Arvind Borde / PHY 12, Week 3: Electric Currents and Ohm's Law

Just to see if you were listening,

(1) What do systems try to minimize? ____________

____

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(2) Why does a ball drop in the language of

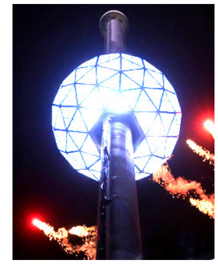
a) Forces ______________

____

b) Potential Energy. _______

____

______



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The language of forces is easier to understand intuitively. The ball goes down rather than up because ____________________________________.
It's never likely to go up.

But, if you describe things in the language of energy, a question arises...

(3) What? _________________________________.

3 ____

Maybe the ball sniffs out other possible paths – some up, some down, some sideways – before it picks the right path.

(4) Sound likely?

____

____

____

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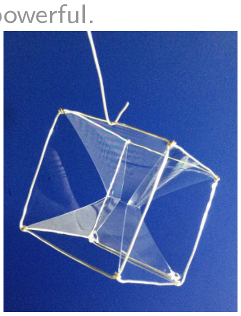
Such principles, where Nature extremizes situations, are very powerful.



If you dip a wire frame into soapy water, the soap film will take on a shape to minimize the total area it occupies.

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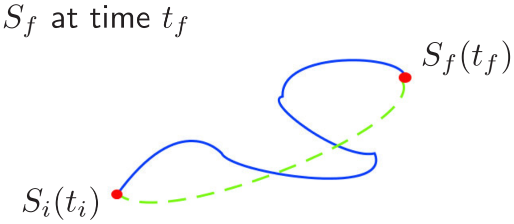
The Principle of "Least" Action

(The basis of all of physics)

For a system to get from state S_i at time t_i to state S_f at time t_f



6 it follows the path that __________________

ADDITIONAL NOTES

(5) Simple, no? ____________________

7

OK, you ________________ the action:

$$\text{Action} = \sum_{t_i}^{t_f} \mathcal{L}\Delta t \qquad \int_{t_i}^{t_f} \mathcal{L}\,dt$$

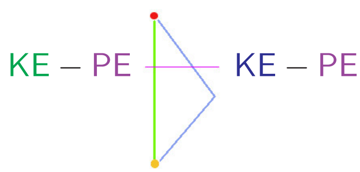
You ________ by adding up integrating the Lagrangian, $\mathcal{L}$, at every point along each path. Different paths will give different answers. The one with the "extremal" – often least – answer will be the one the system takes.

8

But, what's this mysterious $\mathcal{L}$ that you use to get the "action"?

For a simple system of particles, $\mathcal{L}$ = KE − PE.

Look at a falling object:



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More fundamentally:

$$\mathcal{L}_{\text{all}} = \underbrace{R}_{\text{grav}} - \underbrace{\tfrac{1}{4}F_{\mu\nu}F^{\mu\nu}}_{\text{bosons}} + \underbrace{i\bar{\psi}\gamma^{\mu}D_{\mu}\psi}_{\text{fermions}} + \text{Higgs}$$

The boson term includes the weak nuclear, the strong nuclear and the _____________ interactions.

Let's get back to electromagnetism.

10

Use all the powers of your imagination to imagine water in them pipes.

(6) In which direction will the water flow?________

11

(7) What, in the name of energy, causes water to flow downhill? ____________________________ _______

Electricity, too, flows from high PE to low PE. For _________________ that would be a flow from high to low _____________________.

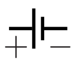
12

ADDITIONAL NOTES

The Electric Battery

A battery is a device that creates a pot. difference.

Invented by Volta around 1800.

Symbol: 

The $+$ and the $-$ indicate that the $+$ end has a higher potential than the $-$. It's the ____________ ________________________ that moves charges.

13

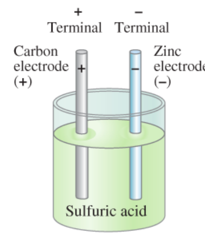


Figure 18–3

A chemical battery

14

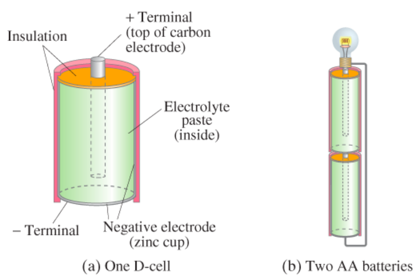


Figure 18–4

Batteries in action. Two "in series" double the voltage

15

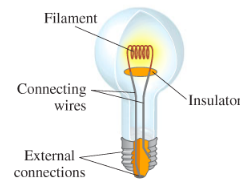


Figure 18–5

A light bulb: Connected correctly, batteries make the bulb shine. How?

16

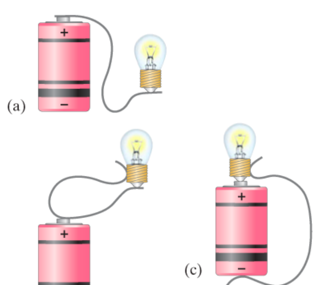


Figure 18–7

Wrong Right

17

Electric Current

The ____ ______________________

I is measured in Coulombs/sec, and is given a special name: ____________________

18

ADDITIONAL NOTES

(8) How much charge is transferred by a current of $10\,\text{A}$ in $2\,$mins? How many electrons is that?

19

(9) What current, in amperes, transfers a billion electrons in $5\,$mins?

20

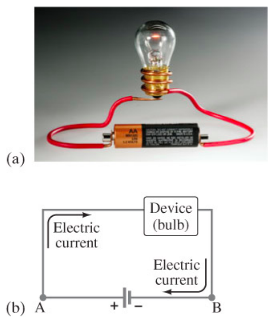


Figure 18–6

The electric current makes the bulb shine

21

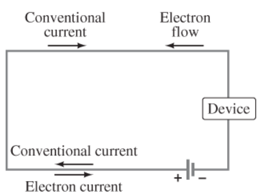
The Direction of the Current

Back in the day, people seem to have proceeded by analogy with gravitation and had current move from high potential to low.

(10) What does that imply about the charge carriers of current – positive or negative? ________

22

(11) What charges do we now believe are the movers?______________________________



Conventional current versus electron

23

Ohm's Law

For many substances, applying a potential difference, V, to two ends makes a current, I, flow from one end to the other. Applying twice the potential difference makes twice the current flow.

(12) What is this type of relationship called?

____

24

ADDITIONAL NOTES

We express this as ______ called ________.

The constant, R, is called the ______ *of that particular conductor,* and is measured in ______

R is ________ unlike k in Colulomb's Law:

$$F = k\frac{q_1 q_2}{d^2}.$$

25

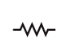
Ohm's Law is an empirical, approximate law, not a fundamental law of nature.

It applies well to some substances (metals, such as copper or silver) and poorly to others (rubber).

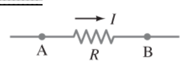
Even for substances to which it applies there's a range of conditions (temperature range, in particular) outside which it fails.

26

Every conductor, every device has some resistance to the flow of current. Symbolically, the resistance is shown this way:



(13) Is the potential at A higher or lower than at B? __________



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(14) A potential difference of $100\,\text{V}$ is applied to a device and causes a current of $5\,\text{mA}$ to flow through it. What is the resistance of the device?

28

Resistivity

For a long conductor, such as wire,

$$R = \rho\frac{l}{A}$$

where l is the length of the conductor, A the cross-sectional area, and ρ the __________

The resistivity is characteristic of the material.

29

For each of ρ, l and A what is the effect of increasing and decreasing it on the resistance, R?

30

ADDITIONAL NOTES

The resistivities of a few substances (in $\Omega \cdot m$) are

Silver: 1.59×10^{-8}
Copper: 1.68×10^{-8}
Aluminum: 2.65×10^{-8}
Rubber: $\sim 10^{14}$

31

(15) What's the best material of these for conducting wires? Insulating wires? ______

(16) Yet, what material is more common, and why? ______

(17) For overhead transmission lines aluminum is often used. Why? ______

32

(18) What is the resistance of a $2.75\,\text{km}$ length of copper wire of diameter $2.5\,\text{mm}$?

$R =$

33

Electrical Power

$$P = IV = I^2R = \frac{V^2}{R}$$

As with all power, it is measured in ______.
(19) What is the power drawn by a $5\,\text{V}$ device that has a resistance of $7\,\Omega$?

34

What Moves when Current Flows?

Electrons drift "against the current," but the current moves more swiftly, propelled by the electric field.

As we will see there are three motions of interest.

35

ADDITIONAL NOTES