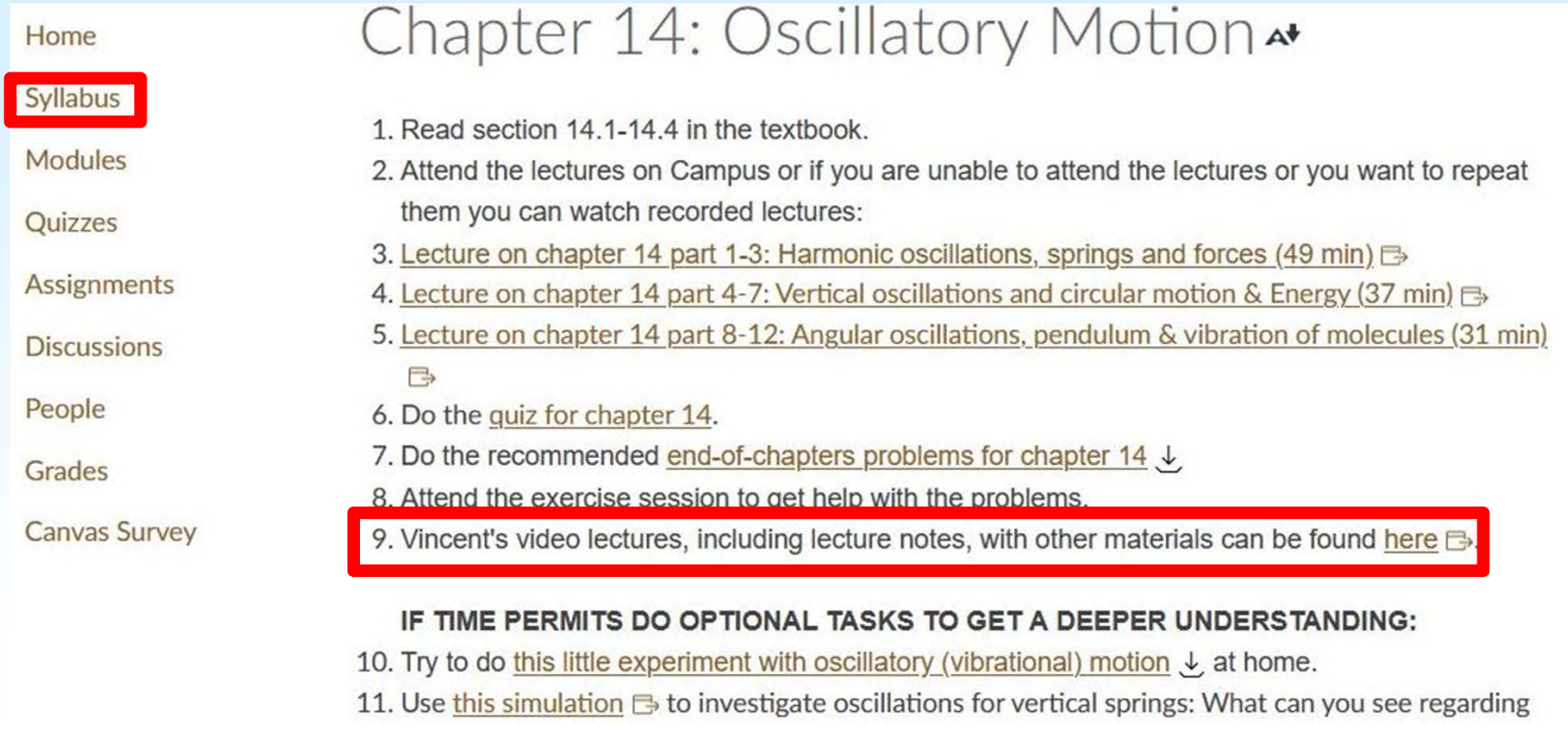
STUDY PLAN

For a visual overview of the schedule for both FYSA13 and FYSA14 click here.

We recommend that you follow the Study Plan below. **Check it daily** for your study day's workload and any scheduled classes or activities.

Mandatory activities are highlighted				
Week	Day	Date	Content (click for study guides)	Scheduled times
	Mon	March 24	Ch. 14 Oscillatory motion	10-12 Introduction meeting (mandatory) and lecture Ch. 14
	Tus	March 25	Ch. 14 Oscillatory	10-12 Lecture: ch. 14

Web pages in Canvas



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Chapter 14: Oscillatory Motion

1. Read section 14.1-14.4 in the textbook.
2. Attend the lectures on Campus or if you are unable to attend the lectures or you want to repeat them you can watch recorded lectures:
3. Lecture on chapter 14 part 1-3: Harmonic oscillations, springs and forces (49 min)
4. Lecture on chapter 14 part 4-7: Vertical oscillations and circular motion & Energy (37 min)
5. Lecture on chapter 14 part 8-12: Angular oscillations, pendulum & vibration of molecules (31 min)
6. Do the quiz for chapter 14.
7. Do the recommended end-of-chapters problems for chapter 14
8. Attend the exercise session to get help with the problems.
9. Vincent's video lectures, including lecture notes, with other materials can be found here.

IF TIME PERMITS DO OPTIONAL TASKS TO GET A DEEPER UNDERSTANDING:

10. Try to do this little experiment with oscillatory (vibrational) motion at home.
11. Use this simulation to investigate oscillations for vertical springs: What can you see regarding

Video web pages

Chapter 14 - Harmonic oscillations

Video lectures in English:

1. Lecture on part 1-3: Harmonic oscillations, springs and forces (mp4 - 49 min)
2. Lecture on part 4-7: Vertical oscillations and circular motion & Energy (mp4 - 37 min)
3. Lecture on part 8-12: Angular oscillations, pendulum & vibration of molecules (mp4 - 31 min)

Print-out version of chapter 14 (pdf)

Video lectures in Swedish:

Föreläsning på del 1-5: Harmonisk oscillator, fjädrar, krafter och vertikal svängning (mp4 - 44 min)
Föreläsning på del 6-11: Cirkulär rörelse, energi, vinkelrörelse, pendeln och molekyles vibration (mp4 - 56 min)

Utskriftsversion av kapitel 14 (pdf)

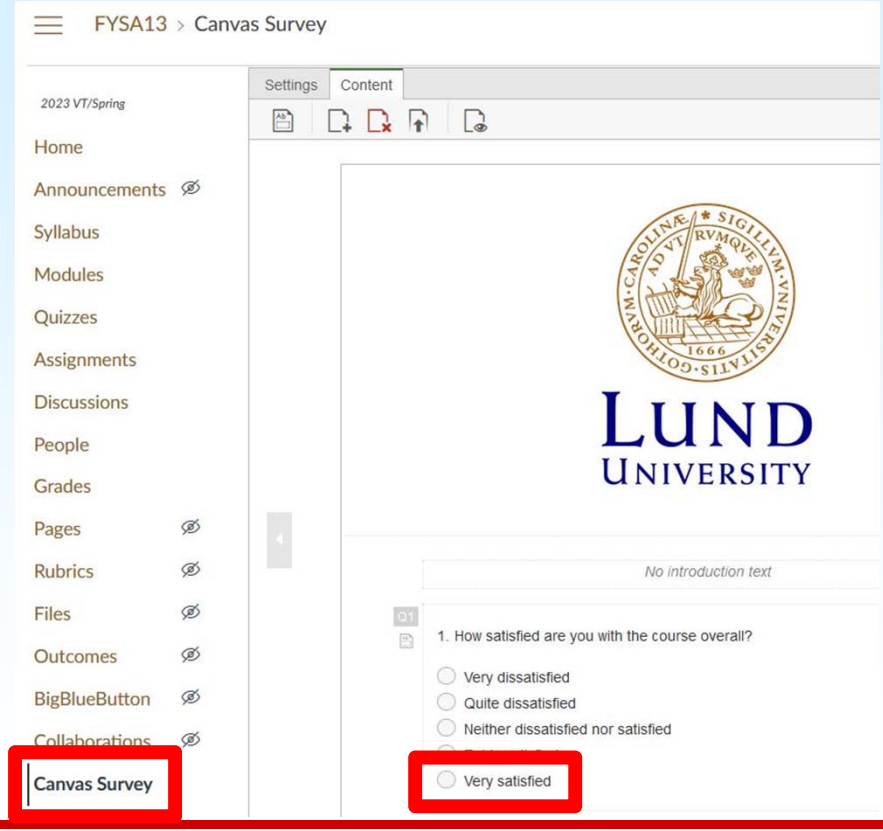
Full-length version of videos, animations and simulations used in the lectures:

 Spray paint oscillator

 Oscillating masses on an air track

Course evaluation

At the end of the course there will an evaluation of the course. It is important that you participate in this.



Student representative

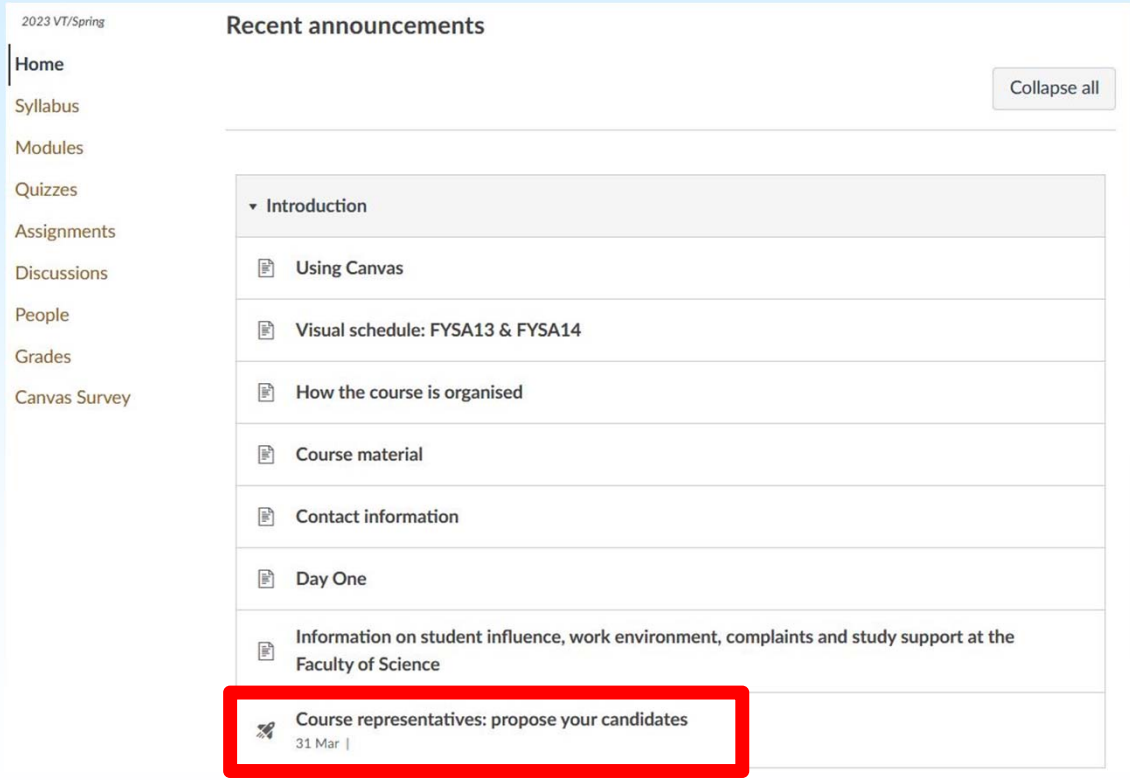
One to two students on the course tasked with acting as a channel of communication between students and teaching staff.

Raise problems that arise.

Reminding students about course evaluations and reviewing them.

Everyone is to be informed as to who is the course representative.

Support from the Lund Science Students' Union (LUNA).



In case of problems…

- The student health and safety representative – a student at your department who works with study environment conditions.
  www.lundsnaturvetarkar.se/complaints/

- The Lund Science Students' Union (LUNA) – science students who work with everything that concerns university studies. They can be contacted anonymously and have a duty of confidentiality.
  www.lundsnaturvetarkar.se/complaints/

- The student ombudsman – works with student matters throughout the University, employed by the Lund University Students' Unions (LUS).
  www.studentombudet.se

Introduction: The physics model

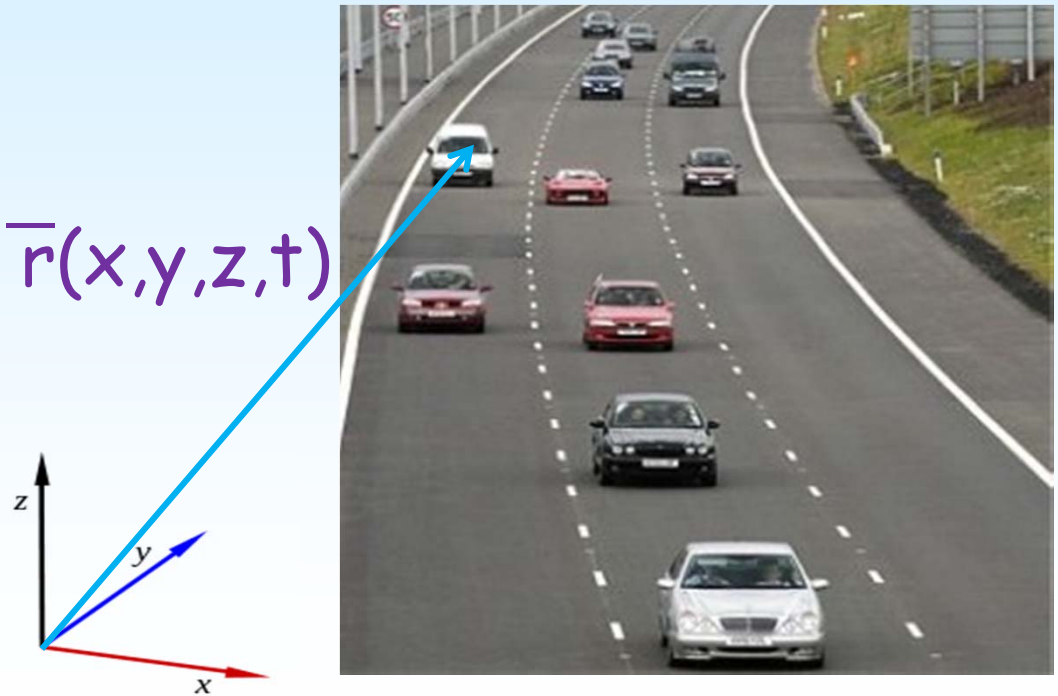
A simple theoretical model:

Velocity =
Distance / Time

Introduction: The physics model

A more complicated model:

Location = $\bar{r}(x,y,z,t)$



Velocity =
derivative of $\bar{r}$ with respect to time

$$\bar{r}(t) = \int \bar{v}(t)\, dt$$

$$\bar{v}(t) = \frac{d\bar{r}}{dt} = \int \bar{a}(t)\, dt$$

$$\bar{a}(t) = \frac{d\bar{v}}{dt}$$

Our physics models: The formula sheet

Formula sheets are available on Canvas.
They will be handed out during the exams.

Formulas for Waves

Harmonic oscillations:

$$f = \frac{1}{T} \qquad \omega = 2\pi f \qquad x(t) = A\cos(\omega t + \phi) \qquad F_x = -kx \qquad \omega = \sqrt{\frac{k}{m}}$$

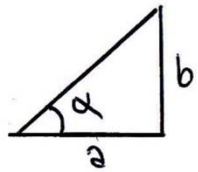
$$E = \frac{1}{2}mv_x^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = const.$$

Strings:

$$y(x,t) = A\cos(kx \pm \omega t + \phi) \qquad \frac{\partial^2 y}{\partial^2 x} = \frac{1}{v^2}\frac{\partial^2 y}{\partial^2 t} \qquad k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T}$$

What you need to know

Trigonometry:



$$\tan(\alpha) = \frac{b}{a}$$

$$\alpha = \arctan\left(\frac{b}{a}\right)$$

Trigonometric relationships:

$$\cos^2(x) + \sin^2(x) = 1$$

Algebra:

$$2a = \frac{4b}{3x} - 1 \Rightarrow x = \frac{4b}{6a+3}$$

Derivation:

$$f(x) = \cos(2x) \Rightarrow \frac{df}{dx} = -2\sin(2x)$$

Logarithms and powers:

$$y = 100\log(x) \Rightarrow x = 10^{y/100}$$

Vectors: