Name:
REN

PhD Admission 2011: Written Test
Department of Energy Science and Technology

Date: 04.05.11

Time: 1 hour

Maximum Marks: 40

Part I

1. A bulb of 100 W operates 5 hours per day. Calculate the kWh of electricity used in a month and the energy input in kJ. [2]

2. Plot $y = 2x + 3$ for $x > 0$. Shade the area that represents $\int_0^1 dx \; y(x)$ [2]

3. Balance the following reaction: $C_nH_m + O_2 \rightarrow CO_2 + H_2O$ [2]

4. $\frac{d}{dx}\left[(x^2 + 2)\exp(m\,x)\right] =$ [2]

5. What is the probability of the sum of two dice to be 7? [2]

6. Plot $y = \exp(-x^2)$ for $-\infty < x < \infty$ [2]

7. A gas mixture has the following composition: 30% carbon dioxide, 30% nitrogen, 20% hydrogen, 10% carbon monoxide, and 10% oxygen (all are in mole fraction). The mixture molecular weight is: ... [2]

8. Consider the series 2,6,12,20,30,42 .... What is the n^{th} element of the series. [2]

9. A source of waste heat is available at 527 °C. The ambient temperature is 27 °C. What is the maximum efficiency of a reversible engine using this source. [2]

10. $\int_0^a dx \int_0^b dy \ (x + y) =$ [2]

11. Plot $y = \tan\theta$ for $-\pi \leq \theta \leq \pi$. [2]

12. $x^3 - 1 = 0$. How many imaginary roots does this equation have? What are they? [2]

13. Elements of a matrix are given as follows: $a_{11} = a_{22} = a_{33} = 1$, $a_{12} = a_{21} = 2$, $a_{23} = a_{32} = -3$, $a_{31} = a_{13} = 0$. Construct the matrix. Find out the trace (sum of the diagonal elements) of the matrix. [2]

14. Vapour pressure of liquid can be determined by the Clausius-Clapeyron equation: $\ln P_{\text{sat}} = A - B/T_{\text{sat}}$ where T is temperature in K, and $B = \frac{\lambda}{R}$. λ is the latent heat of vaporisation and R is the universal gas constant. The following data is given: $\lambda_{\text{toluene}} = 351\text{kJ/kg}$ and the boiling point of toluene is 110.6 °C. Determine the vapour pressure of toluene at 298 K. [2]

15. $\int dx\ (a\,x^3 + b\,x^{-2})$

[2]

Part II: Comprehension Test

Read the article attached and answer the following questions in brief (in your own words)

1. What according to the inventor is "kinetic surplus"? [2]

2. Give examples of two demonstrations for harnessing the kinetic surplus. [2]

3. Explain in your own words the technology being used by Innowattech (less than 50 words) [2]

4. What was Haim Abamovich's new material originally developed for? [2]

5. Why did the Israel's national road company ask if they could drive a freight train over Abamovich's invention? Respond to their question, explain what would be the potential benefit. [2]

Extract from IEEE Spectrum Author: L.Larson, October 2010

Visitors to aerospace engineer Haim Abramovich's office at the Israel Institute of Technology, in Haifa, once asked if they could run a freight train over his latest invention. Abramovich didn't blink: The visitors were from Israel's National Road Company, and they wanted to know whether his piezoelectric material—which he developed to warp aerodynamic surfaces at the command of an electric current—would instead generate power if embedded beneath rumbling roads and rails.

Abramovich, who had just launched start-up Innowattech to develop wearable microgenerators for powering mobile devices, was convinced the road and track were better homes for his technology. So the company "turned around 180 degrees," he recalls, and figured out how to embed piezoelectric material beneath a road. Now, along with several other inventive start-ups, Innowattech is poised to harvest some of the spare kinetic energy of the world's moving vehicles—call it the kinetic surplus.

Innowattech's design consists of a thin box around the piezoelectric material, which is then placed underneath a layer of asphalt. When a car drives over the box, it takes the vertical force and compresses the piezoelectric material, thereby generating electricity, Abramovich explains. The energy—80 kilowatt-hours per kilometer of road for car traffic—can be stored in a nearby battery or supercapacitor, depending on the application, or sent directly to streetlights and other roadside devices.

But wait. The energy must come from somewhere, right? "We do not take the energy from the car," Abramovich says, preemptively. "We take the energy which will otherwise be wasted by heat when the road deforms" under the weight of the car. The layer of piezoelectric material is stiffer than the road material it replaces, so it even saves passing vehicles a tiny amount of energy.

Another design, from U.S. tech-transfer firm New Energy Technologies, aims to capture energy when vehicles are slowing down. Cars or trucks would drive over a mat that would be installed on top of the road, on a highway off-ramp, or near a toll booth, saving wear and tear on the car brakes and transforming some of the slowing vehicle's motion into electricity. The mat uses mechanical or hydraulic cells to generate electricity and can be customized for cars or cargo truck traffic.

The idea of skimming kinetic energy from slowing vehicles before it gets wasted as heat has already undergone a few real-world tests, with mixed results. Last summer, Highway Energy Systems, in Henstridge, England, which was founded by serial inventor and independent mechanical engineer Peter Hughes, installed his Electro-Kinetic Road Ramps in the parking lot of a grocery store in Gloucester. The panels produced as much as 40 kilowatt-hours, but Hughes reports that the panel seals suffered damage from grit, temperature extremes, and torsion from trucks turning on them. He is planning to replace that system. "We were premature," Hughes says, "but we do not consider the problems insurmountable."

New Energy Technologies ran brief demonstrations last year at a fast-food chain in New Jersey and a hotel in Washington, D.C., and the company is planning future demonstrations with other city and state transportation departments. Innowattech, which has both road and rail demos outside Haifa, may install its first commercial unit in Italy or the United States by the end of this year, Abramovich says.

The firms competing in this sector are diverse, but they have this in common: It's the little guys who have bet first. Entrepreneur and military veteran Terry Kenney sold a hydraulic system of his own design to the Port of Oakland, Calif. KinergyPower, in Welland, Canada, whose founder once worked as a welder, plans to install its first unit for the municipality in early October.

Now that governments are taking notice—the U.S. Federal Highway Administration just gave mechanical engineer Dan Inman and colleagues at Virginia Tech a three-year $1 million contract—will utilities and road builders be next? "It's a matter of being convinced that there is a big market," says Abramovich. "It might take another two or three years before they see that you can do some profit." In the meantime, the road is full of potential.