Quantum Physics Conceptual Survey (QPCS)
Version 1

PhysPort
Supporting physics teaching with research-based resources

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Format: Pre/post, Multiple-choice
Duration: 30 minutes
Focus: Modern / Quantum Content knowledge (wave particle duality, de Broglie wavelength, double slit interference, uncertainty principle, photoelectric effect)
Level: Intermediate, Intro college

Security Warning!

Students may not have unsupervised access to this assessment instrument!
It takes many years to create and validate reliable assessment instruments.
If students can access and study from them, these instruments lose their validity.

Please do **not**:
- allow students to keep copies of this instrument
- post this instrument on a website without security to prevent copying, downloading or sharing
- share this instrument with anyone who hasn't agreed to these guidelines

How to give the test

- Give it as both a pre- and post-test to measure student learning or as a pre-test only to get a sense of your students' initial ideas.
  - Give the pre-test before you cover relevant course material.
  - Give the post-test at the end of the term.
- Use the whole test, with the original wording and question order. This makes comparisons with other classes meaningful.
- Make the test required, and give credit for completing the test (but not correctness). This ensures maximum participation from your students.
- Tell your students that the test is designed to evaluate the course (not them), and that knowing how they think will help you teach better. Tell them that correctness will not affect their grades (only participation). This helps alleviate student anxiety.
- Refer to the test by a generic title like "Modern / Quantum Survey" to prevent students from looking up the answers.
- For more details, read the **PhysPort Guides** on implementation:
  - **PhysPort QPCS implementation guide** (www.physport.org/implementation/QPCS)
  - **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** (www.physport.org/expert/AdministeringConceptInventories/)

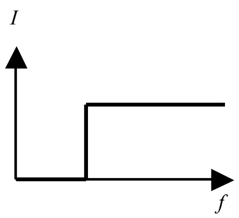
How to score the test

- Download the answer key from PhysPort (www.physport.org/key/QPCS)
- Each student's score is their percentage correct out of 25 questions.
- See the **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** for instructions on calculating normalized gain and effect size (www.physport.org/expert/AdministeringConceptInventories/)
- Use the **PhysPort Assessment Data Explorer** for analysis and visualization of your students' responses (www.physport.org/explore/QPCS)

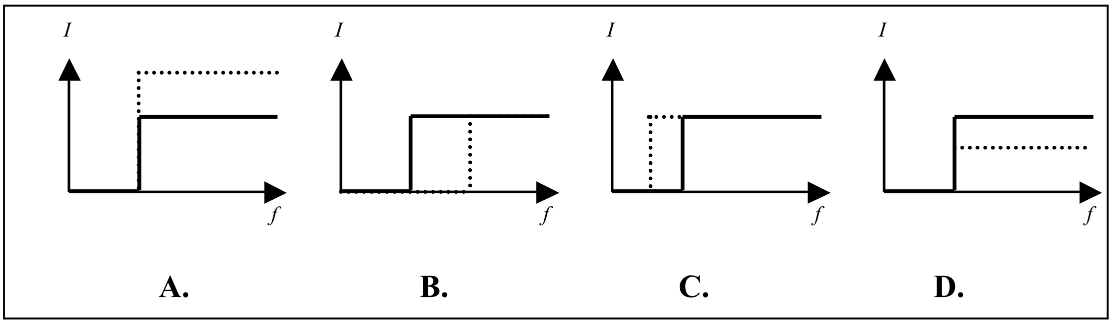
Quantum Physics Conceptual Survey (QPCS)

Questions 1 through 3 refer to the following.

In a hypothetical experiment to demonstrate the photoelectric effect, a light source of variable frequency is shone on a photo-sensitive surface. Ejected photoelectrons are collected by an anode. A graph of the resulting photocurrent (I) as a function of frequency (f) looks like this.



Select your answers to the questions below from these graphs.



Which graph would be most appropriate when,

___**1.** the intensity of the light is increased?

___**2.** the work function of the surface is increased?

3. In an experiment to demonstrate the photoelectric effect the following observations are made:

- light of high frequency shone onto some materials causes electrons to be ejected; and
- if the frequency of light is decreased (with any amplitude) there is a cut-off frequency below which electrons are no longer ejected.

These observations are believed to support a particle theory of light, rather than a wave theory. Which one of the statements is inconsistent with the observations?

A. In a particle theory, ejection of electrons is explained by collisions with photons. Each collision can give a single electron enough energy to escape.

B. In a wave theory, ejection of electrons is explained by the electromagnetic wave causing the electrons to vibrate, which gives some electrons enough energy to escape.

C. In a particle theory, the cut-off is explained because at very low frequencies the photons have very low energies and no individual photon has enough energy to eject an electron.

D. In a wave theory, the cut-off is explained because a very low frequency wave could not make the electrons vibrate energetically enough, even at very high amplitudes.

Questions 4 through 7 refer to the following experiments.

- In one experiment electrons are traveling from a source to a detecting screen.
- In a second experiment light is traveling from a source to a photographic plate.

For each question, choose from A through D the most appropriate answer according to the standard (Copenhagen) interpretation of quantum mechanics.

A. It is behaving like a particle.

B. It is behaving like a wave.

C. It is behaving like both a particle and a wave.

D. You cannot tell if it is behaving like a particle or a wave.

How is the particle/wave behaving when,

___**4.** an electron travels from the source to the screen?

___**5.** light travels from the source to the plate?

___**6.** the electron interacts with the screen?

___**7.** the light interacts with the plate?

For each question 8 through 10, choose the most appropriate answer from A through C.

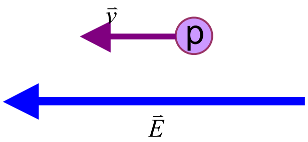
A. The de Broglie wavelength of the particle will increase.

B. The de Broglie wavelength of the particle will decrease.

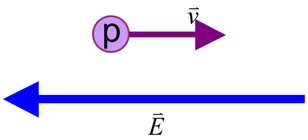
C. The de Broglie wavelength of the particle will remain the same.

What will happen when a positively charged particle is,

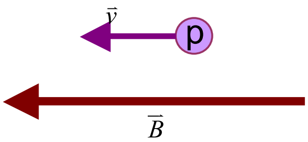
___**8.** moving through an electric field, in the same direction as the field, and is therefore speeding up?



___**9.** moving through an electric field, in the opposite direction as the field, and is therefore slowing down?



___**10.** moving through a magnetic field, in the same direction as the field, and its velocity is therefore constant?



For each question 11 through 13, choose the most appropriate answer from A through C.

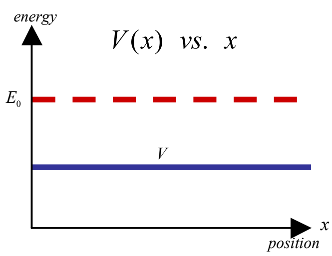
A. The de Broglie wavelength of the particle will increase.

B. The de Broglie wavelength of the particle will decrease.

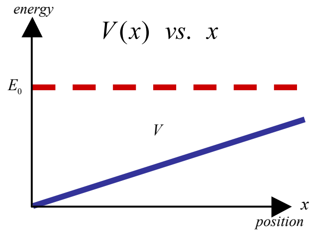
C. The de Broglie wavelength of the particle will remain the same.

What will happen when a quantum particle is traveling from left to right with constant total energy, E_0, in a region in which the potential energy is,

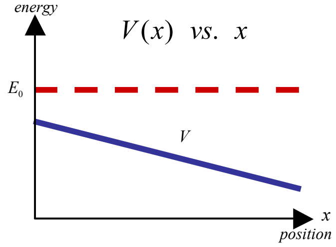
___**11.** constant?



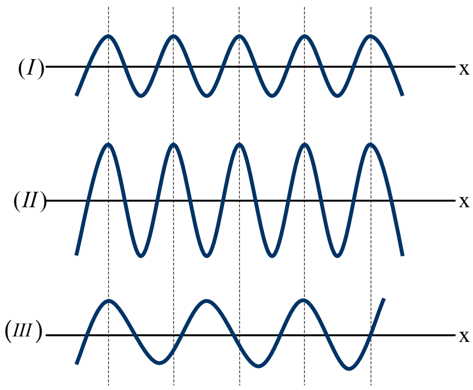
___**12.** increasing?



___**13.** decreasing?



14. Three particles of equal mass are traveling in the same direction. The de Broglie waves of the three particles are as shown.



Rank the speeds of the particles (I), (II) and (III) by circling one of these four possibilities.

A. $v_{II} > v_I > v_{III}$

B. $v_{II} > v_{III} > v_I$

C. $v_I = v_{II} > v_{III}$

D. $v_{II} > v_I = v_{III}$

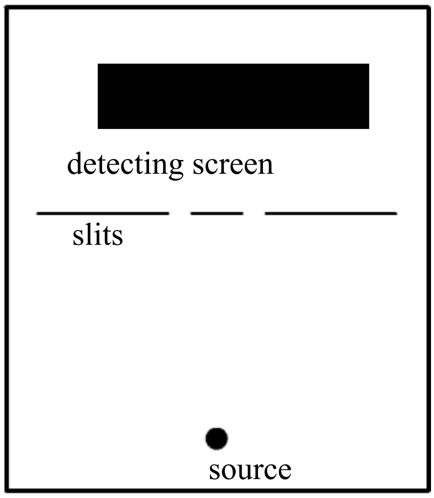
Questions 15 through 19 refer to the following experiments.

- In one experiment electrons are traveling

Top view of experimental set-up (not to scale)

from a source to a detecting screen, through a double slit.

- In a second experiment light is traveling from a source to a photographic plate, through a double slit.
- In a third experiment marbles are traveling from a source to an array of collecting bins, through two slit-like openings, side by side.



The right-hand figure shows the experimental set-up and the figures below show roughly the possible patterns which could be detected on the various screens.

Possible patterns (not to scale)

A. **B.** **C.**

A through C represent some patterns which might be observed. If you think none is appropriate, answer D.

Which pattern would you expect to observe when,

___**15.** light passes through the double slit?

___**16.** marbles pass through the double opening?

___**17.** electrons pass through the double slit?

___**18.** light passes through the apparatus when one of the slits is covered?

___**19.** <u>electrons</u> pass through the apparatus when <u>one of slits is covered</u>?

In questions 20 and 21, circle the most appropriate statement.

20. According to the uncertainty principle, the more we know about an electron's position, the less we know about its,

A. speed.

B. momentum.

C. kinetic energy.

D. all of these.

21. Choose the answer A through D which is most appropriate answer according to the standard (Copenhagen) interpretation of quantum mechanics?

The Heisenberg Uncertainty Principle is mostly applied to very small objects such as electrons and protons. Why don't we use the uncertainty relation on larger objects such as cars and tennis balls?

A. The errors of measurement can always, in principle, be made smaller by using more sensitive equipment.

B. Large objects at any instant of time have an exact position and exact momentum and with sufficient care we can measure both precisely.

C. Large objects obey Newton's laws of motion, to which the uncertainty principle does not apply.

D. Because it does apply to large objects, but the uncertainties are so small that we don't notice them.

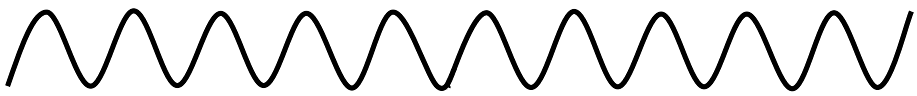
For each question 22 through 24, choose the description from A through D which best describes the illustrated wave packet.

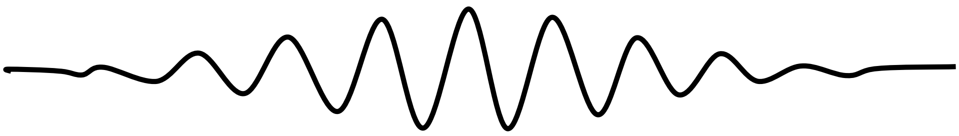
A. Poorly defined position, well defined wavelength

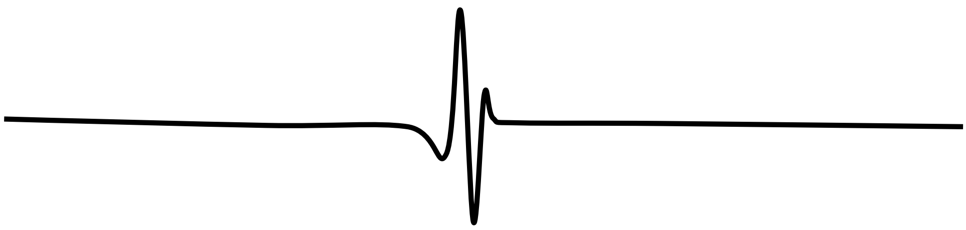
B. Well defined position, poorly defined wavelength

C. Well defined position, well defined wavelength

D. Poorly defined position, poorly defined wavelength

__**22.** 

__**23.** 

__**24.** 

25. For the double slit experiment with electrons, which one of the following statements is true according to the standard (Copenhagen) interpretation of quantum mechanics?

A. It is, in principle, possible to measure which slit an electron went through and still see a multiple fringe pattern, if the technology is sophisticated enough.

B. Each electron must have gone through one slit or the other, but it is impossible to measure which slit any one particular electron went through.

C. It is possible to measure which slit an electron went through, but if you make this measurement, the beam of electrons will no longer form the multiple fringe pattern on the screen.