VJC 2014 PRELIM H2 P2 answers

1(a) From 2nd graph, $v_0 = \omega x_0$

$$= \frac{2\pi}{T} x_0$$

$$T = \frac{2\pi x_0}{v_0}$$

$$= \frac{2\pi \times 0.45}{1.2}$$

= 2.4 s

(b) From 1st graph, $F_{max} = m\omega^2 x_0$

$$m = \frac{F_{\max}}{\left(\frac{2\pi}{T}\right)^2 x_0}$$

$$= \frac{0.63}{\left(\frac{2\pi}{2.36}\right)^2 0.45}$$

= 0.20 kg

2(a) First law of thermodynamics: $\Delta U = Q + W$

So if heat supplied to the gas, Q = work done by the gas, -W, then $\Delta U = 0$

Since temperature of the gas, T α U, $\therefore$ T remains constant.

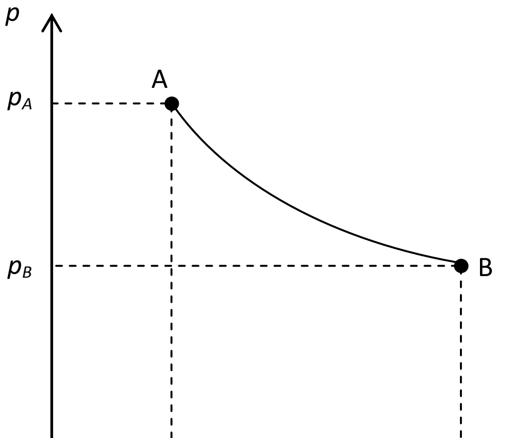
(b)(i) Since the gas is not heated, and the container is insulated, Q = 0.

$\therefore$ $\Delta U = W$, which is negative, since the gas expands.

$\therefore \Delta T$ is negative, which means T drops.

Since pV = nRT, for the same volume, p will be lower.

(ii)



3(a)

$$\frac{GMm}{r^2} = mr\omega^2$$

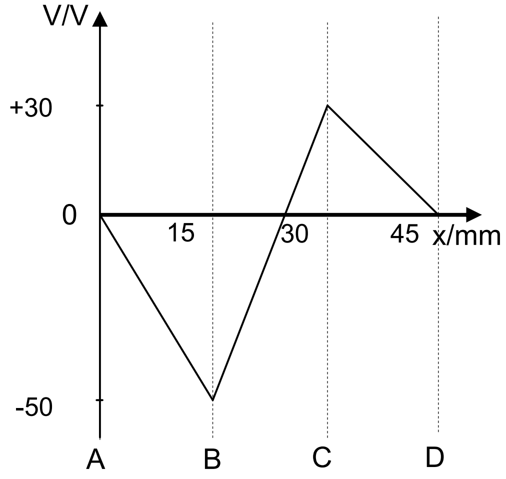
$$\frac{GM}{r^3} = \left(\frac{2\pi}{T}\right)^2$$

$$r^3 = \frac{GMT^2}{4\pi^2} = \frac{6.67\times10^{-11}\left(5.98\times10^{24}\right)\left(24\times60\times60\right)^2}{4\pi^2}$$

$$r = 4.23\times10^7 m$$

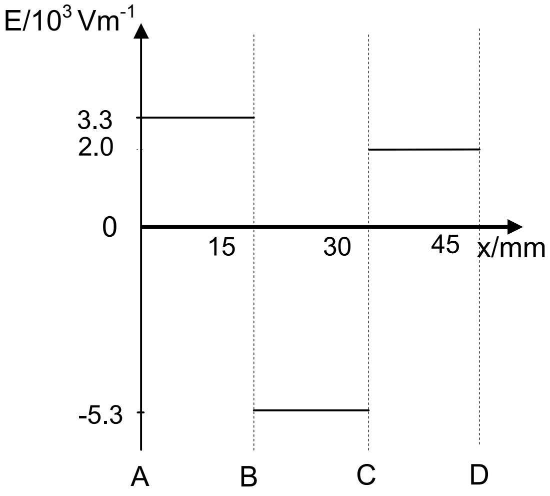
(b) No. For the orbit to be geostationary, it must lie in the earth's equatorial plane. Any orbit above or below the equator would have a satellite moving north and south, and hence it would not be geostationary. The satellite must also travel eastward to follow the rotation of the Earth from west to east.

4(a) **1.** The electric potential



2 The electric field intensity

$$use\ E = -\frac{dV}{dr}$$



4(b)

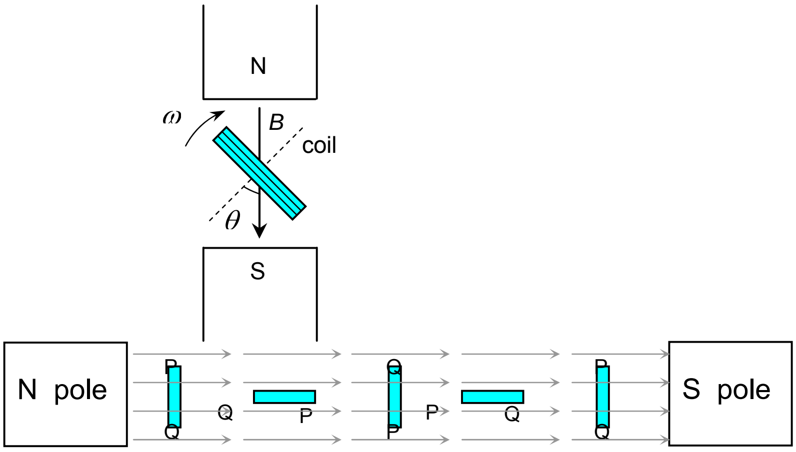
Work done by E force = change in kinetic energy of electron

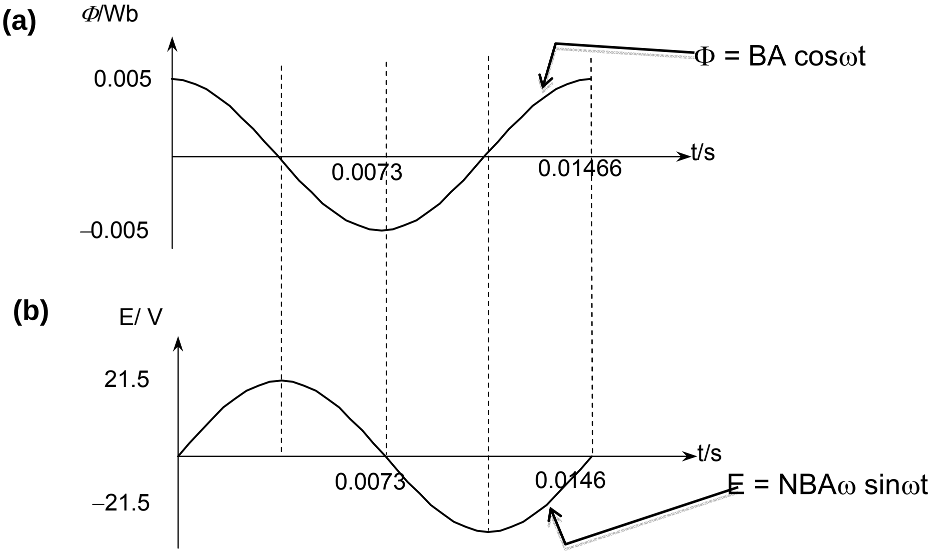
$$eV = \frac{1}{2} m_e \left(v_f^2 - v_i^2\right)$$

$$\left(1.6\times10^{-19}\right)\left(-25\right) = \frac{1}{2}\left(9.11\times10^{-31}\right)\left[v_f^2 - \left(7.0\times10^{6}\right)^2\right]$$

$$v_f = 6.34\times10^{6}\ \text{m s}^{-1}$$

5(a) The magnetic flux, ϕ = BA cosθ = BA cos ωt





(b) Induced emf = rate of change of flux linkage, $E = -\frac{d\Phi}{dt}$

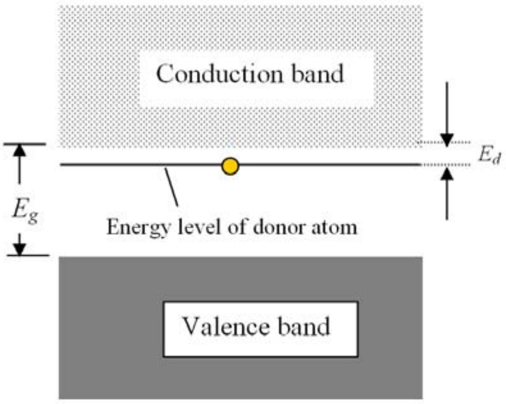
thus, induced emf E= E_0 sin ωt

where peak value, E_o = NBAω

= (10) 2.0 (5.0 x 5.0 x 10^{-4}) 430

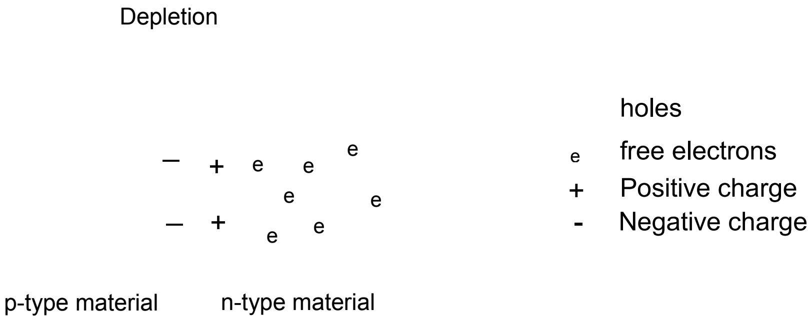
= 21.5 V

6(a)

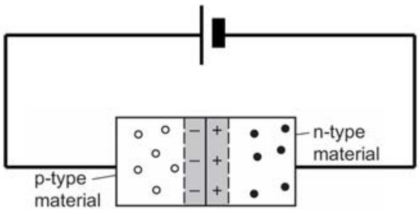


In an n-type semiconductor, the impurity pentavalent atoms are called donor atoms. The energy level of the electron of the donor atom is separated from the bottom of the conduction band by a very small amount E_d (E_d is typically about 0.05 eV).
Since E_d is very small, only a small amount of thermal excitation is required to cause this electron to move into the conduction band, increasing the conductivity of the semiconductor.

(b)



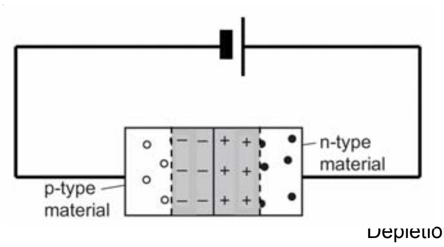
In a p-n junction, electrons diffuse from the n-type to the p-type material and holes diffuse from the p-type to the n-type material. This diffusion-recombination process sets up a depletion layer.



Forward bias

Depletion region becomes narrower

In forward bias, the electric potential of the *p*-side is raised and that of the *n*-side is lowered, thus decreasing the height of the potential barrier ΔV. The reduction in ΔV corresponds to a narrowing of the width of the depletion region and a substantial reduction in the resistance of the junction and the charge carriers can cross the p-n junction easily (more *n*-side electrons can now surmount this smaller potential barrier and move to the *p*-side. Similarly, more *p*-side holes can move to the *n*-side.) and current can flow across the junction.



Reverse bias

In reverse bias, the electric potential of the *n*-side is raised, and that of the *p*-side is lowered. The internal potential barrier ΔV within the junction is increased and the junction acquires a very high resistance. The depletion layer widens and it is now more difficult for the majority charge carriers on either side of the junction interface to cross the junction, so no current can flow across the junction.
Therefore, the p-n junction can act as a rectifier to convert an alternating current to a current that only flow in one direction.

7(a) Since the electron and positron collide head-on with equal speeds, the total momentum of the two-particle system is zero.
By the principle of conservation of momentum, the total momentum after the collision should still be zero.
If only a single photon is produced, its non-zero momentum $\left(p = \frac{h}{\lambda} \text{ or } \frac{E}{c}\right)$ would violate the principle of conservation of momentum.
Hence, it is not possible for only one photon to be produced.

(b) Let the momentum of photon 1 be $p_1 = \frac{E_1}{c}$, where E_1 is the energy of photon 1.
Let the momentum of photon 2 be $p_2 = \frac{E_2}{c}$, where E_2 is the energy of photon 2.
If only two photons are produced, the two photons must have equal but opposite momenta (in accordance with the principle of conservation of momentum).
That is, $|p_1| = |p_2|$

$$\frac{E_1}{c} = \frac{E_2}{c}$$

So, $E_1 = E_2$
The two photons must have equal energy.

7(c) (To get the maximum wavelength, we should assume that the initial kinetic energies of the electron and positron are negligibly small.)

Since the electron and positron have equal masses, and the two photons have equal energies, the mass of each particle will be converted into a single photon.

Minimum energy of each particle, $E_{\text{min}} = mc^2$

$= (9.11 \times 10^{-31})(3.00 \times 10^{8})^2$

$= 8.199 \times 10^{-14}$ J

Maximum wavelength of each photon, $\lambda_{\text{max}} = \dfrac{hc}{E_{\text{min}}}$

$$= \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{8.199 \times 10^{-14}}$$

$= \mathbf{2.43 \times 10^{-12}}$ **m**

(d) Gamma radiation

8(a) $E_{total} = Pt$

$= IAt$

$= IA(d/v)$

$= 0.90 \times 10^3 \times 7.7 \times (200/67) \times 60 \times 60$

$= 7.5 \times 10^7$ J

(b) $E_{electric} = e_{cell}\, E_{total}$

$= 0.26 \times 7.45 \times 10^7$

$= 1.9 \times 10^7$ J

(c) $P_{output} = P_{motor}/e_{motor}$

$= 1100/0.92$

$= 1200$ W

(d) No. of cells, $N = A_{total}/A_{1\ cell}$

$= 7.7/(6.4 \times 10^{-3})$

$= 1200$

Energy collected by each cell $= E_{total}/N$

$= 7.45 \times 10^7/1200$

$= 6.2 \times 10^4$ J

(e) $P_{output} = Fv$

Tractive force, $F = P/v$

$$= 1100 \times \frac{60 \times 60}{67 \times 10^3}$$

$= 59$ N

Resistive force = tractive force = 59 N, since speed is constant.

(f) $I = P_{total}/V$

$= 1200/50$

$= 24$ A

(g) t = charge capacity/I

$= 60/24$

$= 2.5$ hrs

(h) Presence of clouds

Dust covering the solar cells

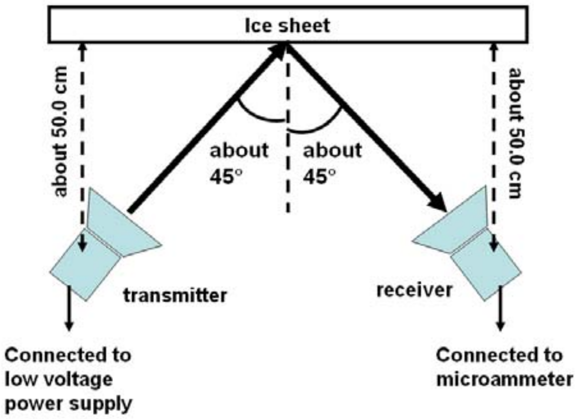
Angle of sunlight incident on the cells

Season of the year

9. Measuring the thickness of a sheet of ice with microwaves

Identifying the variables to be measured:

After reflecting off the sheet of ice, the microwaves will be detected by the microwave receiver, with the microammeter connected to it. The magnitude of the microammeter reading (the dependent variable) will be taken as a measure of the “strength of the reflected wave”. The thickness of ice (the independent variable) will be measured with Vernier calipers. As a first trial, the thickness can be varied from 2.0 cm to 10.0 cm.



Procedures:

1. Set up the sheet of ice, microwave transmitter and receiver as shown in the diagram above. Two clamps, positioned at both ends of the sheet of ice, will used to hold the sheet upright. An isosceles triangle can be drawn on the floor, and the equipment aligned to the triangle. The distance between the emitter/receiver and the ice sheet can be ensured to be equal by using a metre rule. The 45° angles can be measured using a protractor. The emitter and receiver can then be aligned with the sides of the triangle.
2. Inspect the ice sheet visually to check that its thickness is roughly uniform (accuracy). (Only ice sheets with uniform thickness should be used.) Then, measure and record the thickness *T* of the ice sheet with Vernier calipers at 3 different positions: top edge, left edge and right edge (see Table below). Take the average of the 3 readings and use it for graph-plotting.
3. Direct the transmitter at about 45° to the ice sheet and switch on the low voltage (fixed) power supply connected to the transmitter. (Microwaves are now directed at the ice and are reflected toward the receiver.) Make fine adjustments to the position of the receiver (also rotate its “bell”) until it detects a maximum ammeter reading (accuracy). When this is achieved, record the ammeter reading *I*. Repeat measurement of *I* and take the average to minimize errors.
4. For consistency, the positions of the transmitter and receiver will not be moved anymore in this experiment (control variable).
5. Use different sheets of ice to vary the thickness. For each sheet, obtain measurements of thickness *T* and current *I*.
6. Plot a graph of *I* against *T* to show how the strength of the reflected waves depends on the thickness of the ice sheet.

Control of other variables:

1. The power output of the transmitter must be kept constant so that all waves emitted will be of the same intensity.

2. The distances between the transmitter and the ice sheet, and between the sheet and the receiver must be kept constant (see Procedure No. 4 above) because the distance travelled by the wave will affect its intensity at the receiver.
3. The thermocouple can be used to ensure that all the ice sheets are at the same temperature, as the temperature will affect the reflectivity of the microwave.

Precautions to obtain reliable results:

1. The temperature of the lab should be kept low and the experiment should be done quickly to prevent too much of the ice from melting. (If the ice melts unevenly, the thickness of the sheet will no longer be uniform.)
2. The reflecting surface of the ice sheet should be placed vertically. This can be ensured with the help of a spirit level (or set square).

Safety:

1. The ice sheet may have sharp edges, so gloves should be worn to protect hands.
2. Do not point the transmitter at people as microwaves can cause harm.
3. The water from melted ice should be quickly wiped off the tables and floors, to prevent slippery floors.