# Solutions – PHYS 251 Final Exam (Old Material) - Practice Test

1C
Although both answer choices B and C will result in an enlarged image, answer choice B provides a virtual image, which means it couldn't actually be projected onto a screen. Thus only option C could provide the desired outcome.

2A
A difficult question, to say the least, we must first recognize that we are expected to know the index of refraction in air (which is equal to 1) and the index of refraction in water (which is equal to 1.33). Using this we can find the angle of refraction in water using Snell's Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$(1)\sin(30) = 1.33\sin\theta_2$$

$$\theta_2 = 22.08°$$

Note that based on the diagram given, the 60° angle is not the angle of incidence, but rather is used to determine that $\theta_1 = 30°$ is the angle relative to the perpendicular line of the water's surface.
The next step is to recognize that the light will travel horizontally both in air and in water in order to reach the 25 cm mark on the ruler, which allows us to relate the displacement along the x-axis with the following function:

$$x_{air} + x_{water} = 25$$

We can relate the vertical distance the light travels in terms of the height of the pool, h, and the depth of the water, d, which is the answer we're looking for. The vertical distance travelled in air is h-d, and the vertical distance travelled in water is just d. This allows us to set up triangles both in the air and in the water (after the light ray bends), where we now have terms for the distance along the x- and y-axis as well as the angles.

They are as follows:

<u>In air:</u>

$$\tan\theta_1 = \frac{h-d}{x_{air}},$$

$$x_{air} = (h-d)\tan\theta_1$$

<u>In water:</u>

$$\tan\theta_2 = \frac{d}{x_{water}},$$

$$x_{water} = (d)\tan\theta_2$$

This becomes:

$$x_{air} + x_{water} = (h-d)\tan\theta_1 + (d)\tan\theta_2 = 25$$

Since the only unknown variable now is the depth, d, we can solve to get d = 23cm.

3E

Using the equation for image formed by refraction:

$$s' = \frac{n_2}{n_1} s$$

where $n_2$ is for always the smaller value (air in this case),
where $n_1$ is for water,
s' is the image distance perceived (equal to 2 m in this case)
s is the actual distance we're solving for.

This rearranges and we solve for s = 2.66 m

4C

To correct near-sightedness you would want the corrected far point (or image distance) to be infinity. Using the Lensmaker's equation, and allowing the image distance to be infinity (which simply causes that term to fall to zero), we solve for the virtual image distance and get 20 cm in front of the glasses. Since these lenses/glasses were 2 cm from the eye, the total distance without glasses for the person's far point would be 22 cm.

5A

Statements II and III correctly show the relationship between distance and magnification for concave mirrors.

6A

The most important aspect of this question is that we recognize the lens must be in between the slide and the image on the screen, which means:

s + s' = 3.90 m.

Given that we have the magnification, we can write that s'/s = 38, or better yet:

s' = 38s.

By combining the above two equations we can solve for s and s', which give us:

s= 10 cm and s' = 380 cm

Lastly, we solve for f using the Lensmaker's equation and get f = 9.74 cm

7A

The safest way to solve this is to sketch ray diagrams, so long as you are sure of how the diagrams are drawn. See the review packet for examples of each scenario.

Alternatively, you could calculate image distance, s', by using the Lensmaker's equation, and by choosing an arbitrary value for the focal length, like f = 10 cm, and then determining the relative object distance, s, in each scenario. Using f = 10 cm, scenario I would have s = 15 cm, scenario II would have s = 30 cm, and scenario III would have s = 5cm. You would have to plug in the f and s values for each scenario to determine s' and then rank them from greatest to least.

8D

If the angle of refraction is smaller, it means the second medium has a larger n value than the first medium (as is the case with scenario III). Thus II must have the largest index of refraction. In option II, the situation is reversed, so the second medium must have a smaller n value than the first. In option I, the light ray is reflected rather than refracted, meaning total internal reflection, which means the index of refraction for the second medium is too low to allow refraction. This means option I must have the smallest index of refraction for the second medium. Thus we know the order is III > II > I.

9A

By drawing complimentary angles to the normal we can use geometry to determine the angle must be 10°.

However, an easier way of solving is to realize the effect of tilting the watch/mirror: Realize that if the watch were not tilted at all, meaning that the angle is 0° from the horizontal, then the reflected angle would bounce back at 30° above the horizontal instead of 10°. Also, if the watch were tilted at 30°, the light pass straight ahead at an angle of 30° below the horizontal. This means that by tilting the watch by 30°, we cause the angle of reflection to change by 60°. So we can conclude that every 1° we tilt the watch, results in a 2° change in the angle of reflection. Since the diagram shows the angle of reflection is now at 10° above the horizontal, it has changed by 20° compared to what would happen if the watch were horizontal, which must have been caused by a 10° tilt.

10A

Using Snell's Law we get:

$$n_{glass} \sin\theta_1 = n_{liquid} \sin\theta_2$$

$$(1.414)\sin(45) = n_{liquid} \sin(30)$$

$$n_{liquid} = 2.00$$

11A

We use Snell's Law twice to determine the angle of refraction for the two ends of the wavelength range, 400 nm and 700 nm, which correspond to indices of 1.55 and 1.45 respectively.

The resulting values are as follows:

$$n_{400}\sin\theta_{400} = n_{air}\sin\theta_{air} \qquad n_{700}\sin\theta_{700} = n_{air}\sin\theta_{air}$$
$$(1.55)\sin\theta_{400} = (1)\sin(30) \qquad (1.45)\sin\theta_{700} = (1)\sin(30)$$
$$\theta_{400} = 18.8° \qquad \theta_{700} = 20.2°$$

As the beam travels for one meter after exiting the surface it will widen as the two extreme wavelengths are moving at different angles from one another. If we set up right triangles for each angle, using the acute angle in each case adjacent to the 1 m side length, we can find the opposite length using:

$$\tan\theta = \frac{w}{l},$$
$$w_1 = l\tan\theta_1 \text{ and } w_2 = l\tan\theta_2$$
$$w_1 = 1\tan(18.8) \text{ and } w_2 = 1\tan(20.2)$$
$$w_1 = 0.340 \text{ and } w_2 = 0.368$$

These difference between these two lengths is the width: 0.368 – 0.340 = 0.028 m.

12C

Using the equation for total internal reflection and the required critical angle of 75° from the normal line, we get:

$$\sin\theta_c = \frac{n_2}{n_1}, \text{ where } n_1 > n_2$$
$$n_1 = \frac{n_2}{\sin\theta_c}$$
$$n_1 = \frac{1.43}{\sin 75} = 1.48$$

13B
The Lensmaker's equation gets us the answer in one step. The only issue might be using consistent units.
Let f = 50 mm, s = 10,000 mm, and solve for image distance, s'.

14D
The rays shown in diagrams 3 and 4 are each false, and would in fact be appropriate in each other's diagram. Thus the ray in diagram 3 belongs on a diverging lens, and the ray in diagram 4 belongs on a converging lens.

15E
The magnification can be used to find the image distance:
s' = -1.667 x 4cm = -6.668cm
Now we use the Lensmaker's equation to solve for focal point, f = 10 cm.

16D
Let us call the two mirrors "top" and "bottom".

The object reflected in the top mirror creates image #2, which in turn, reflects via the extension of the bottom mirror to make image #3.

The object reflected in the bottom mirror creates image #5, which in turn, reflect via the extension of the top mirror to make another image (not shown) slightly beneath the location given by #4.

None of the reflections are capable of making images at positions #4 and #1.

17A
Where the density of the field lines has been halved, we can assume the electric field is half its original value. Since the force is proportional to the field strength, when the field is halved, so too is the force, thus it becomes 5 pN. Also, since we have switched from a proton to an electron, the charge has flipped and so too must the direction of the force, thus we move to the right instead of the left.

18E

If the ball is attracted to the rod, it must be made of a conductive material, otherwise it would not have been influenced by the nearby positive charge. The reason it is then attracted to the rod is due to "induction", where the electrons rearrange themselves to be as close to the positive charge as possible (or as far away from the negative charge if the rod was negatively charged). Thus we pick answer choice E.

19A

Remember that according to Coulombs Law the force acting on each sphere will be equal in size but acting in opposite directions. This is why they repel. Since the forces acting on each sphere have the same magnitude, and since the spheres have the same mass as well, the acceleration acting on each sphere will also be the same (this is comes from Newton's second law: F = ma). Thus if they each experience the same acceleration, they will move the same distance apart from each other, and answer choice A is the correct choice depicting that.

20E

We use Coulomb's law to determine the force on the negative charge due to the other two charges located on either side:

The force due to the +50μC charge is:

$$F_1 = \frac{k(50\mu C)(40\mu C)}{2^2} = 4.495N, \text{ in the } -\text{x direction}$$

where the distance is 2m based on the location of each charge along the x-axis.

The force due to the +30μC charge is:

$$F_2 = \frac{k(30\mu C)(40\mu C)}{2^2} = 2.697N, \text{ in the } +\text{x direction}$$

where the distance is 2m based on the location of each charge along the x-axis.

Thus the net force is $F_1 + F_2 = (-4.495 + 2.697) = -1.798$ N along the x-axis.

21A

To answer this, we must use Coulomb's law to determine the magnitude and direction of each force acting on q1 from the other charges:

$$F_{12} = \frac{k(20\mu C)(20\mu C)}{2^2} = 0.899N, \text{ in the } +\text{y axis}$$

$$F_{13} = \frac{k(20\mu C)(40\mu C)}{2^2} = 1.798N, \; 30^\circ \text{ above the } -\text{x axis}$$

Note that we know the force from q3 is $30^0$ above the –x axis since all the charges form an equilateral triangle 60 degrees apart.

In order to get the correct magnitude, we must first take the forces and place them in the respective x- and y-components:

> $F_{12}$ is already along the y-axis, so need not be altered.
> $F_{13,\text{x axis}} = F_{13}\cos 30 = 1.56\text{N}$, $F_{13,\text{y axis}} = F_{13}\sin 30 = 0.899\text{N}$

Thus using vector analysis we see that the total force along each axis is:

> y-axis: 0.899 + 0.899 = 1.798 N
> x-axis: 1.56 N

The magnitude using Pythagorean theory: $F = \sqrt{(1.798)^2 + (1.56)^2} = 2.38N$

Thus we choose answer choice A.

22D

The general equation for electric field is E = F/Q, where represents a test charge placed in the field. So if we solve this equation for force, we get:

> $F = EQ = (200)(-1.6 \times 10^{-19}) = -3.2 \times 10^{-17}$

The charge is based on the charge of an electron (given on your test's data sheet) and since it is negative, it must travel in the opposite direction of the field, thus we choose answer choice D.

23E
The only equation relating potential energy and electric potential is $\Delta V = \Delta U/q$. This means to calculate the change in potential energy, we need to multiply $\Delta V$ with q. Note that in this particular problem, q represents the negative charge that is moved from the x-axis to the y-axis.
The change in electric potential, $\Delta V$, is a scalar quantity that is essentially only interested in the fixed point charge and its distance, r, where we measure the potential. In this particular problem, the initial and final locations of the moving charge are the same distance from the fixed charge, thus the potential at each location is identical. This means that the change in potential as the negative charge moves from its initial to its final location is zero, and thus the change in potential energy is also zero.

24D
This scenario is indicative of a positive point charge, which decreases in field strength the further you are from it. The potential of such a point charge will also decrease as you move away from the charge, and thus answer D is the appropriate choice.

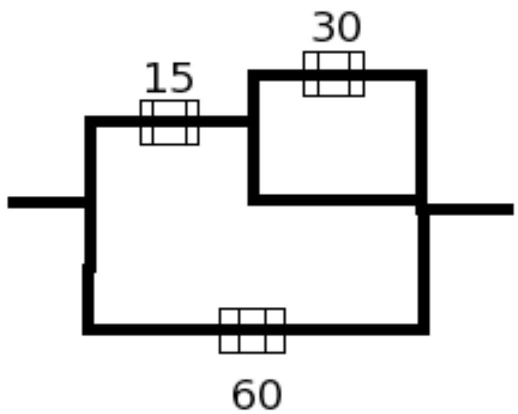
25B
Positive charges always move in the direction of the electric field. The resulting motion always moves the positive charge from a region of higher to potential to one of lower potential, and so its electric potential energy decreases accordingly.

26E
In order to use the equation for discharging, we should consider the amount of charge *remaining* after three time constants, which would have to be $q(t)/q_0$. Also we can substitute time, t, with $3\tau$, which is three time constants. We can also substitute RC, which is also equal to $\tau$, and we get:

$$\frac{q(t)}{q_0} = e^{\frac{-t}{RC}} = e^{\frac{-3\tau}{\tau}} = e^{-3} = 0.0498 = 4.98\%$$

This means that after three time constants, we have 4.98% left, which means that charge has been reduced by 95.02%.
Note that the fact that charge had been reduced by 63% after one time constant was useless information if you solve it this way.

27D
Using the appropriate equations for resistors in parallel, the two resistors at the top left of the circuit can be combined into equivalent resistance of 15 ohms. Also, the two resistors in series at the bottom are the equivalent of 60 ohms. Thus the circuit can be redrawn as shown below:




At this stage the current can get from “a” to “b” by travelling through either the 15 ohm resistor or the 60 ohm resistor. It does not need to go via the 30 ohm resistor at the top right. Which means that for all intents and purposes we can ignore it. So now we really have a simple parallel circuit with resistors of 15 and 60 ohms, and an equivalent resistance of 12 ohms.

28D
Looking at the currents entering and leaving any of the junctions where the wires meet gives the following equation: $I_2 + I_3 = -I_1$.
This can be rewritten to get answer D.

29D
We treat the resistors in series on the top half of the circuit as one resistor of 12 ohms, and the resistors at the bottom as one resistor of 596 ohms. So the circuit is really a parallel circuit with equivalent resistance of 11.8 ohms.

30D
The voltage drops from 9 V to 8.5 V due to the internal resistance. This 0.5 V lost within the battery can be set equal to V = IR, allowing us to solve for the current, I, to get:

$$I = V/R = 0.5/0.1 = 5 \text{ A}$$

31D
Energy dissipation is the same thing as power. So let's see the equations for power:

$$P = V_0 I = I^2 R = \frac{V^2}{R}$$

We can analyze each answer choice as follows:

(a) False – if you half V (with R constant) the power decreases by a factor of one fourth.
(b) False – if you half I (with R constant) the power decreases by a factor of one fourth.
(c) False – if you half R (with V constant) the power will double.
(d) True – according to $P = I^2R$, if you half R (with I constant) the power will half.
(e) False – if you half both V and I the power decreases by a factor of one fourth..

32C
Remember that the capacitance is decided once the capacitor is built, and cannot be changed after that point. Thus, plate separation, plate area, and the insertion of a dielectric material, are the only factors that influence capacitance.

33D
Initially, the capacitor will not affect the resistance of the circuit, and you can pretend that it is not even there. Thus the current in the circuit will be I = V/R, regardless of the capacitance, and is thus 18/2 = 9 Amps.

34C
Remember that resistivity is a property of a material, and so both wires have the same resistivity (this rules out A).

The graph shows that at any given voltage the current in wire A is greater than that of wire B. This can only happen if wire A has a smaller resistance, since current and resistance are inversely proportional. That means that statement ii is correct. We should also remember that if everything else is held constant, the shorter the conductor is, the smaller the resistance will be. So since wire A has the smaller resistance, we can assume it has a shorter length, and thus statement v is also correct.