Question 2

(a) Identify THREE strategies that the federal government could implement to encourage the use of battery electric vehicles (BEVs).
(3 points: 1 point for each strategy; examples of acceptable strategies are shown)

The federal government could:

- Increase subsidies for BEV industry **OR** decrease subsidies for ICE industry
- Increase tax on carbon/gasoline/diesel fuel
- Offer tax incentives or rebates for purchasing BEVs **OR** institute a tax on the purchase of ICE vehicles
- Increase subsidies for power companies **OR** decrease subsidies for petroleum industry
- Run educational campaigns/commercials/PSAs supporting BEVs
- Allow BEVs to use HOV/carpool lanes or provide funds for BEV lanes
- Replace federal ICE vehicles with BEVs
- Restrict ICE vehicles (e.g., prohibit use of ICE vehicles in urban areas or at certain times)
- Make charging stations more accessible
- Adopt stricter federal standards for tailpipe emissions or gas mileage (e.g., CAFE)
- Offer tax incentives for purchasing home charging stations
- Offer financial incentives for trading in an ICE vehicle for a BEV

(b) Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs $3.75 per gallon (gal). Calculate the cost of gasoline per mile.
(2 points: 1 point for the correct setup (including units) and 1 point for the correct answer)

$$\frac{\$3.75}{\text{gal}} \times \frac{\text{gal}}{25 \text{ miles}} = \$0.15 \text{ [per mile]} \quad \textbf{OR} \quad \frac{\$3.75}{25 \text{ miles}} = \$0.15 \text{ [per mile]}$$

Question 2 (continued)

(c) The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is $0.11 per kilowatt-hour (kWh).

(i) Calculate the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with.
(2 points: 1 point for the correct setup (including units) and 1 point for the correct answer)

$$7.0 \text{ hours} \times 4.0 \text{ kW} \times \frac{\$0.11}{\text{kWh}} = \$3.08^{*}$$

*$3.10 also earns a point.

(ii) Calculate the cost of electricity per mile to drive the BEV.
(1 point can be earned for the correct answer, with or without work shown; wrong answer from (c)(i), used correctly, can still earn a point)

$$\frac{\$3.08}{100 \text{ miles}} = \$0.03 \text{ [per mile]}$$

(d) Calculate the difference in the amount of CO_2 that would enter the atmosphere if both cars were driven 100 miles.
(1 point can be earned for the correct answer with work shown; first equation is optional)

72.8 + 17.7 = 90.5 lb
90.5 - 63.6 = 26.9 lb

Question 2 (continued)

(e) Describe TWO economic impacts (excluding costs related to climate change resulting from CO_2 emissions or the cost of gasoline at the pump) that result from an increased number of BEVs on the road.

(2 points: 1 point for each correct impact; only 1 point is allowed per row in table)

Impacts from Increased Use of BEVs Include:	Impacts from Decreased Use of ICE Vehicles Include:
Increase in jobs/profit in electrical industry (e.g., power plants, charging stations)	Decrease in jobs/profit in gasoline/petroleum industry (e.g., gas stations)
Increase in expenditures for production of electricity (e.g., exploration, coal mining, building wind farms) or for transport of coal/transmission of electricity **OR** Increase in revenue in industries related to the production of electricity (e.g., coal mines, wind turbine producers)	Decrease in expenditures for the production or transport of petroleum (e.g., exploration, drilling, refining) **OR** Decrease in revenue in industries related to the production or transport of petroleum (e.g., exploration, drilling, refining)
Increase in jobs/profit for manufacturing and repair of BEVs	Decrease in jobs/profit for manufacturing and repair of ICE vehicles
Increase or decrease in cost of BEVs with appropriate supporting explanation (e.g., economies of scale, law of supply and demand)	Increase or decrease in cost of ICE vehicles with appropriate supporting explanation (e.g., economies of scale, law of supply and demand)
Increase in expenditures associated with controlling smokestack emissions (e.g., SO_2) from power stations	Decrease in expenditures for cleanup of oil spills or gasoline leaks
Increase in price of electricity or fuel used to generate electricity because of increased demand **OR** Increase in household expenditures for electricity	Decrease in revenue from gas tax
BEV drivers save money that can be spent elsewhere	
Expenses required for installing charging stations or converting gas stations	
Decrease in expenditures for health care associated with exposure to air pollution (e.g., photochemical smog, gasoline vapors)	
Increase in expenses for/sales of batteries or for battery disposal	

2A1

2. Battery electric vehicles (BEVs) have been introduced to consumers as an alternative way to reduce the environmental effects caused by use of internal-combustion engine (ICE) vehicles. A comparison of both vehicle types can help determine whether the use of BEVs would be beneficial in the future. Where calculations are required, show your work.

   (a) **Identify** THREE strategies that the federal government could implement to encourage the use of BEVs.

   (b) Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs \$3.75 per gallon (gal). **Calculate** the cost of gasoline per mile.

   (c) The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is \$0.11 per kilowatt-hour (kWh).

      i. **Calculate** the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with.

      $\frac{\$.11}{kWh} \cdot \frac{7 hours}{1} \cdot \frac{4.0 kW}{1} = .77 \cdot 4$ \$3.08

      77 × 4 = 308

      ii. **Calculate** the cost of electricity per mile to drive the BEV.

When it is driven 100 miles, the ICE vehicle contributes 72.8 pounds (lb) of CO_2 from the burning of the gasoline. The drilling, refining, and transportation costs of getting the gasoline to the gas station add an additional 17.7 lb of CO_2 per 100 miles. The BEV does not emit any CO_2 itself, but the extraction, transportation, and combustion of the coal that produced the electricity at the power plant add 63.6 lb of CO_2 for the same 100 miles.

   (d) **Calculate** the difference in the amount of CO_2 that would enter the atmosphere if both cars were driven 100 miles.

   (e) **Describe** TWO economic impacts (excluding costs related to climate change resulting from CO_2 emissions or the cost of gasoline at the pump) that result from an increased number of BEVs on the road.

a) One strategy to promote BEVs would be the implemention of a gasoline tax. The higher gasoline prices would push consumers towards buying BEVs in hopes of saving money. Another strategy that could be employed by the federal government would be to set up tax exemptions for people purchasing BEVs. The economic incentive of saving tax dollars that would otherwise be used towards the federal sales tax would again encourage the use of BEVs. Lastly, the government could mandate a certain amount of recharging stations for BEVs on all major U.S. highways, making the use of BEVs more practical and accepted.

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2A₂

b) $\frac{\$3.75}{gal} \cdot \frac{1 gal}{25 mi} = \boxed{\$.15/mile}$

c) i) $\frac{\$.11}{1 KW\text{-}hour} \cdot \frac{7 hours}{1} \cdot \frac{4.0 KW}{1} = \boxed{\$3.08}$

ii) ~~$$$~~ $\frac{\$3.08}{1 charge} \cdot \frac{1 charge}{100 miles} = \boxed{\$.03/mile}$

d) 72.8 + 17.7 = 90.5   90.5 − 63.6 = $\boxed{26.9 lb \text{ of } CO_2}$

e) One economic impact would be the ~~expansion of electrical technology used to create~~ necessity for more recharging stations to be built, creating ~~a new~~ a cost that most gas stations would have to undertake. Also, less money would have to be dedicated to the reduction of pollution caused by the reduction in the amount of CO_2 being released ~~into~~ into the air.

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2B1

2. Battery electric vehicles (BEVs) have been introduced to consumers as an alternative way to reduce the environmental effects caused by use of internal-combustion engine (ICE) vehicles. A comparison of both vehicle types can help determine whether the use of BEVs would be beneficial in the future. Where calculations are required, show your work.

   (a) **Identify** THREE strategies that the federal government could implement to encourage the use of BEVs.

   (b) Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs \$3.75 per gallon (gal). **Calculate** the cost of gasoline per mile.

   (c) The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is \$0.11 per kilowatt-hour (kWh).

      i. **Calculate** the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with.

      ii. **Calculate** the cost of electricity per mile to drive the BEV.

   When it is driven 100 miles, the ICE vehicle contributes 72.8 pounds (lb) of CO_2 from the burning of the gasoline. The drilling, refining, and transportation costs of getting the gasoline to the gas station add an additional 17.7 lb of CO_2 per 100 miles. The BEV does not emit any CO_2 itself, but the extraction, transportation, and combustion of the coal that produced the electricity at the power plant add 63.6 lb of CO_2 for the same 100 miles.

   (d) **Calculate** the difference in the amount of CO_2 that would enter the atmosphere if both cars were driven 100 miles.

   (e) **Describe** TWO economic impacts (excluding costs related to climate change resulting from CO_2 emissions or the cost of gasoline at the pump) that result from an increased number of BEVs on the road.

2. A) Raising the price of gas necessary to power internal-combustion engine vehicles will deterr the public from wanted to continue to use them. Advertising the benefits, environmentally and economically, of purchasing a battery electric vehicle will also create interest for the public, or at least in those searching for a new car. Lastly, making the price for a battery electric vehicle initially lower than what one would have to pay for an internal-combustion engine vehicle will result in much of the public to go out and purchase these new modes of transportation.

b) \$3.75 gal = 25 miles

$25\overline{)3.75} = .15$; -25; 125; -125; 0

Cost of gas = \$0.15 per mile.

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2B2

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

c) (i) $\frac{(4.0\ kW)(7.0\ h) = 28\ kWh}{1} \Big| \frac{\$0.11}{1\ kWh} = 28 \times .11 = 3.08$ **\$3.08 to fully charge**

(ii) $\frac{\$3.08}{100\ miles}$ = cost per mile $100 \overline{)3.08} = 0.0308$ **\$0.03 per mile**

d) 72.9 lb CO_2 + 17.7 lb CO_2 = 90.5 lb CO_2 per 100 miles (ICE)

63.6 lb CO_2 = 63.6 lb CO_2 per 100 miles (BEV)

90.5 − 63.6 = 26.9 lb. CO_2.

~~ICE~~ ICE vehicles contribute 90.5 lb CO_2 per 100 miles while BEV's contribute only 63.6 lb CO_2 per 100 miles. **ICE vehicles contribute 26.9 more lbs. CO_2 per 100 miles than BEV vehicles.**

e) An increased number of BEVs would result in a probable increase in the cost of electricity as the demand for it would have risen dramatically. Another result would be the reduction of the prices of ~~former~~ internal-combustion engine vehicles as they aren't in such high demand anymore and have been out-dated.

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2C1

2. Battery electric vehicles (BEVs) have been introduced to consumers as an alternative way to reduce the environmental effects caused by use of internal-combustion engine (ICE) vehicles. A comparison of both vehicle types can help determine whether the use of BEVs would be beneficial in the future. Where calculations are required, show your work.

   (a) **Identify** THREE strategies that the federal government could implement to encourage the use of BEVs.

   (b) Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs \$3.75 per gallon (gal). **Calculate** the cost of gasoline per mile.

   (c) The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is \$0.11 per kilowatt-hour (kWh).

      i. **Calculate** the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with.

      ii. **Calculate** the cost of electricity per mile to drive the BEV.

   When it is driven 100 miles, the ICE vehicle contributes 72.8 pounds (lb) of CO_2 from the burning of the gasoline. The drilling, refining, and transportation costs of getting the gasoline to the gas station add an additional 17.7 lb of CO_2 per 100 miles. The BEV does not emit any CO_2 itself, but the extraction, transportation, and combustion of the coal that produced the electricity at the power plant add 63.6 lb of CO_2 for the same 100 miles.

   (d) **Calculate** the difference in the amount of CO_2 that would enter the atmosphere if both cars were driven 100 miles.

   (e) **Describe** TWO economic impacts (excluding costs related to climate change resulting from CO_2 emissions or the cost of gasoline at the pump) that result from an increased number of BEVs on the road.

a. The federal government could offer financial incentives to people that buy BEVs. They could also offer tax breaks to those people. The federal government could provide subsidies to companies that sell BEVs.

b. ~~25 miles/gallon x \$3.75/gallon~~

$\$3.75/\text{gallon} \div 25 \frac{\text{miles}}{\text{gallon}} = \$0.15/\text{mile}$

ci. $4\ kW \times 7\ \text{hours} \times \$0.11/kWh = \$3.08$

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2C2

Cii. \$3.08 x \$.15/mile = \$0.46/mile

d. ~~72.8 lb + 17.7 lb~~

72.8 lb + 17.7 lb = 90.5 lb CO_2

90.5 lb − 63.3 lb = 27.2 lb CO_2

e. Because BEVs do not burn fossil fuels they do not release NO_x into the atmosphere. The cost for the clean up of acid rain would be less because NO_x in the atmosphere create acid rain. Because the acid rain will not end up acidifying the rivers or lakes the fishing industry will be saving lots of many. The acid from the rain would have made the pH of the water too low for the fish to survive in.

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Question 2

Overview

The intent of part (a) was to ask students to identify viable strategies that the federal government could implement to encourage the use of battery electric vehicles (BEVs). Part (b) asked students to perform calculations relating to the cost of gasoline needed to operate an internal combustion engine (ICE) vehicle. Part (c) asked students to perform mathematical calculations and dimensional analyses relating to the cost of electricity needed to operate a BEV. Part (d) asked students to perform mathematical calculations relating to the amount of CO_2 produced by BEVs compared to ICE vehicles. Part (e) asked students to describe economic impacts of an increased use of BEVs.

Sample: 2A
Score: 10

Three points were earned in part (a): 1 point was earned for indicating that the government could implement a gasoline tax; 1 point was earned for indicating that the government could set up tax exemptions for people purchasing BEVs; and 1 point was earned for indicating that the government could mandate recharging stations. Two points were earned in part (b): 1 point was earned for indicating the correct setup (including units) and 1 point was earned for indicating the correct answer (including units). Three points were earned in part (c): 1 point was earned for indicating the correct setup (including units) in part (i); 1 point was earned for indicating the correct answer (including units) in part (i); and 1 point was earned for indicating the correct answer (including units) in part (ii). One point was earned in part (d) for indicating the correct answer (including units). One point was earned in part (e) for indicating the cost of installing charging stations at gas stations.

Sample: 2B
Score: 8

One point was earned in part (a) for indicating that the government could advertise the environmental and economic benefits of purchasing a BEV. One point was earned in part (b) for indicating the correct answer (including units). No point was earned for setup because the student did not show all units. Three points were earned in part (c): 1 point was earned for indicating the correct setup (including units) in part (i); 1 point was earned for indicating the correct answer (including units) in part (i); and 1 point was earned for indicating the correct answer (including units) in part (ii). One point was earned in part (d) for indicating the correct answer (including units). Two points were earned in part (e): 1 point was earned for indicating the increased cost of electricity as the demand for it rises and 1 point was earned for indicating the reduction in cost for an ICE vehicle with decreased demand.

Sample: 2C
Score: 6

Two points were earned in part (a): 1 point was earned for indicating that the government could offer tax breaks to people who buy BEVs and 1 point was earned for indicating that the government could provide subsidies to companies that sell BEVs. Two points were earned in part (b): 1 point was earned for indicating the correct setup (including units) and 1 point was earned for indicating the correct answer (including units). Two points were earned in part (c): 1 point was earned for indicating the correct setup (including units) in part (i) and 1 point was earned for indicating the correct answer (including units) in part (i). No point was earned in part (ii). No point was earned in part (d). No points were earned in part (e) because the student did not specify an alternative energy source that would not emit NO_x during the production of electricity needed for charging BEV batteries.