VER A PART I Solve all MC problems below. Enter your answers into the scantron sheet. Each question is othe same value. 6 best out of 7 answers count towards the 48% of the test grade.

1. The figure shows a uniform rod (length *L* = 1.0 m, mass = 2.0 kg) suspended from a pivot a distance *d* = 0.25 m above its center of mass. The period (in s) for small oscillations is approximately:

a. 1.0 **b.** 2.5
c. 1.5 **d.** 4.1
e. 3.5

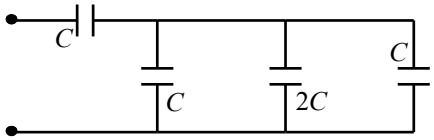
2. A point source emits sound waves with a power output of 100 watts. What is the sound level (in dB) at a distance of 30 m?

A 99 **B** 119 **C** 129 **D** 109 **E** none of the above

3. A truck moving at 36 m/s approaches a police car moving at 45 m/s in the opposite direction. If the frequency of the siren relative to the police car is 500 Hz, what is the frequency (in Hz) heard by an observer in the truck as the police car approaches the truck? (The speed of sound in air is 343 m/s.)

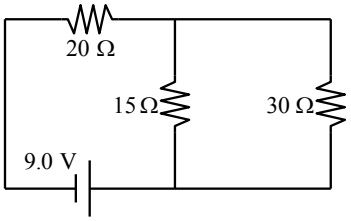
A 396 **B** 636 **C** 361 **D** 393 **E** 617

4. Determine the equivalent capacitance in pF for the network shown when $C = 15\ \text{pF}$.



a. 20 b. 16
c. 12 d. 24
e. 75

5. What is the current in A in the 15 Ω resistor?



a. 0.20 b. 0.30
c. 0.10 d. 0.26
e. 0.60

6 The Potential V(x,y,z) is given by the expression: $V(x,y,z) = \dfrac{x^2 + y^2}{z}$

Find vector **E** as well as the its magnitude at point (1,1,1) .

a) $\vec{E} \equiv (\frac{2x}{z^2}, \frac{2y}{z^2}, \frac{1}{z^2}); \left|\overrightarrow{E(1,1,1,)}\right| = 3\sqrt{2}$

b) $\vec{E} \equiv -(\frac{2x}{z}, \frac{2y}{z}, -\frac{x^2 + y^2}{z^2}); \left|\overrightarrow{E(1,1,1,)}\right| = 2\sqrt{3}$

c) $\vec{E} \equiv (\frac{2x}{z}, \frac{2y}{z}, \frac{x^2 + y^2}{z^2}); \left|\overrightarrow{E(1,1,1,)}\right| = -2\sqrt{3}$

d) $\vec{E} \equiv -(\frac{2x}{z}, \frac{2y}{z}, -\frac{1}{z^2}); \left|\overrightarrow{E(1,1,1,)}\right| = \sqrt{3}$

e) none of the above

7. A diver shines an underwater searchlight at the surface of a pond (*n* = 1.30). The light produced by the searchlight is well collimated and may be treated as parallel beam of light. What is the maximum angle **(between the beam and the surface)** at which will the light be totally reflected?

a. 47° b. 40° c. 50° d. 58° e. 49°

PART II

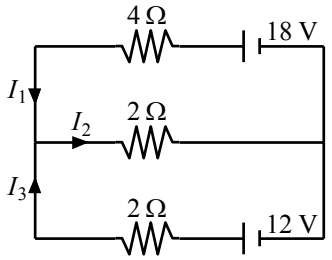
In the exam booklet, answer 4 out of 5 problems. On the front page clearly indicate which solutions are you submitting for grading. Each problem is worth 13 points.

1[13p]

A)[7p] Three identical charges q =1nC, are placed in three vertices of equilateral triangle of side 1 meter. Make large clear diagram of this situation and find the electric field at the center of the triangle (where the angle bisectors cross.)

B)[6p] An O_2 ion of mass m= 5.34×10^{-26}kg, and charge Q=$+1.6\times10^{-19}$ C is moving along the x axis with velocity v=5000m/s when it enters the area with constant uniform magnetic field B =0.01T along z axis. As result of interaction with the field the ion will enter circular trajectory of radius R. Find R.

2[13p] Given the circuit show, find I_1



3[13p] A lobsterman's buoy is a solid wooden cylinder of radius *r* and mass *M*. It is weighted with mass m at one end so that it floats upright in calm sea water, having density ρ. A passing shark tugs on the slack rope mooring the buoy to a lobster trap, pulling the buoy down a distance *x* from its equilibrium position and releasing it.

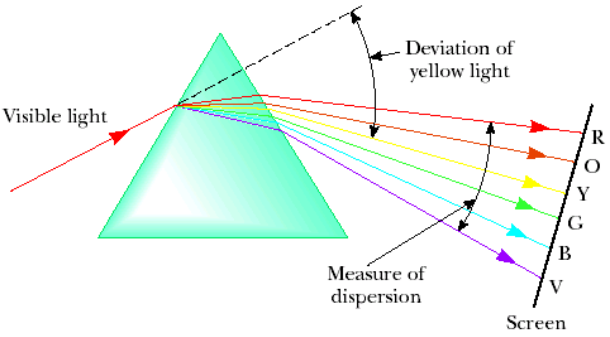
A))[3p] Draw large and clear diagram of this situation including all relevant forces.

B))[7p] Show that the buoy will execute simple harmonic motion if the resistive effects of the water are neglected.

C))[3p] Determine the period of the oscillations.

4. [13p] A loudspeaker is placed between two observers who are 110 m apart, along the line connecting them. If one observer records a sound level of 60.0 dB, and the other records a sound level of 80.0 dB, how far is the speaker from each observer?

5[13p] The index of refraction for violet light in sapphire is 1.70, and that for red light is 1.64.
What is the angular dispersion of visible light passing through a prism of apex angle 60.0° if the angle of of incidence is 40.0°?



VER B PART I Solve all MC problems below. Enter your answers into the scantron sheet. Each question is of the same value. 6 best out of 7 answers count towards the 48% of the test grade.

1. The figure shows a uniform rod (length *L* = 1.0 m, mass = 1.0 kg) suspended from a pivot a distance *d* = 0.20 m above its center of mass. The period (in s) for small oscillations is approximately:

A 1.0 **B** 1.6 C 1.5 **D** 4.5
E none of the above

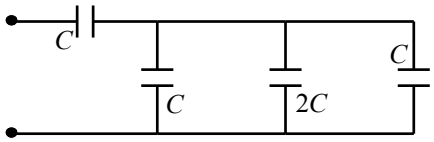
2. A point source emits sound waves with a power output of 100 watts. What is the sound level (in dB) at a distance of 20 m?

A 139 **B** 119 **C** 103 **D** 109 **E**10

3. A truck moving at 36 m/s approaches a police car moving at 45 m/s in the opposite direction. If the frequency of the siren relative to the police car is 600 Hz, what is the frequency (in Hz) heard by an observer in the truck as the police car approaches the truck? (The speed of sound in air is 343 m/s.)

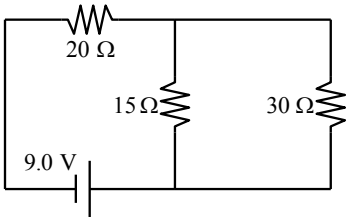
A 316 **B** 441 **C** 509 **D** 636 **E** 763

4. Determine the equivalent capacitance in pF for the network shown when C=20pF.



A 20 B 16
C 12 D 24
E 75

5. What is the current in A in the 20 Ω resistor?



A 0.20 B 0.30
C 0.10 D 0.26
E 0.60

6. The Potential V(x,y,z) is given by the expression: $V(x,y,z)=\frac{x^2+y^2}{z}$

Find vector **E** as well as the its magnitude at point (1,1,1).

A $\vec{E}\equiv(\frac{2x}{z^2},\frac{2y}{z^2},\frac{1}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=3\sqrt{2}$ B $\vec{E}\equiv-(\frac{2x}{z},\frac{2y}{z},-\frac{1}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=\sqrt{3}$

C $\vec{E}\equiv-(\frac{2x}{z},\frac{2y}{z},-\frac{x^2+y^2}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=2\sqrt{3}$ D) $\vec{E}\equiv(\frac{2x}{z},\frac{2y}{z},\frac{x^2+y^2}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=-2\sqrt{3}$

E none of the above

7. A diver shines an underwater searchlight at the surface of a pond (*n* = 1.33). The light produced by the searchlight is well collimated and may be treated as parallel beam of light. What is the maximum angle (**between the beam and the surface)** at which will the light be totally reflected?

A 41° B 40° C 49° D 50° E none of the above

PART II

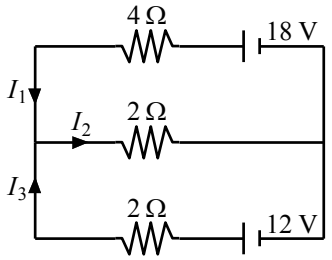
In the exam booklet answer 4 out of 5 problems. On the front page clearly indicate which solutions are you submitting for grading. Each problem is worth 13 points.

1[13p]

A)[7p] Three identical charges q =2nC, are placed in three vertices of equilateral triangle of side 1 meter. Make large clear diagram of this situation and find the electric field at the center of the triangle (where the angle bisectors cross.)

B)[6p] An O_2 ion of mass m= 5.34×10^{-26}kg, and charge Q=$+1.6\times10^{-19}$ C is moving along the x axis with velocity v=8000m/s when it enters the area with constant uniform magnetic field B =0.02T along z axis. As result of the interaction with the B-field the ion will enter circular trajectory of radius R. Find R.

2[13p] Given the circuit show, find I_3



3[13p] A lobsterman's buoy is a solid wooden cylinder of radius *R* and mass m_1. It is weighted with mass m_2 at one end so that it floats upright in calm sea water, having density ρ. A passing shark tugs on the slack rope mooring the buoy to a lobster trap, pulling the buoy down a distance y from its equilibrium position and releasing it.

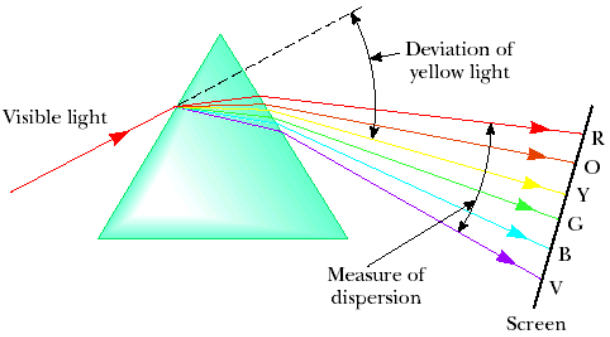
A))[3p] Draw large and clear diagram of this situation including all relevant forces.

B))[7p] Show that the buoy will execute simple harmonic motion if the resistive effects of the water are neglected.

C))[3p] Determine the period of the oscillations.

4. [13p] A loudspeaker is placed between two observers who are 100 m apart, along the line connecting them. If one observer records a sound level of 60.0 dB, and the other records a sound level of 80.0 dB, how far is the speaker from each observer?

5[13p] The index of refraction for violet light in crown glass is 1.56, and that for red light is 1.52.
What is the angular dispersion of visible light passing through a prism of apex angle 60.0° if the angle of of incidence is 52.0°?



ver C PART I Solve all MC problems below. Enter your answers into the scantron sheet. Each question is of the same value. 6 best out of 7 answers count towards the 48% of the test grade.

1. The figure shows a uniform rod (length *L* = 1.0 m, mass = 1.0 kg) suspended from a pivot a distance *d* = 0.40 m above its center of mass. The period (in s) for small oscillations is approximately:

a. 1.0 **b.** 2.5
c. 1.6 **d.** 4.1
e. 3.5

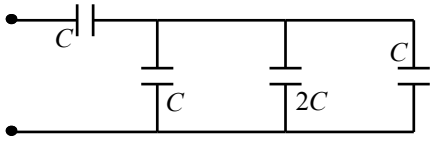
2. A point source emits sound waves with a power output of 100 watts. What is the sound level (in dB) at a distance of 10 m?

A 139 **B** 119 **C** 129 **D** 109 **E** none of the above

3. A truck moving at 36 m/s passes a police car moving at 45 m/s in the opposite direction. If the frequency of the siren relative to the police car is 400 Hz, what is the frequency (in Hz) heard by an observer in the truck as the police car approaches the truck? (The speed of sound in air is 343 m/s.)

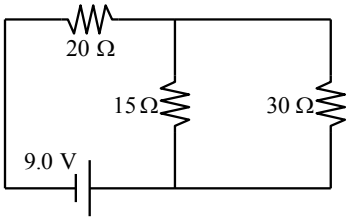
A 509 **B** 636 **C** 361 **D** 393 **E** 617

4. Determine the equivalent capacitance in pF for the network shown when C=10pF.



a. 8 b. 16
c. 12 d. 24
e. 75

5. What is the current in A in the 30 Ω resistor?



a. 0.20 b. 0.30
c. 0.10 d. 0.26
e. 0.60

6 The Potential V(x,y,z) is given by the expression: $V(x,y,z)=\frac{x^2+y^2}{z}$

Find vector **E** as well as the its magnitude at point (1,1,1).

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b) $\vec{E}\equiv-(\frac{2x}{z},\frac{2y}{z},-\frac{x^2+y^2}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=2\sqrt{3}$

c) $\vec{E}\equiv(\frac{2x}{z},\frac{2y}{z},\frac{x^2+y^2}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=-2\sqrt{3}$

d) $\vec{E}\equiv-(\frac{2x}{z},\frac{2y}{z},-\frac{1}{z^2});\left|\overrightarrow{E(1,1,1,)}\right|=\sqrt{3}$

e) none of the above

7. A diver shines an underwater searchlight at the surface of a pond (*n* = 1.37). The light produced by the searchlight is well collimated and may be treated as parallel beam of light. What is the maximum angle (**between the beam and the surface)** at which will the light be totally reflected?

a. 47° b. 40° c. 43° d. 47° e. 49°

PART II

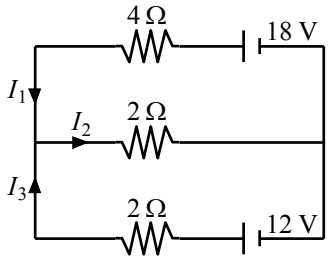
In the exam booklet, answer 4 out of 5 problems. On the front page clearly indicate which solutions are you submitting for grading. Each problem is worth 13 points.

1[13p]

A)[7p] Three identical charges q =1nC, are placed in three vertices of equilateral triangle of side 0.5 meter. Make large clear diagram of this situation and find the electric field at the center of the triangle (where the angle bisectors cross.)

B)[6p] An O_2 ion of mass m= 5.34×10^{-26}kg, and charge Q=$+1.6\times10^{-19}$ C is moving along the x axis with velocity v=8000m/s when it enters the area with constant uniform magnetic field B =0.02T along z axis. As result of interaction with the field the ion will enter circular trajectory of radius R. Find R.

2[13p] Given the circuit show, find I_2



3[13p] A lobsterman's buoy is a solid wooden cylinder of radius *r* and mass M_1. It is weighted with mass M_2 at one end so that it floats upright in calm sea water, having density ρ. A passing shark tugs on the slack rope mooring the buoy to a lobster trap, pulling the buoy down a distance *h* from its equilibrium position and releasing it.

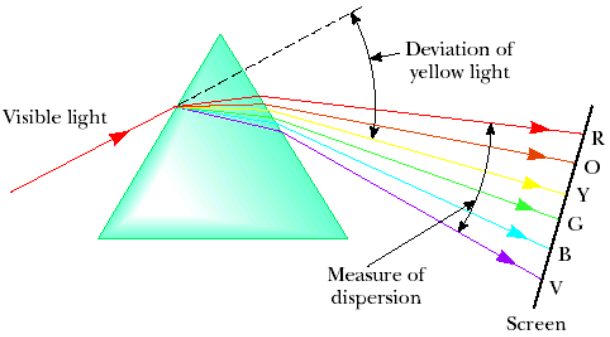
A))[3p] Draw large and clear diagram of this situation including all relevant forces.

B))[7p] Show that the buoy will execute simple harmonic motion if the resistive effects of the water are neglected.

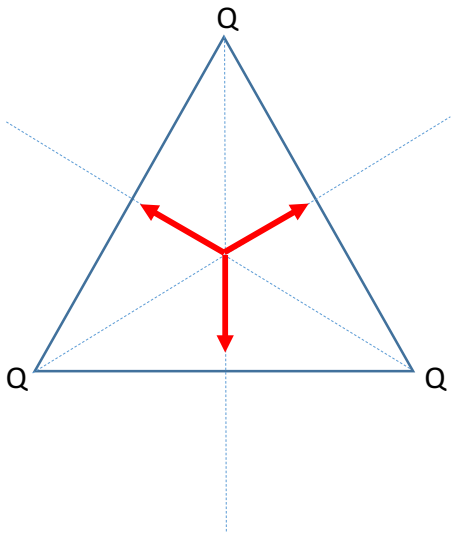
C))[3p] Determine the period of the oscillations.

4. [13p] A loudspeaker is placed between two observers who are 120 m apart, along the line connecting them. If one observer records a sound level of 60.0 dB, and the other records a sound level of 80.0 dB, how far is the speaker from each observer?

5[13p] The index of refraction for violet light in flint glass is 1.58, and that for red light is 1.54.
What is the angular dispersion of visible light passing through a prism of apex angle 60.0° if the angle of of incidence is 50.0°?



1A all versions



We pick vertical axis as the reference we get

Because and the symmetry of the situation (equidistance) each of the charges produces the same magnitude of field at the center point: ($E_1 = E_2 = E_3 = k\frac{Q}{r^2} = E$

$$\sum E_y = 2E_{2y} - E_{3y} = 2Ecos60 - E = E - E = 0$$

$$\sum E_x = E_{2x} - E_{1x} = Ecos30 - Ecos30 = 0$$

ANS 1A The field at the center is 0 regardless of the charge

1B Magnetic Field Force provides the centripetal force. The electric field is 0. All versions

$$qvB = \frac{Mv^2}{R} \Rightarrow qB = \frac{Mv}{Rr} \Rightarrow R = \frac{M}{Q}\frac{v}{B}$$

$$R = \frac{M}{Q}\frac{v}{B} = \frac{5.34\times10^{-26}}{1.6\times10^{-19}}\frac{8000}{0.02}m = 0.1335m$$

$$R = \frac{M}{Q}\frac{v}{B} = \frac{5.34\times10^{-26}}{1.6\times10^{-19}}\frac{5000}{0.01}m = 0.1669m$$

ANS. 2 Kirhchoff: all versions

Using the notations from the diagram we can write for the junction:

$$I_1 + I_3 - I_2 = 0$$

Applying our sign convention for the clockwise direction in the upper loop we get:

$$2I_2 + 4I_1 - 18 = 0$$

Applying our sign convention for the clockwise direction in the lower loop we get:

$$-2I_2 - 2I_3 + 12 = 0$$

this leads to the following:

$$I_2 = -2I_1 + 9$$

$$I_3 = 2I_1 - 3$$

and thus: $I_1 + 2I_1 - 3 - (-2I_1 + 9) = 0$

$$I_1 = \frac{12}{5}A = 2.4A$$

$$I_2 = -4.8 + 9 = 4.2A$$

$$I_3 = 1.8A$$

ANS3: all versions (please pay attention to the different symbols used in different versions

Missing diagram of upright cylinder:

A) FROM FIRST PRINCIPLES:

(the total mass of the system) x Acceleration = - Buoyant force acting on extra volume of the submerged stick (length y)

$$(M+m)\frac{d^2y}{dt^2} = -(\pi r^2)\rho g h \Rightarrow$$

$$\frac{d^2h}{dt^2} = -\frac{(\pi r^2)\rho g}{(M+m)}h \quad \text{this is SHO Equation}$$

$$T = 2\pi\sqrt{\frac{(\pi r^2)\rho g}{(M+m)}}$$

ANS4 one version

Let r_1 and r_2 be the distance from the speaker to the observer that hears 60.0 dB and 80.0 dB, respectively.

We begin with $\beta_2 = 10\log\left(\frac{I_2}{I_0}\right)$, and $\beta_1 = 10\log\left(\frac{I_1}{I_0}\right)$, so $\beta_2 - \beta_1 = 10\log\left(\frac{I_2}{I_1}\right)$.

Also, $I_2 = \frac{\wp}{4\pi r_2^2}$, and $I_1 = \frac{\wp}{4\pi r_1^2}$, giving $\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2$. Then, $\beta_2 - \beta_1 = 10\log\left(\frac{r_1}{r_2}\right)^2 = \boxed{20\log\left(\frac{r_1}{r_2}\right)}$.

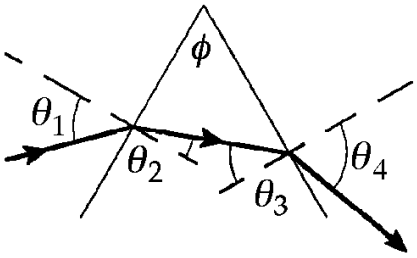
$\beta_2 - \beta_1 = 20\log\left(\frac{r_1}{r_2}\right)$, gives $80.0 - 60.0 = 20\log\left(\frac{r_1}{r_2}\right)$.

Thus, $\log\left(\frac{r_1}{r_2}\right) = 1$, so $r_1 = 10.0 r_2$. Also: $r_1 + r_2 = 110\ \text{m}$, so

$10.0 r_2 + r_2 = 110\ \text{m}$ giving $\boxed{r_2 = 10.0\ \text{m}}$, and $\boxed{r_1 = 100\ \text{m}}$.

ANS 5

the incoming ray, $\sin\theta_2 = \dfrac{\sin\theta_1}{n}$.



Using the figure to the right,

$$(\theta_2)_{\text{violet}} = \sin^{-1}\left(\frac{\sin 50.0^\circ}{1.66}\right) = 27.48^\circ$$

$$(\theta_2)_{\text{red}} = \sin^{-1}\left(\frac{\sin 50.0^\circ}{1.62}\right) = 28.22^\circ \ .$$

For the outgoing ray, $\theta_3 = 60.0^\circ - \theta_2$
and $\sin\theta_4 = n\sin\theta_3$:

$$(\theta_4)_{\text{violet}} = \sin^{-1}\left[1.66\sin 32.52^\circ\right] = 63.17^\circ$$

$$(\theta_4)_{\text{red}} = \sin^{-1}\left[1.62\sin 31.78^\circ\right] = 58.56^\circ .$$

The angular dispersion is the difference

$$\Delta\theta_4 = (\theta_4)_{\text{violet}} - (\theta_4)_{\text{red}} = 63.17^\circ - 58.56^\circ = \boxed{4.61^\circ}$$

In one case the angle of incidence θ_1 results in the θ_3 to be larger than critical angle – in such case the ray will not be leaving the prism.