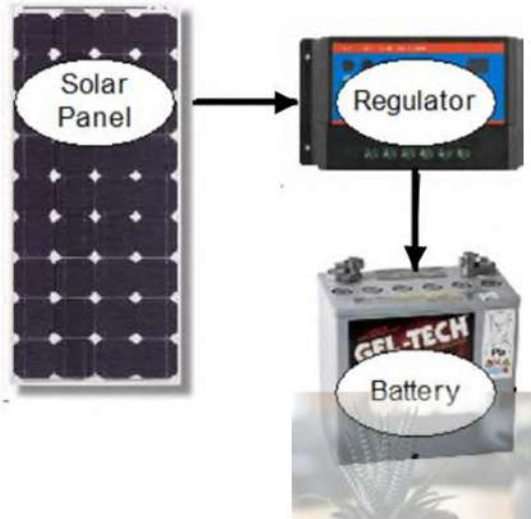
NATURAL SCIENCES GRADE 9 **TERM 3 PROJECT**
MARKS: 30

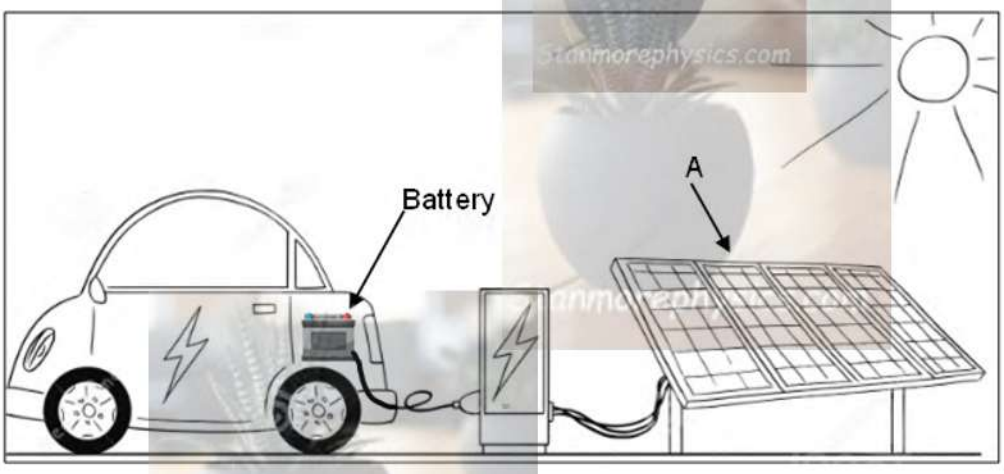
SOLAR POWER, FOR TODAY AND TOMORROW

SECTION A: BACKGROUND KNOWLEDGE

A **solar panel** converts energy from the Sun into electrical energy which can be used to charge a **battery**. This electricity is fed to the battery via a **solar regulator** which ensures the battery is charged properly and not damaged. The battery is in effect used to store the solar energy from the sun. High quality batteries can be re-charged multiple times.



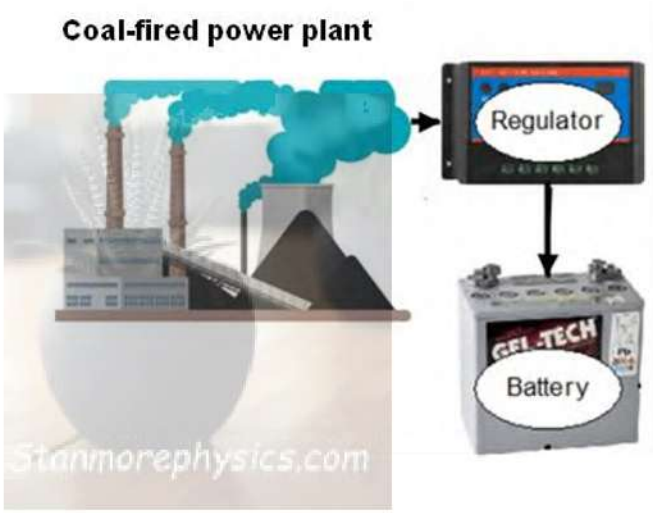
Study the diagram below:



1. Label A and state the energy conversion that takes place in A. (3)

2. The vehicle in the picture is an example of a battery-operated vehicle which does not make use of combustible fuel as an energy source.
   What energy conversion takes place in the engine of this vehicle? (2)

Batteries can also be charged with energy from other sources. This includes electricity received from coal-fired power plants.



3. Copy the following table and tabulate advantages and disadvantages of solar energy and the energy coming from fossil fuels (e.g., coal) when electricity needs to be generated for the community in large quantities.

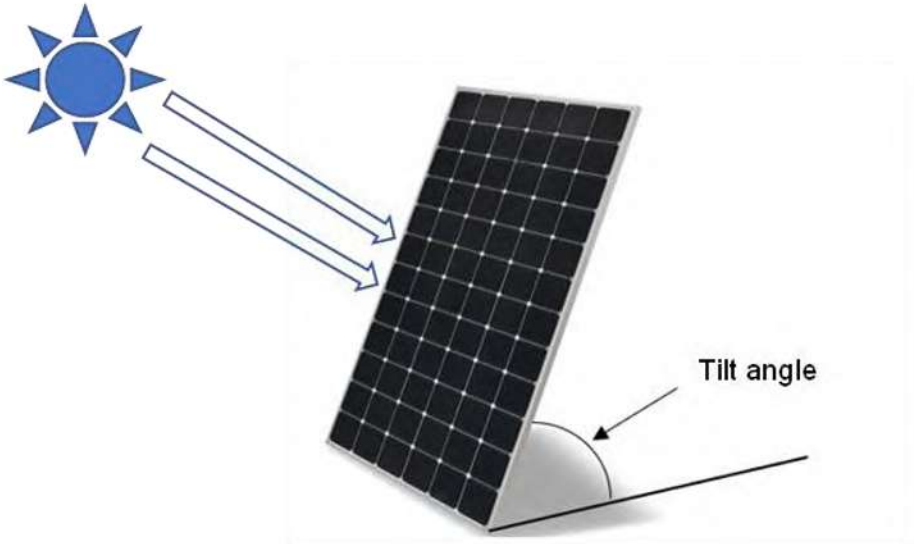
	Advantages	Disadvantages
Solar energy		
Fossil fuels		

(4)
[9]

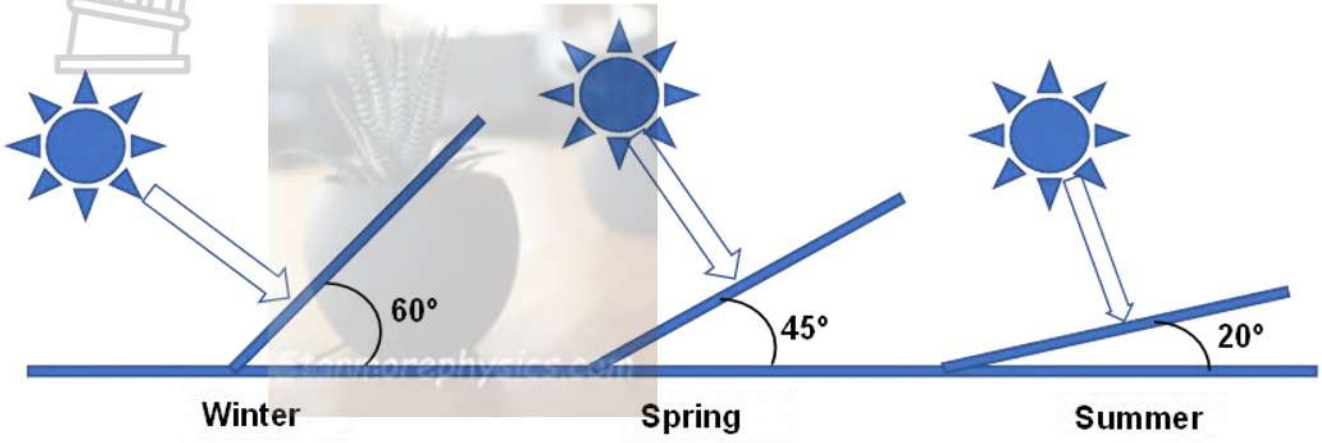
SECTION B: SCIENTIFIC INVESTIGATION

Why is the tilt of the solar panels so important?

The angle between the horizontal plane and the solar panel is called the tilt angle



The tilt angle of the panels is important because solar panels will produce a maximum energy when the sun is directly perpendicular to them. During the winter, for example, the sun is low in relation to the horizon. In this case, for the solar panels to get their best performance, a steep angle or tilt of 60° is best. During the spring the best angle is 45°, and during the summer when the sun is high in the sky, it's best to have lower tilt, in the region of 20°. It is, however, not practical to adjust the tilt of solar panels after they have been installed on roof structures, poles etc.



A project was launched to establish the best **fixed tilt angle** at which solar panels should be installed, which will give the user the maximum amount of **energy-output** when measured over a period of one year (annual energy-output). Energy-output refers to the amount of energy in kWh which is converted from sunlight energy to electrical energy and made available to output devices such as electrical appliances.

Seven solar panels were installed in an open field. Each panel was installed at a different fixed tilt angle. The energy-output of the seven panels were then measured over a period (time) of exactly one year (365 days).

The RESULTS can be found in the table below:

Panel number	Tilt (angle with the horizontal plane)	Total annual energy-output of the panel (kWh/year)
1	0º	350
2	10º	370
3	20º	390
4	30º	410
5	40º	385
6	50º	360
7	90º	220

4.1 Draw a bar graph to illustrate the annual energy-output at different tilt angles for the seven solar panels. (6)

4.1.1 Which tilt angle gives the highest annual energy-output? (1)

4.2 Which factors were kept constant (which variables were controlled) during this experiment? (3)

4.3 Identify the independent variable in this experiment. (1)

4.4 "In summertime the sun sits high above the horizon in the sky." Use this statement and explain why a fixed tilt angle of 90° produced such a low energy-output value. You can make use of a labelled sketch to explain your answer. (3)

[14]

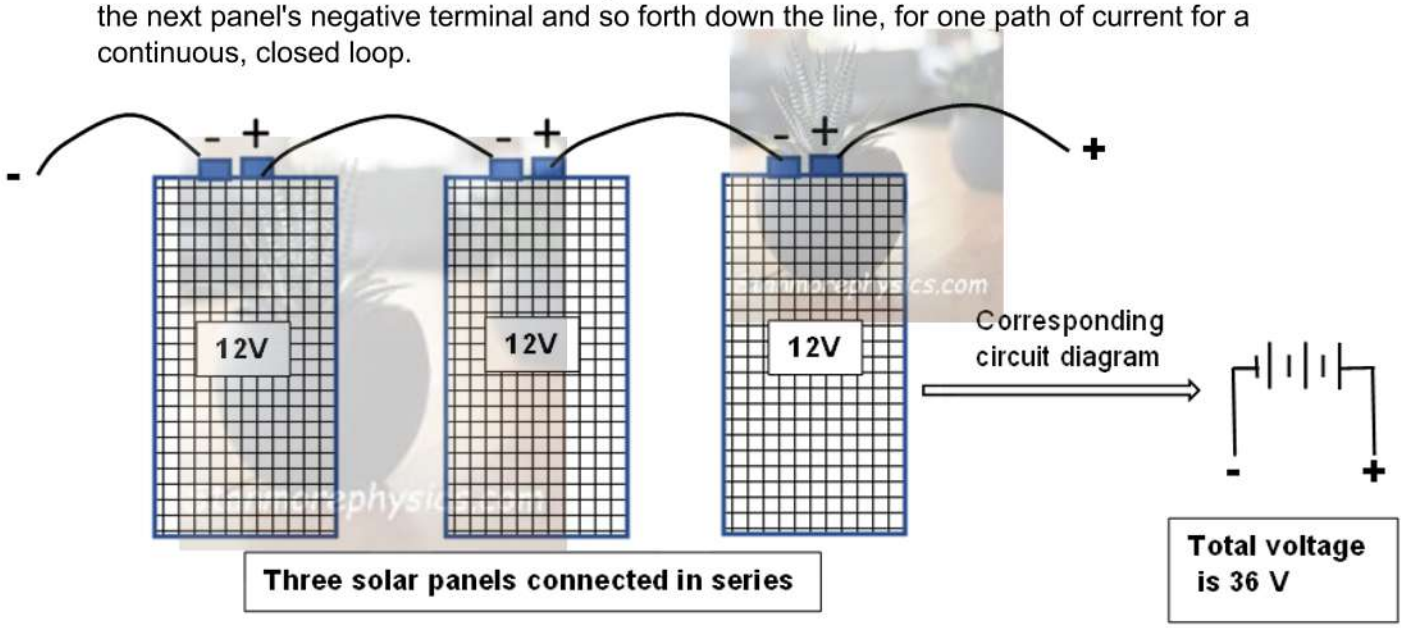
SECTION C

APPLICATION: WIRING SOLAR PANELS - IN SERIES OR PARALLEL?

The important difference between wiring panels in series or in parallel is that it affects the voltage of the circuit. In a series circuit, you sum the voltage of each panel to get the overall voltage. With panels connected in parallel, the voltage of the overall circuit stays the same with every panel added in parallel.

Series

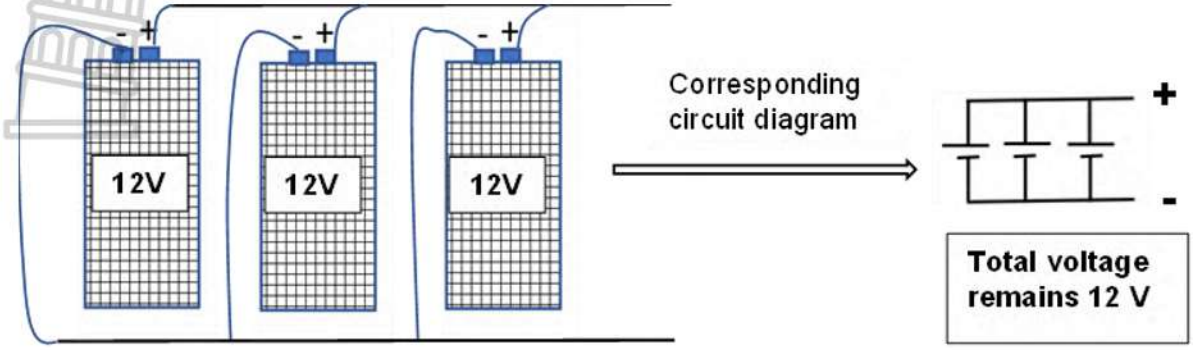
When you connect your solar panels in series, you are wiring each panel to the next. This creates a string circuit. The wire running from the panel's positive terminal is connected to the next panel's negative terminal and so forth down the line, for one path of current for a continuous, closed loop.



In a series circuit, the sum of the voltage of each panel is equal to the overall voltage of the array (combination of panels).

Parallel

Instead of connecting each panel to the next, with a parallel connection, each panel is connected to a centralised wire. There is one wire for connecting the wires from all the positive terminals and one wire for the wires from the negative terminals.

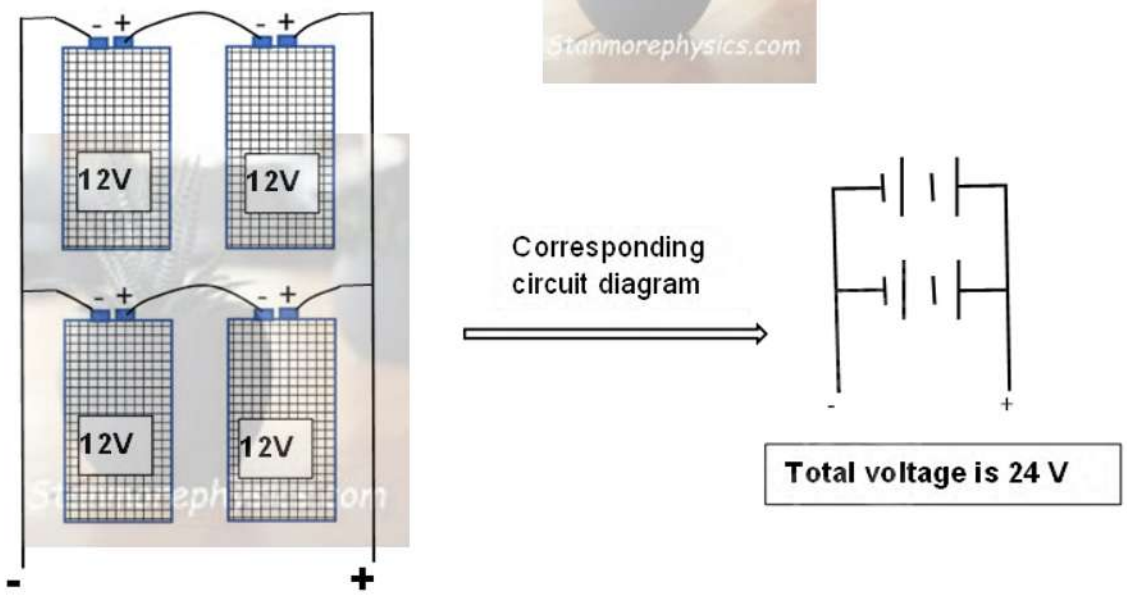


Three solar panels connected in parallel

With panels connected in parallel, the voltage of the overall circuit stays the same as the voltage for each individual panel.

In practice

When installing a solar panel system, there will probably be a combination of parallel and series connections. You could for instance have 4 panels, with 2 branches of 2 panels. Each branch contains two panels connected in series.



Four solar panels connected in a combination of series and parallel

5.1. Use your knowledge on series and parallel circuits and explain why the total voltage in the previous example is given as 24 V. (2)

5.2 Some of the solar panels on the roof of the house below is sometimes partially in the shade of a tree.

All commercial solar installations are done by connecting solar panels in combinations of series AND parallel connections.

5.2.1 Give TWO reasons why solar panels are almost never connected in series only. (2)

5.3 An electrical contractor is given 18 solar panels with a voltage rating of 40 volts each. He is expected to install all of the panels in such a way that the total voltage output of the installation (array) is 240 V.

5.3.1 Draw a diagram which indicates how the solar panels should be connected to achieve the required voltage of 240 V by using **all of the solar panels.** Indicate the positive and negative poles on each of the solar panels. (**Hint:** A combination of series and parallel connections is needed to achieve the above requirement.) (3)

[7]

TOTAL MARKS: 30

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MARKING GUIDELINE **MARKS: 30**

1. A = Solar panel ✓
   Energy is converted from light energy✓ (OR solar energy) to electrical energy.✓ (3)

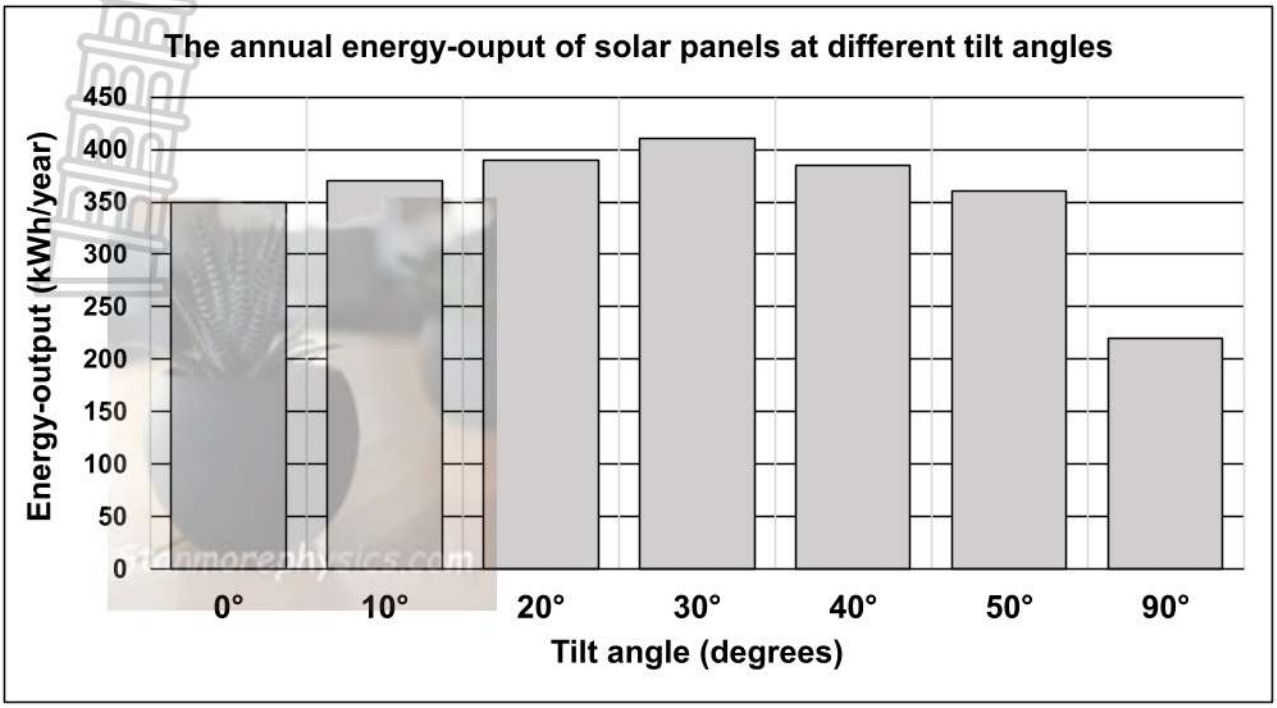
2. Electrical energy✓ is converted to kinetic energy.✓ (2)

3.

	Advantages	**Disadvantages**
Solar energy	Solar energy is an inexhaustible and renewable energy source. Solar power is pollution-free and produces no harmful greenhouse gases. Solar power reduces our country's dependence on foreign oil and fossil fuels as an energy source. Solar energy is a safe energy source with no potential harmful radiation like nuclear power.	Large areas (of land) need to be covered with solar panels for effective generation of solar energy. Solar power is not 100% reliable. E.g., when the sun is not shining or during night-time, there is no generation of electricity. Expensive to install.
Fossil fuels	Large amounts of energy can be produced in a reliable manner (including during night-time). Fossil fuels are considered as a cheap energy source. Fossil fuels as a resource to generate electricity is considered as a mayor job creator,	All fossil fuels are non-renewable sources of energy which will be depleted over time. Fossil fuels are responsible for global warming and climate change. **Other disadvantages include:** • Water pollution and oil spills. • Refinery- and oil-rig explosions. • Acid rain. • Air pollution that causes lung disease in animals and humans.

One advantage✓ and one disadvantage✓ of solar energy.
One advantage✓ and one disadvantage✓ of fossil fuels.
Alternative answers (not included in the table) can also be considered. (4)
[9]

4.1.1



4.1

Marking criteria	Marks
Type of graph; **bar graph**, with equal spaces between y-axis and other bars	✓
Heading; containing both variables (energy-output and tilt angles)	✓
Label on x-axis; degrees indicated	✓
Label on y-axis, with unit (kWh/year)	✓
First four bars plotted correctly; Last three bars plotted correctly	✓ ✓

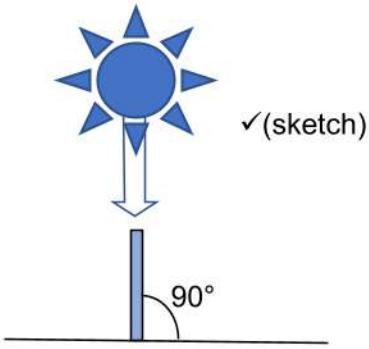
(6)

4.1.1 30° ✓ (1)

4.2 Type/size of solar panels / Ability of the solar panels to convert solar energy ✓
Time / Period ✓(The experiment was conducted over a period of one year.)
Amount of daily sunlight.✓ (All panels were installed in the same open field; therefore, all the panels received the same amount of sunlight per day.) (3)

4.3 The tilt angle✓ (1)

4.4.



✓(sketch)

With a tilt angle of 90° the flat surface of the solar panel receives very little direct sunlight.✓ The panel will be able to absorb only a small amount of solar energy✓ and therefore produce a small amount of electrical energy (output-energy).

(3)
[14]

5.1 Each parallel branch consists of two 12 V-panels connected in series which can produce a potential difference of:

12 V x 2 = 24 V✓ per branch

The total potential difference (voltage) of the two branches connected in parallel remains 24 V.✓ (2)

5.2 If one solar panel connected in series gets damaged / malfunction / is in the shade, then the current stops flowing, and no solar energy can be converted to useful electrical energy.✓

The voltage of solar panels connected in series are added up to get the total voltage of a solar panel installation. When installing a large number of panels in series ONLY the total voltage output might exceed the maximum potential difference that the regulator can handle.✓ Therefore a combination of series and parallel connections are more practical. (2)

5.3

SIX panels connected in series with each other, in each of THREE branches.✓

Three branches connected in parallel with each other. ✓

Positive and negative terminals indicated, and panels wired correctly to each other.✓

(3)
[7]

TOTAL: 30