Physics 40S Exam Review Key

Extended Answer Key

I: Mechanics

1. A turtle and a bunny decide to have a race. The turtle (at t=0) is running with a constant velocity of 0.2 m/s. The bunny waits 160 s before starting to hop. Once the bunny starts hopping, he hops with a constant acceleration and catches up to the turtle. The turtle takes 200 s to finish the race.

   a. If the race ends in a tie, what is the acceleration of the bunny?

$$d = v_{turtle} t_{turtle} = (0.2)(200) = 40m$$
$$t_{bunny} = t_{turtle} - 160 = 200 - 160 = 40s$$
$$d = v_i t_{bunny} + \frac{1}{2} a_{bunny} t_{bunny}^2$$
$$a_{bunny} = \frac{2d}{t_{bunny}^2} = \frac{2(40)}{(40)^2} = 0.05 m/s^2$$

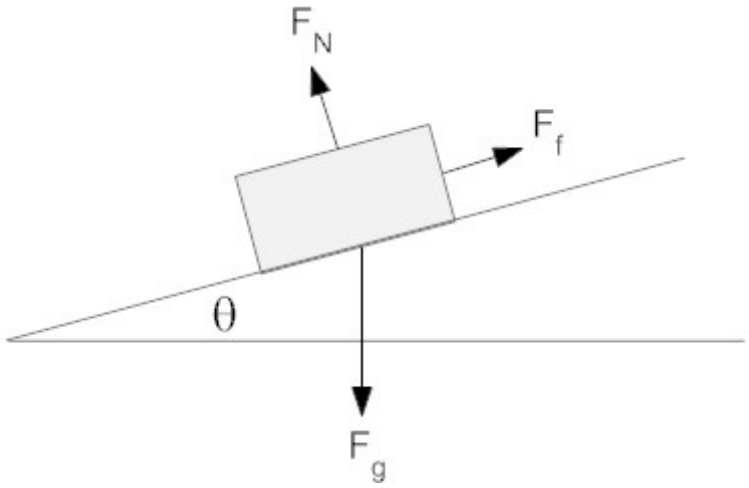
   b. How fast is the bunny hopping at the end of the race?

$$v_f^2 = v_i^2 + 2ad$$
$$v_f = \sqrt{v_i^2 + 2ad} = \sqrt{0 + 2(0.05)(40)} = 2m/s$$

   c. The fastest the bunny can hop is 4 m/s. What is the longest time he could wait before starting to hop?

$$d = \left(\frac{v_i + v_f}{2} \right) t$$
$$t = \frac{2d}{v_f} = \frac{2(40)}{4} = 20s$$
$$200 - 20 = 180s$$

2. A 30 kg block is stationary on a rough inclined plane as shown.



a. Draw and label arrows representing the forces acting on the block.

b. The coefficient of static friction is 0.1. Calculate the angle θ.

$$F_f = F_g \sin\theta$$
$$\mu F_N = F_g \sin\theta$$
$$F_N = F_g \cos\theta$$
$$\mu F_g \cos\theta = F_g \sin\theta$$
$$\mu = \tan\theta$$
$$\theta = \tan^{-1}(\mu) = \tan^{-1}(0.1) = 5.7^\circ$$

c. Would the angle be different if the mass was greater? Explain.

No, the coefficient of friction is not dependent on the mass of the object.

3. A boy is pulling his wagon along a horizontal sidewalk with a force of 50 N. The handle makes an angle of 37^o with the ground. The wagon is moving with a constant velocity.

   a. A force is being exerted on the wagon. Why is the wagon moving with constant velocity?

      Applied force is equal and opposite to the force of friction.

   b. Calculate the frictional force acting on the wagon.

      $$F_f = F_{applied} \cos 37$$
      $$F_f = 50 \cos 37 = 39.9N$$

   c. The coefficient of kinetic friction, μ, is 0.2. Calculate the normal force the ground exerts on the wagon.

      $$F_f = \mu F_N$$
      $$F_N = \frac{F_f}{\mu} = \frac{39.9}{0.2} = 199.7N$$

   d. Calculate the mass of the wagon.

      $$\Sigma F_y = 0$$
      $$F_N + F_{applied} \sin 37 - mg = 0$$
      $$m = \frac{F_N + F_{applied} \sin 37}{g} = \frac{199.7 + 50 \sin 37}{9.8} = 23.4kg$$

   e. What causes the frictional force on the wagon?

      Any reasonable response
      For example: the bearings in the wheels

4. A train car of mass M = 1000 kg moving with a velocity 15 m/s hits a second train car of mass 4M moving in the opposite direction with a velocity of 5 m/s. The two cars connect together as a result of the collision.

   a. Ignoring friction, calculate the velocity of the cars after the collision.

$$m_1 v_1 + m_2 v_2 = m_{1+2} v_{1+2}$$
$$m(15) + 4m(-5) = 5mv$$
$$v = \frac{15 - 5}{5} = -1 m/s$$

   b. Assuming the train cars are traveling at the same velocities for each car as given above, calculate the ratio of the masses, such that after the collision the connected cars have a velocity of zero.

$$m_1 v_1 + m_2 v_2 = 0$$
$$m_1(15) + m_2(-5) = 0$$
$$\frac{m_1}{m_2} = 0.33 \quad \text{or} \quad \frac{m_2}{m_1} = 3$$

5. A car is found 20 m away from the bottom of a 5 m high cliff. The road at the top of the cliff is horizontal. What was the speed of the car, in km/h, when it drove off the cliff?

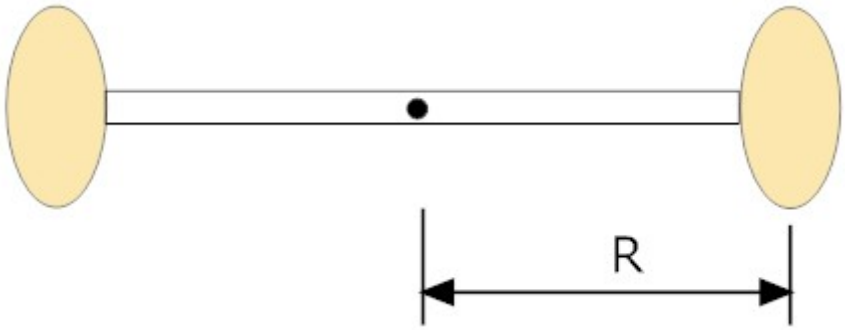
$$y = v_y t + \frac{1}{2} a_y t^2$$

$$t = \sqrt{\frac{2y}{a_y}} = \sqrt{\frac{2(-5)}{-9.8}} = 1.01s$$

$$v_x = \frac{x}{t} = \frac{20}{1.01} = 19.8m/s$$

$$19.8\left(\frac{3600}{1000}\right) = 71.3km/h$$

6. A carnival ride consists of two carts that spin in a horizontal circle around a center point. The top view of the ride is as shown:



A 70 kg rider on the ride experiences a centripetal force of 2g. The radius R, is 3 m.

a) What is the frequency of rotation of the ride?

$$F_c = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{2gr}{m}} = \sqrt{\frac{2(9.8)(3)}{70}} = 0.917 m/s$$

$$v = \frac{2\pi r}{T}$$

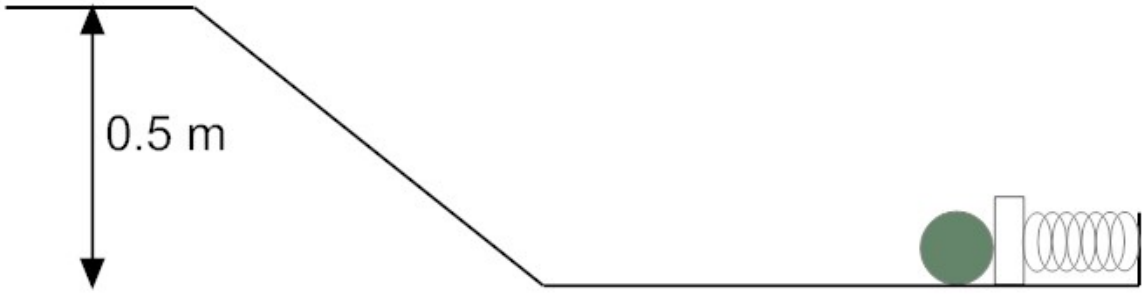
$$T = \frac{2\pi r}{v} = \frac{2\pi(3)}{0.917} = 20.56 s$$

$$f = \frac{1}{T} = \frac{1}{20.56} = 0.049 Hz$$

b) If the radius was doubled, would the frequency of rotation need to increase or decrease to maintain a force of 2g?

Decrease

7. Consider the following situation:



The spring, with a spring force constant of 100 N/m, is compressed 20 cm. The ball has a mass of 1 kg.

a. The spring is released causing the ball to move to the left. Calculate the velocity of the ball as soon as it leaves the spring.

$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{kx^2}{m}} = \sqrt{\frac{(100)(0.2)^2}{1}} = 2m/s$$

b. The ball then travels up the ramp. Does the ball make it to the top of the ramp? Provide proof.

$$\frac{1}{2}mv^2 = mgh$$

$$h = \frac{v^2}{2g} = \frac{(2)^2}{2(9.8)} = 0.2m$$

No, the ball does not make it to the top of the ramp.

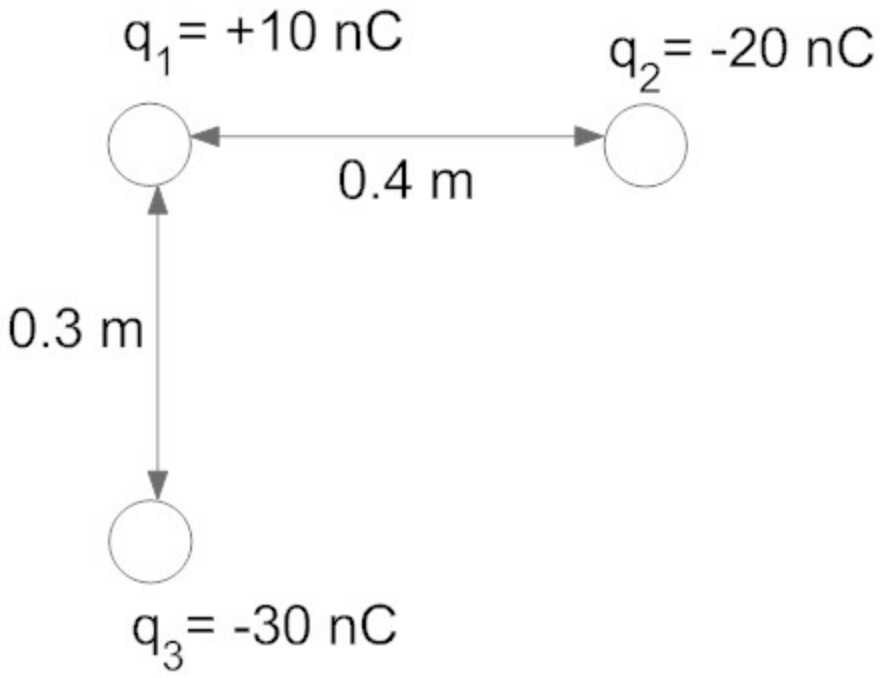
c. How much must the spring be compressed so that the ball just makes it to the top of the ramp?

$$\frac{1}{2}kx^2 = mgh$$

$$x = \sqrt{\frac{2mgh}{k}} = \sqrt{\frac{2(1)(9.8)(0.5)}{(100)}} = 0.31m$$

II: Fields

8. Three charges are placed as shown:



Calculate the net electrostatic force on q_3.

$$F_{31} = \frac{kQq}{r^2} = \frac{(9x10^9)(10x10^{-9})(30x10^{-9})}{(0.3)^2} = 3x10^{-5}\,N \text{ attractive}$$

$$F_{32} = \frac{kQq}{r^2} = \frac{(9x10^9)(30x10^{-9})(20x10^{-9})}{(0.5)^2} = 2.16x10^{-5}\,N \text{ repulsive}$$

$$\theta = \tan^{-1}\left(\frac{0.4}{0.3}\right) = 53^\circ$$

$$x: -2.16x10^{-5}\sin 53 = -1.73x10^{-5}\,N$$

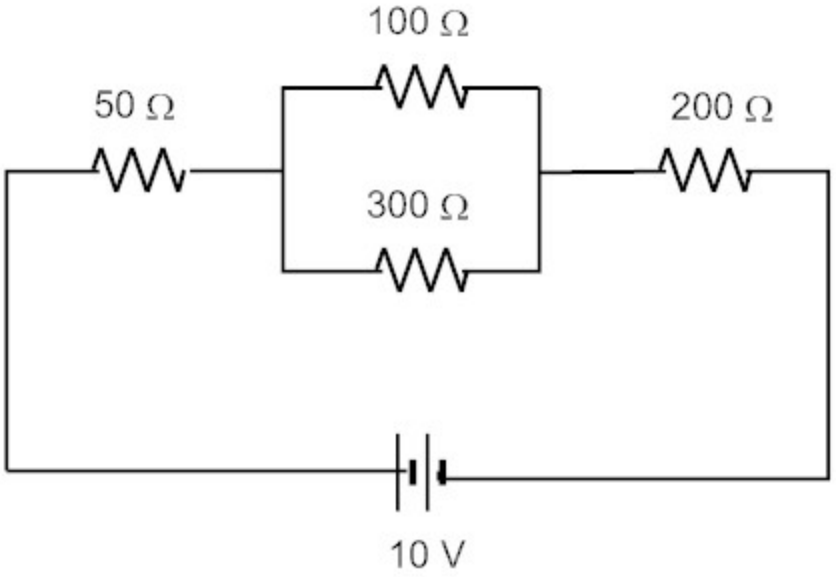
$$y: 3x10^{-5} + -2.16x10^{-5}\cos 53 = 1.7x10^{-5}\,N$$

$$F_{net} = \sqrt{(-1.73x10^{-5})^2 + (1.7x10^{-5})^2} = 2.4x10^{-5}\,N$$

$$\theta = \tan^{-1}\left(\frac{1.7x10^{-5}}{1.73x10^{-5}}\right) = 44.5^\circ \text{ above the } -\text{x axis or } 134.5^\circ$$

III: Electricity

9. Consider the following circuit.



a. Calculate the equivalent resistance of the circuit.

$$R_{parallel} = \left(100^{-1} + 300^{-1}\right)^{-1} = 75\Omega$$
$$R_{eq} = 50 + 75 + 200 = 325\Omega$$

b. Calculate the current flowing through the 200 Ω resistor.

$$V = IR$$
$$I = \frac{V}{R} = \frac{10}{325} = 0.03A$$

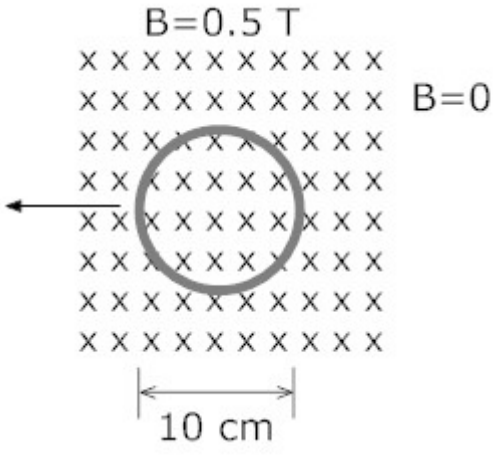
c. Calculate the voltage drop across the 200 Ω resistor.

$$V = IR$$
$$V = (0.03)(200) = 6V$$

d. What would happen to the voltage drop across the 200 Ω resistor if the 300 Ω resistor was removed from the circuit?

The voltage drop would decrease.

10. A 10 cm diameter circular coil of 100 loops is positioned perpendicular to a magnetic field of 0.5 T going into the page.



a. List two ways that an EMF can be induced in the coil.

Any two possibilities:
Change the angle of the coil
Change the magnetic field
Change area of the loop
Change the number of loops

b. The loop is uniformly pulled from the field (moving perpendicular to the magnetic field) to a region where the magnetic field drops abruptly to zero. It takes 2 seconds for the whole coil to reach the field-free region. Calculate the induced EMF.

$$V = -\frac{N\Delta\Phi}{\Delta t}$$
$$\Phi = BA\cos\theta$$

After 2 second the entire loop will have been removed from the magnetic field.

Therefore: $\frac{\Delta\Phi}{\Delta t} = \frac{(0 - BA)}{2} = \frac{-BA}{2}$

$$V = \frac{-N(-BA)}{2} = \frac{-100(-0.5)\pi(0.05)^2}{2} = 0.2V$$

c. What is the direction of the induced current in the wire?

clockwise

11. Manitoba Hydro produces AC current in Northern Manitoba using hydroelectric dams and AC generators.

    a. Referring to electromagnetic induction, explain briefly how an AC generator works.

    b. Manitoba Hydro's transmission system transports electricity in a range from 24 kV to 500 kV. Why is the electricity transmitted on high voltage lines instead of 240 V lines?

        Less power loss due to resistance over long distances

    c. Manitoba Hydro transmits the electricity from Northern Manitoba as direct current on two trunk lines. Why is the electricity transmitted as direct current instead of alternating current?

        Sample responses:
        Less power loss due to resistance over long distances
        Lower cost to build DC transmission lines

    d. Manitoba Hydro is in the process of building 3 new power generating stations in Northern Manitoba. These generating stations are scheduled to be completed by 2012. All of the power produced by these stations would be for export until around 2020. Give an environmental or economic reason why this is a good or bad idea.

        Any reasonable response

Multiple Choice Key

Question	Answer
1	D
2	A
3	A
4	A
5	C
6	C
7	A
8	A
9	D
10	D
11	D
12	B
13	C
14	D
15	B
16	B
17	C
18	D
19	B
20	B
21	A
22	B
23	B
24	C
25	B
26	A
27	A