Efficiency of the pump in the conversion of electric energy to potential energy

Task and equipment

Information for teachers

Additional information

The efficiency attained in this experiment, only 2 % to 3 %, is very low compared to that of pumps used in practice, which can reach 20 % to 90 %. This difference is mainly due to the size of the pump and, in particular and despite the small scale of it, the fact that the robustness needed for the stability of the rotor is attained at the cost of the performance.

Notes on the setup and procedure

Students must always stand behind the wind generator during the experiment for avoidance of a risk of injury.
Make sure that there is no air in the pump as this would result in a greatly reduced performance.
It is advisable to use exclusively distilled water to avoid jamming of the impeller and other problems associated with furring.

Measures for improvements in pump performance:
- Switch the voltage source on and off several times so that the water head air that has formed is pressed out by the water return.
- If necessary, incline the pump and then switch the voltage source on and off several times.
- Knock the pump lightly against the bottom of the dish.
- Turn the impeller in the pump should it have jammed, for example because of furring.
(The impeller is visible through the opening in the bottom of the pump.)

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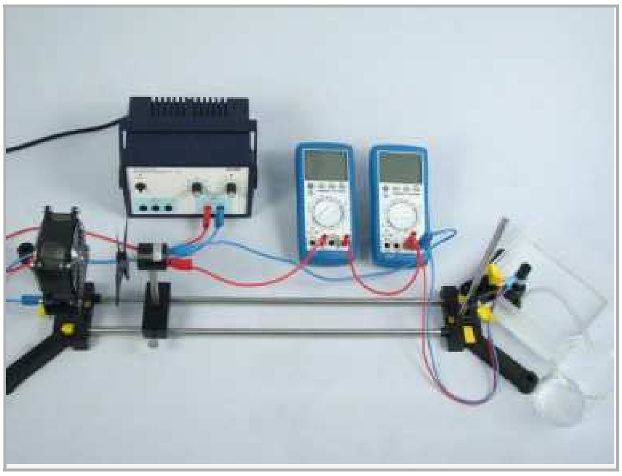
Task

How efficiently does the pump work?

The purpose of this experiment is to bring home the efficiency calculation.



Equipment

Position No.	Material	Order No.	Quantity
1	Connecting cord, 32 A, 250 mm, red	07360-01	2
2	Connecting cord, 32 A, 500 mm, red	07361-01	1
3	Connecting cord, 32 A, 500 mm, blue	07361-04	2
4	Support base, variable	02001-00	1
5	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
6	Blower, 12V	05750-00	1
7	Generator with metrical thread axis and nut	05751-01	1
8	Rotor, 2 pieces	05752-01	1
9	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
10	Measuring tape, l = 2 m	09936-00	1
11	Slide mount for optical bench	09822-00	1
12	Glass beaker DURAN®, short, 400 ml	36014-00	1
13	Boss head	02043-00	1
14	clamp, d = 16 mm, with mounting rod	05764-00	1
15	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
16	Water pump/ water turbine/ generator	05753-00	1
17	Dish, plastic, 150x150x65 mm	33928-00	1
18	DMM with NiCr-Ni thermo couple	07122-00	2
19	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
	Water		

Set-up and procedure

Set-up

Construct the rail support from the variable support stand and the two rods (Figs.1 and 2).

Fig. 1

Fig. 2

Fit the short support rod in the right part of the support stand and the blower in the left part so that the side with the sockets is facing away from the rail support (Fig. 3).

Fig. 3

Successively plug the two rotors on the axis of the generator (Fig. 4).
The six vanes must be at the same distance from each other, with the writing readable from the front (Fig. 5).

Fig. 4

Fig. 5

Fix the generator in the slide mount and position it so on the rail support that the distance between generator and blower is 5 cm (Fig. 6).

Fig. 6

Connect the blower to the direct voltage output of the power supply with the long cables (Fig. 7).
The power supply is in the switched-off state.

Fig. 7

Use the boss head to fit the clamp on the short rod (Fig. 8).

Fig. 8

Position the plastic dish so that one corner is under the clamp. Fix the tubing to the pump and press the pump in the clamp. The pump should be at a distance of about 2 mm from the bottom of the dish (Fig. 9).

Fig. 9

Connect the pump to the voltmeter as shown in Fig. 10.

Fig. 10

Connect an ammeter to go out from the generator and in series with the pump so that the following circuit diagram is given (Fig. 11)
In reality, it should look as in Fig. 12.

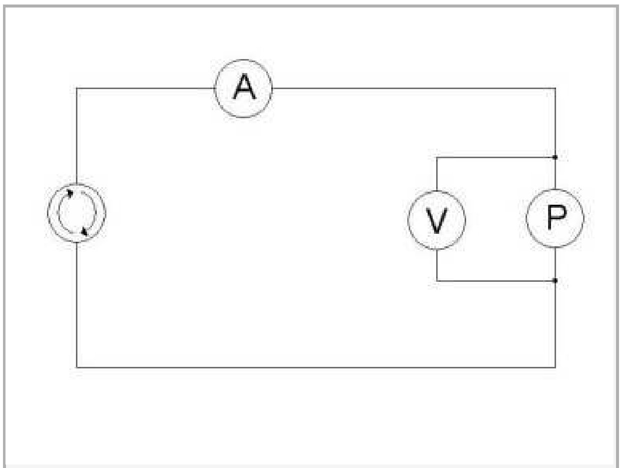


Fig. 11

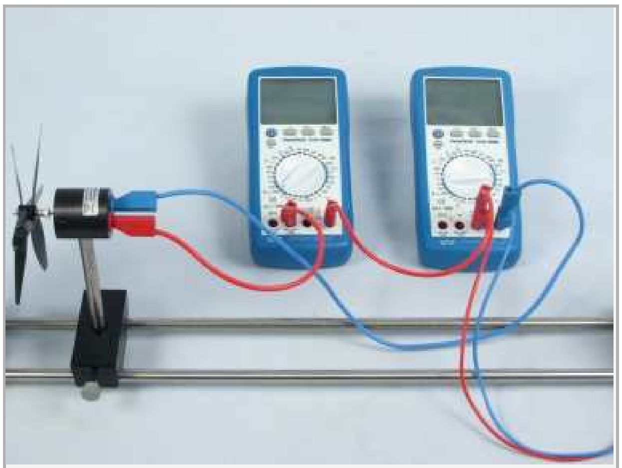


Fig. 12

Fill water into the plastic dish until the pump stands to about 2 cm in water. Position the large beaker under the free end of the tubing from the pump (Fig. 13).

Fig. 13

The complete experimental set-up should now look as shown in Fig.14.

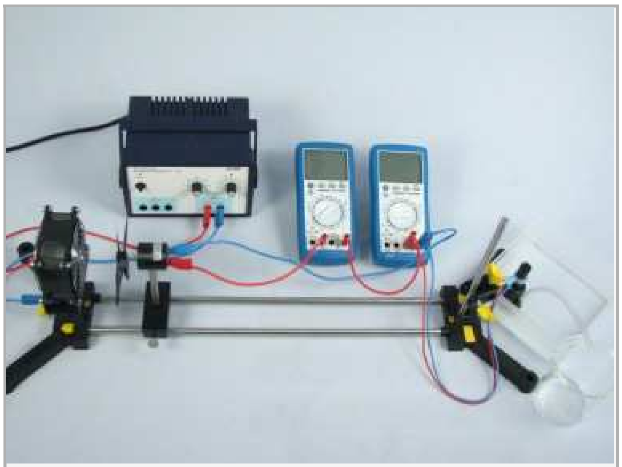


Fig. 14

Procedure

Turn the adjusting knobs for voltage and current completely clockwise.
Set the measurement range of the voltmeter to 20 V- and that of the ammeter to 200 mA-.

Switch the power supply on and check that the pump is running properly. Observe the note below regarding this.
Allow the pump to run for about a minute, then switch it off and empty the beaker before you start to carry out the actual measurement.

Press the tubing gently against the edge of the beaker and note under Result - Observations the height (h) which the water must overcome.

Continue pressing the tubing gently against the edge of the beaker and start the stop watch when you now switch the power supply on (Fig. 15).

Fig. 15

Note the distance a = 5 cm between wind generator and rotor, the voltage (U), the current (I) and the time (t) required to fill the 200 ml beaker with water in Table 1.

Switch the power supply off, empty the beaker in the tray and repeat the procedure but with a distance (a) between wind generator and blower of 10 cm. Again enter the results in Table 1.

Switch the power supply off.

Note:
If you have adhesive tape available, use it to fix the tubing to the beaker, so that it does not have to be held down by hand.
The tubing can also be held down, for example, by a pen placed across the beaker.

Should the pump not run properly, try the following helping measures:
- Knock the pump gently against the bottom of the dish
- Switch the power supply on and off several times.
- Turn the impeller from the pump underside.

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Result - Observations

Which height *h* must the water overcome?

Result - Table 1

Record your measured values in the table.

a in cm	*U* in V	*I* in mA	*t* in s
5	1 ±0	1 ±0	1 ±0
10	1 ±0	1 ±0	1 ±0

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Evaluation - Question 1

Calculation of the potential energy

The height reached by pumping gives the water a potential energy that is utilisable.

Use the following formula to calculate the utilisable energy obtained with each of the distances *a* (5 cm, 10 cm):

$E_{pot} = m \cdot g \cdot h$

m = Mass of the water in kg

g = Acceleration due to gravity = 9,81 m / s^2

h = Height the water had to overcome in m

Note:

1 Litre of water weighs 1 kg.

Evaluation - Question 2

Calculate the electric energy

The pump was supplied with electric energy to lift the water up high.

Use the following formula to calculate the energy needed for each distance *a* (5 cm, 10 cm):

$E_{el} = U \cdot I \cdot t$

U = Voltage applied in V

I = Current supplied in A

t = Time in s

Remember that *I* is given in mA in Table 1.

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Evaluation - Question 3

Calculation of the energetic efficiency

Energetic efficiency describes the relationship between the actually utilisable energy and the energy supplied. In this experiment, we supplied electric energy and wanted to bring the water to a certain height with the help of a pump.

Calculate the energetic efficiency as given. What does this tell us?

Note:

1 Litre of water weighs 1 kg.

$$\eta_a = \frac{E_{usable}}{E_{supplied}} = \frac{E_{potential}}{E_{electrical}} = \frac{m \cdot g \cdot h}{U \cdot I \cdot t}$$

η_a = efficiency at a distance of a

a = distance between wind generator and rotor in cm

m = mass of water in kg

g = gravitational acceleration = $9{,}81 \frac{m}{s^2}$

h = height to overcome for water in m

U = applied voltage in V

I = applied current in A

t = time in s

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Evaluation - Question 4

Why is the energetic efficiency of the pump not 100 %?

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Evaluation - Question 5

How are the greatly better efficiencies of up to 90 % reached by pumps used in practice?

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