COMPUTATIONAL ASTROPHYSICS

Observatorio
Astronómico
Nacional

Computational Astrophysics

01. Introduction to MHD

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MHD. Basic Concepts

MagnetoHidroDynamics (MHD)

Description of the dynamics of a electrically conducting fluid in the presence of electromagnetic fields.

The physical properties used to describe these systems include:

- Mass density: ρ
- Velocity of the fluid: $\overrightarrow{v}$
- Pressure: p
- Temperature: T
- Magnetic field $\overrightarrow{B}$

Isotropic Medium

In an isotropic medium, there is not a preferred direction in space, i.e. it looks and behaves the same in all directions.

When there is an external (or internal) magnetic field, it usually defines a preferred direction in space and therefore a *magnetized fluid* is an *anisotropic medium*.

Length Scales

We will define some length scales to describe a fluid:

- a_0 : atomic radius
- λ : mean free path between atomic collisions
- δ : *physically* infinitesimal distance
- L : smallest distance that is macroscopically relevant for the system. An example is the shortest wavelength of interest in the system:

$$L \sim \frac{1}{k_{max}} \sim \lambda_{min}$$

Length Scales

- A fundamental assumption in MHD is that

$$\lambda \sim a_0 \ll \delta < L$$

When $\lambda \geq \delta$ or $\lambda \geq L$ the MHD model must be extended.

Time Scales

We will also define a characteristic time scale. First we define the following properties:

- v : characteristic velocity of the fluid
- c : speed of light (in vacuum)
- ω : characteristic frequency

Time Scales

Low-frequency motion is characterized by

$$\frac{v^2}{c^2} \ll 1$$

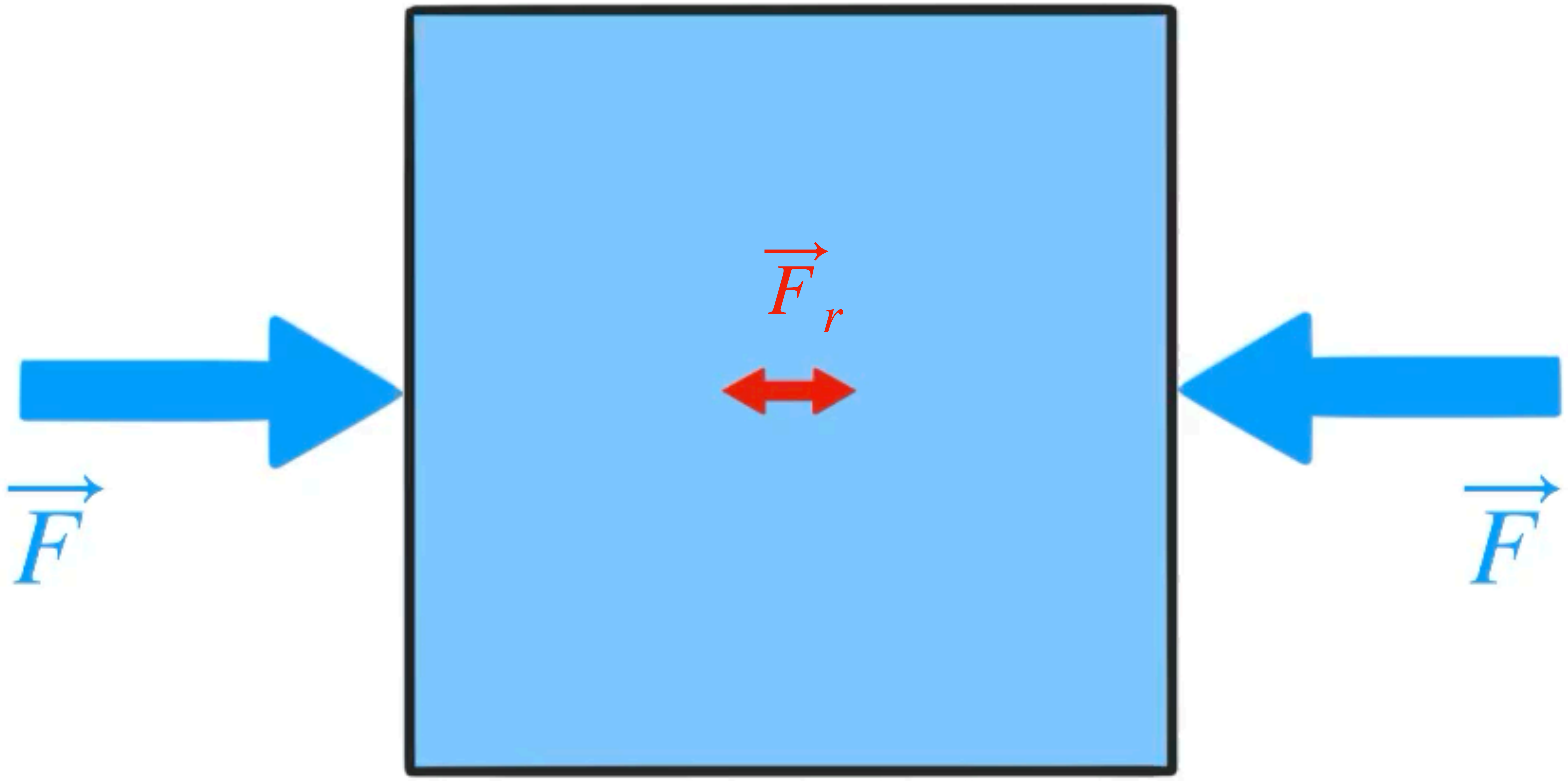
Using $v = \omega L$, we have $\omega \ll \dfrac{c}{L}$

and therefore, $\tau = \dfrac{1}{\omega} \gg \dfrac{L}{c} = \tau_c$,

i.e. the characteristic time τ is much greater than the time interval in which light travels the macroscopic system, τ_c .

Fluids

A fluid is a substance that *resist the action of compressive stresses* but *continually deforms (flows) under the action of shear stresses.*



$\vec{F}_r$
$\vec{F}$
$\vec{F}$

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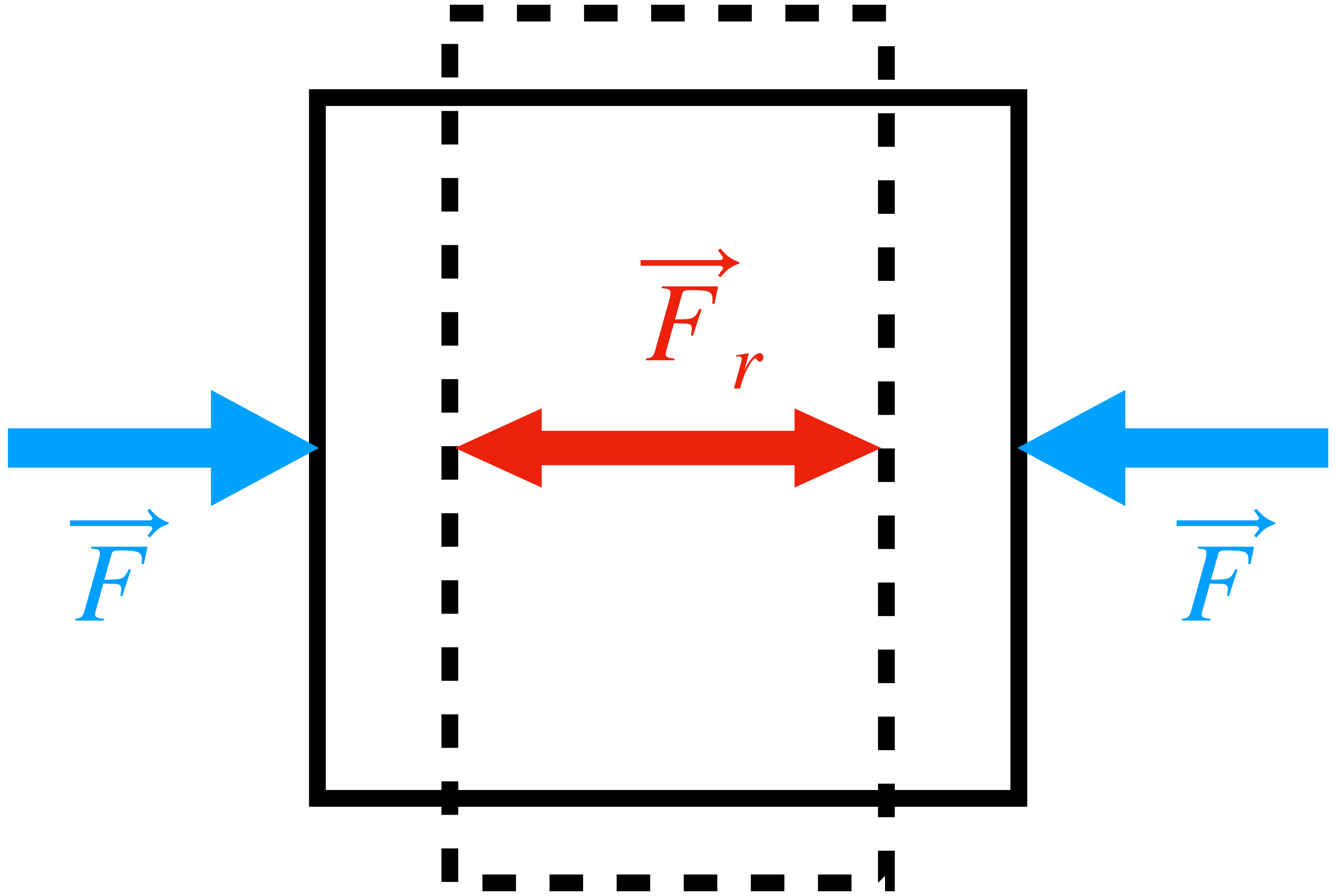
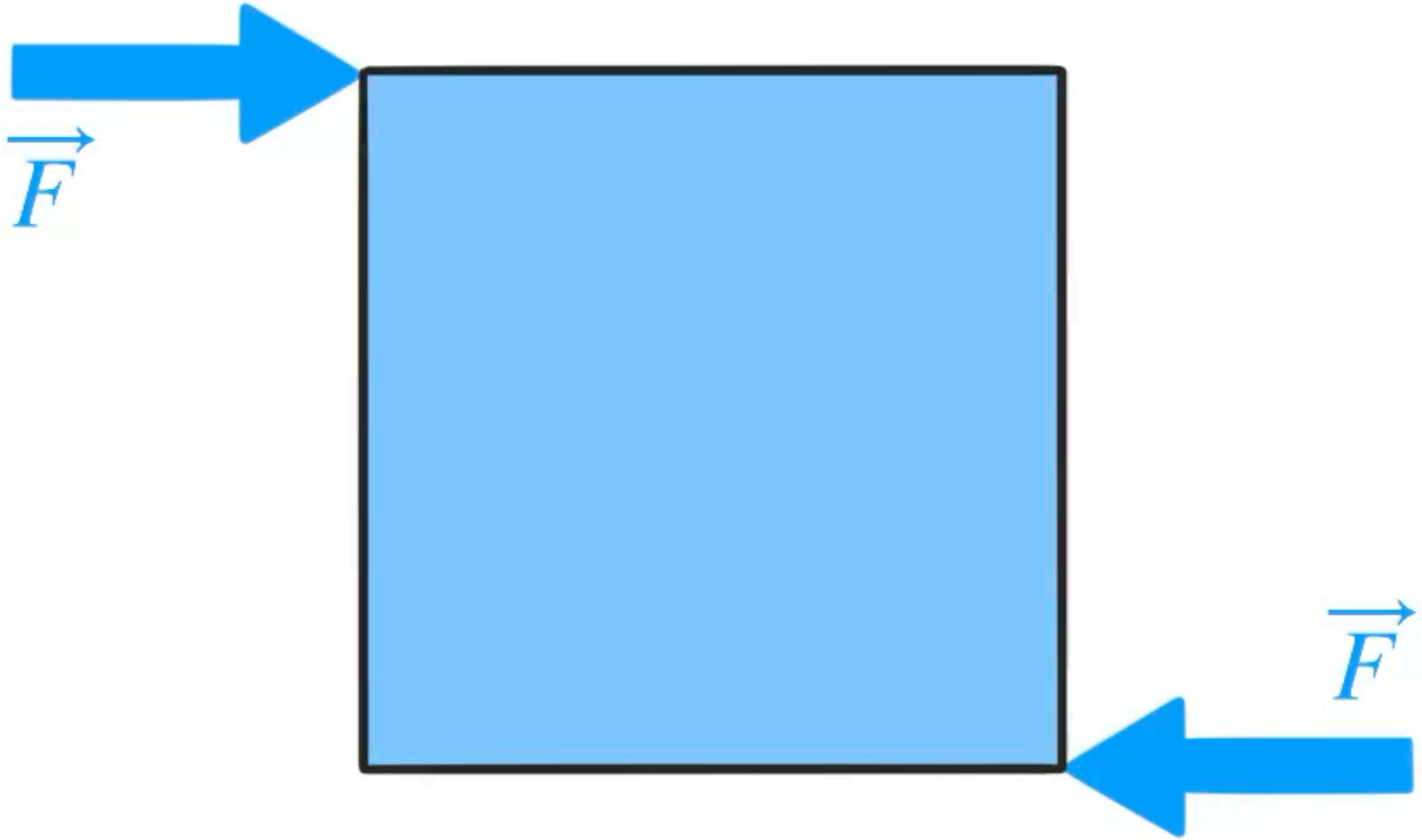


F_r is the restoring force that supports the compressive stress. This produces *compressional waves*.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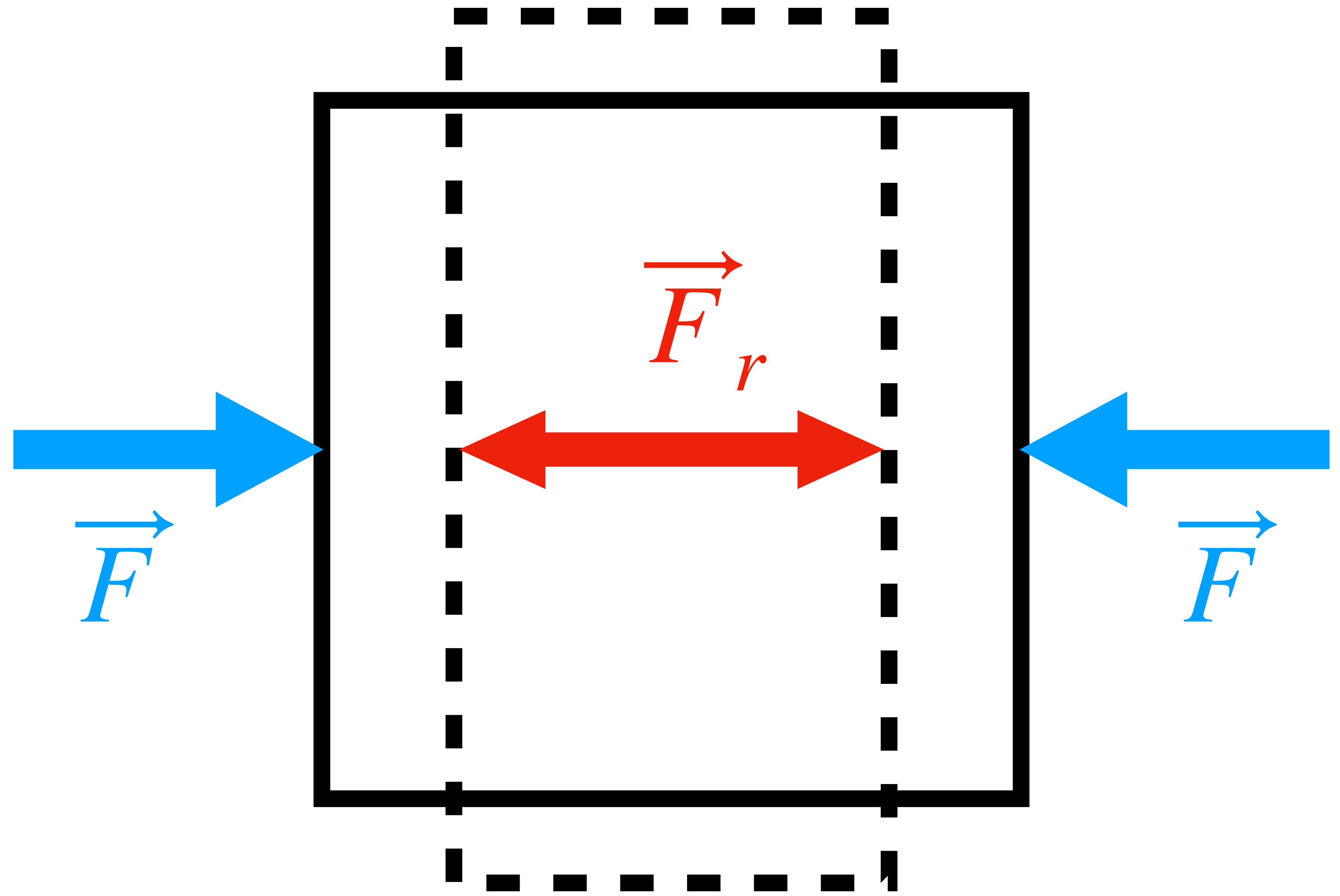

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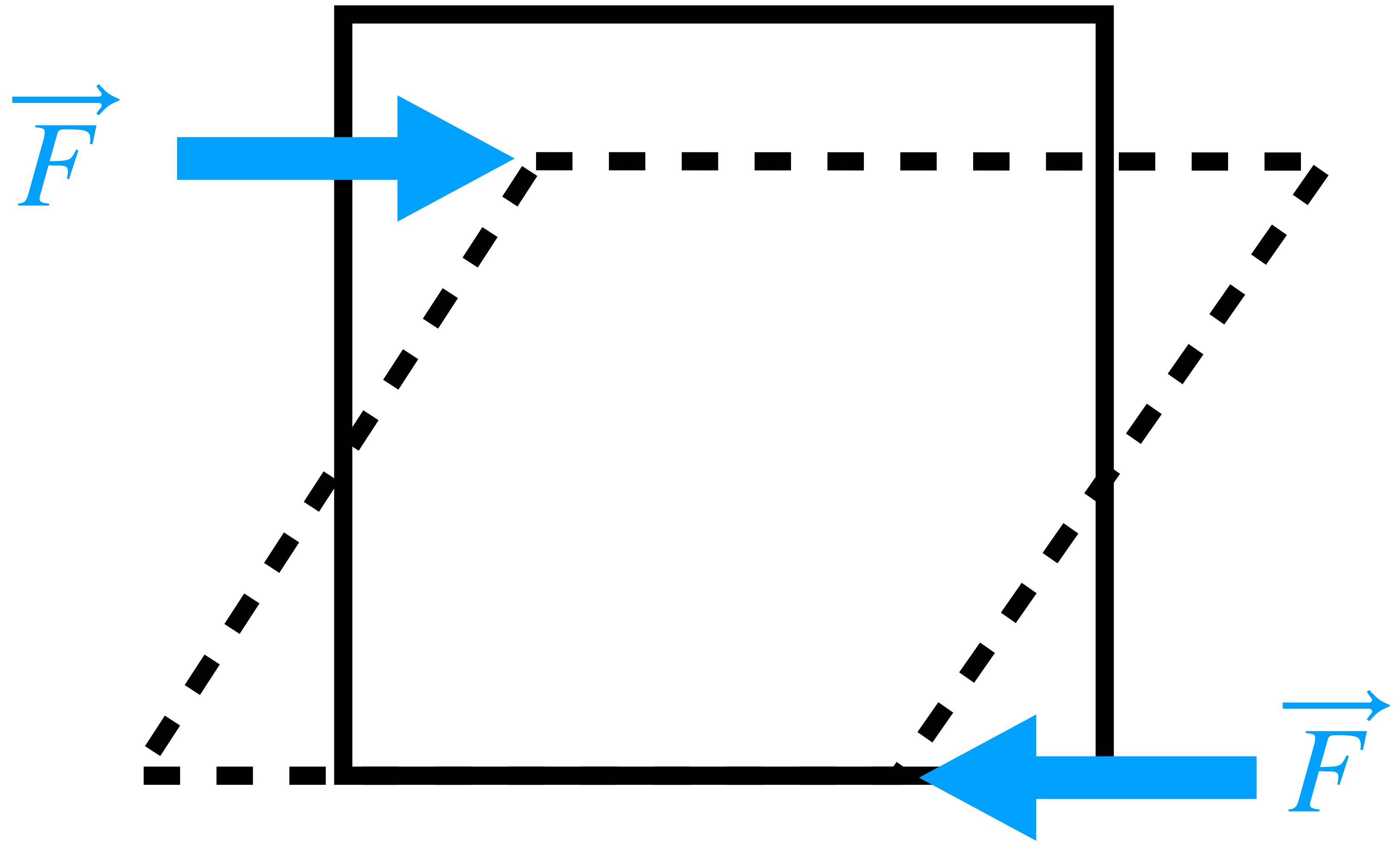

The fluid cannot support the shearing stress. There are not *shear waves*.