ANSWER KEY

SCIENCE OLYMPIAD™
Exploring the World of Science

Wind Power Exam

Science Olympiad – Division B
Casa Grande Invitational
16th January 2016

Team Number: _____

School: _____

Students: _____

_____

Exam Points	_____	/ 50
Blade Points	_____	/ 50
Total Points	_____	/ 100

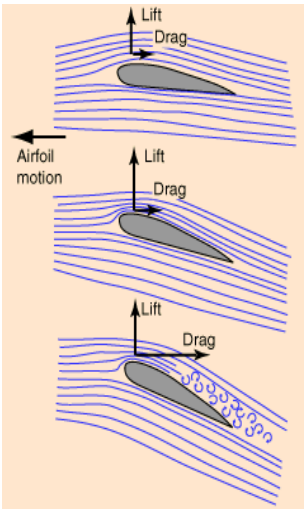
While waiting to be called to demonstrate your Blade Assembly you should work ***silently*** with your partner and complete this exam. You may not talk to anyone else while working on this exam. Please answer all questions legibly. For multi-choice answers circle the letter corresponding to your answer. If multiple answers are possible pick the best one.

1) With the air flowing from left to right, which of the following wind turbine blade angles is likely to produce the most electrical power ? (1 pt)

a.

b.

c.



2) What is the wind power passing through a wind turbine with the following conditions? Turbine radius = 0.2m, Wind speed = 3 m/s, Air density = 1.23 kg/m^3 (2 pts)

$0.5\ A\ \rho\ v^3 = 0.5 * (pi * 0.2^2) * 1.23 * 3^3 = 0.0628 * 1.23 * 27 = 2.086$ W

3) The Betz Limit (or Betz' Law) specifies the theoretical maximum power efficiency of any design of wind turbine. What is the value as a percentage? (1 pt)

59.3 %

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4) A wind turbine has a 5 ohm resistor connected in series with the CD motor, and the voltage measured across the resistor is 100 mV. Include units in your answer (2 pts)

   a. What is the current flowing through the resistor? 100 mV / 5 ohms = 20 mA

   b. What is the power generated by the CD motor? 100 mV * 20 mA = 2 mW

5) Which of the following is **NOT** a type of wind turbine? (1 pt)
   a. Savonius
   b. Fuller
   c. Cumulus
   d. Darrieus

6) In what year was the first electricity generating wind turbine built? (1 pt)
   a. 1776
   b. 1810
   c. 1887
   d. 1921
   e. 1950
   f. 2000

7) What do the following acronyms stand for? (3 pts)
   a. AC ____ALTERNATING CURRENT_____
   b. DC _____DIRECT CURRENT_____
   c. HVDC ____HIGH VOLTAGE DIRECT CURRENT _____

8) What is the SI Unit for: (2 pts)
   a. Energy _____JOULE_____
   b. Power _____WATT_____

9) Why is AC mostly used for distributing electricity instead of DC? (2 pts)

THE VOLTAGE CAN BE STEPPED UP AND DOWN USING TRANSFORMERS TO REDUCE LOSSES

10) In the U.S. in 2014 what percentage of the energy consumed to generate electricity is lost due to conversion losses in electricity generation, transmission and distribution? (1 pt)
   a. 7%
   b. 32%
   c. 65%
   d. 91%

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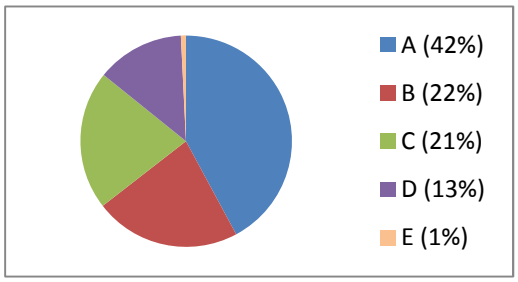
11) For each of the different energy sources, indicate if they are renewable or not: (3 pts)

Energy Source	Renewable	Not Renewable
Solar	X	
Oil (Petroleum)		X
Nuclear		X
Wind	X	
Gas		X
Tidal	X	
Geothermal	X	
Biomass	X	

12) The pie chart shows how much of different energy sources the U.S. used in 2014 to generate electricity. Identify each by writing the corresponding letter next to the energy type: (2 pts)



i. Oil (Petroleum) __E__
ii. Coal __A__
iii. Nuclear __C__ B and C can be swapped because they are close
iv. Natural Gas __B__
v. Renewables __D__

13) On July 9th, 2015 Denmark achieved a record by using wind turbines to generate 140% of the electricity that it was consuming. What did it do with the excess 1 GW electric power? (1 pt)

a. Sell it to Norway, Sweden and Germany
b. Bury it in Russia
c. Recharge 2300 Lead Acid car batteries
d. Store it in the Baltic Sea
e. Donate it to Tesla

14) Which of the following is **NOT** an electricity grid within the US? (1 pt)

a. Eastern Interconnection
b. Northern Interconnection
c. Texas Interconnection
d. Western Interconnection

15) Why is pumped hydro electricity a complementary technology to wind turbines and solar? (1 pt)

NON-DEPENDABLE ENERGY SOURCES CAN BE STORED FOR USE LATER WHEN NO WIND / SUN

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16) Windmills / wind turbines have **NOT** been used to: (1 pt)

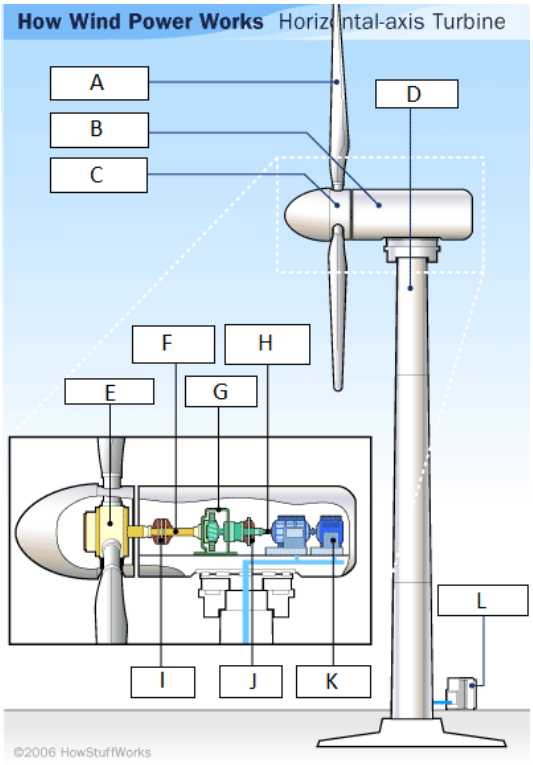
a. Grind grain
b. Pump water
c. Make gun powder
d. Charge batteries

17) Electrical energy is normally measured in kWh, but the SI unit is Joules. How many Joules are in 1 kWh? (1 pt)

3.6 MJ = 3,600 kJ = 3,600,000 J

18) Identify the parts of the horizontal axis wind turbine shown below by writing the letter next to the description that best fits: (6 pts)

i.	Brake	I or J
ii.	Brake	I or J
iii.	Gearbox	G
iv.	Generator	K
v.	High Speed Shaft	H
vi.	Low Speed Shaft	F
vii.	Nacelle	B
viii.	Rotor Blade	A
ix.	Rotor Hub	C or E
x.	Rotor Hub	C or E
xi.	Tower	D
xii.	Transformer	L



19) A 70 km long electrical power line carries power from Palo Verde to Phoenix. The line supplies 750 MW on a 500 KV line. The line has a resistance of 0.1 ohms per km. Assume all values are RMS and only pure resistive effects. Include units. (4 pts)

a. What is the current flowing along the line? **750 MW / 500 KV = 1,500 A**

b. What is the voltage drop between the ends of the line? **1,500 A * 70 * 0.1 = 10.5 kV**

c. How much power is lost in the line? **1,500 A * 10.5 kV = 15.75 MW**

d. What percentage of the power that the line supplies is lost in the power line? **2.1%**

ANSWER KEY

20) The highest generation capacity (MW) pumped hydro facility in the world is Bath County Pumped Storage Station in Virginia. The upper and lower reservoirs are separated by 380m in elevation. It is approximately 88% efficient in generating and in pumping modes. (5 pts)

a. What is the roundtrip efficiency of the facility (storing and then generating electricity)?

88% * 88% = 77.44%

b. If the dam releases 100 m^3/s of water how much electric power will be produced?

P = 88% * m * g * h = 0.88 * 100,000 * 9.81 * 380 = 328 MW

c. How many cubic meters (m^3) of water will be pumped up by 1 kWh of electric energy?

V = 88% * (1000 * 60^2) / (1000 * 9.81 * 380) = 0.85 m^3

21) At what time is energy **most** likely to be stored in an energy storage facility? (1pt)

a. 3 am
b. 9 am
c. 3 pm
d. 9 pm

22) Which technology is **NOT** used for energy storage? (1 pt)

a. Compressed gas
b. Flywheels
c. Hydrogen
d. Tidal
e. Superconducting magnets
f. Zinc / Air batteries

23) HAWT (Horizontal Axis Wind Turbine) and VAWT (Vertical Axis Wind Turbine) designs have advantages and disadvantages over each other. For each of the reasons below mark if it is an advantage for a HAWT or an advantage for a VAWT: (3 pts)

Reason	HAWT advantage	VAWT advantage
Less strain on the axle, reduces maintenance	X	
Easy maintenance because rotor housing is near ground		X
Wind direction does not matter		X
Has a higher efficiency because the blades don't rotate into the wind (so don't drag)	X	
Can be installed in locations where taller structures are prohibited or are undesirable		X
Higher installations increase the available wind energy	X	

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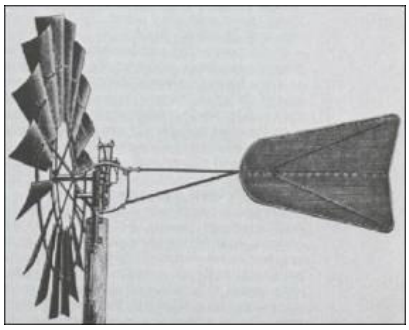

24) In 1854 Daniel Halliday invented a farm wind pump that has been adopted throughout the world for pumping water in remote locations. It was successful because of two key features. Please explain the benefit of each feature: (2 pts)

a. Self Directing

AUTOMATICALLY TURNS SO THAT THE BLADES FACE INTO THE WIND

b. Self Governing

BLADES AUTOMATICALLY FURL WHEN WIND SPEED INCREASES TO AVOID DAMAGING THE PUMP IN STRONG WINDS

25) Based on the information below, which bulk energy storage technologies would you consider if you wanted a low cost, short term, electrical energy storage? (2 pts)

FLYWHEELS
SUPER CAPACITORS

Technology	Location	Output	Efficiency (%)	Initial investment cost (USD/kW)	Primary application
PSH	Supply	electricity	50 - 85	500 – 4,600	long-term storage
UTES	Supply	thermal	50 - 90	3,400 – 4,500	long-term storage
CAES	Supply	electricity	27 - 70	500 - 1 500	long-term storage
Pit storage	Supply	thermal	50 - 90	100 – 300	medium
Molten salts	Supply	thermal	40 - 93	400-700	high-temperature applications
Batteries	Supply, demand	electricity	75 - 95	300 – 3,500	distributed/ offgrid storage, short-term storage
Thermo-chemical	Supply, demand	thermal	80 ~ 99	1,000 – 3,000	low, medium, and high temperature applications
Chemical – hydrogen storage	Supply, demand	electrical	22 - 50	500- 750	long-term storage
Flywheels	T&D	electricity	90 - 95	130 – 500	short-term storage
Super-capacitors	T&D	electricity	90 - 95	130 – 515	short-term storage
Solid media storage	Demand	thermal	50 - 90	500 – 3000	medium temperature applications
Ice storage	Demand	thermal	75 - 90	6,000 – 15,000	low temperature applications

IEA - Energy Storage Technology Roadmap – Technology Annex, 19 March 2014
https://www.iea.org/media/freepublications/technologyroadmaps/AnnexA_TechnologyAnnexforweb.pdf