Entrance Examination in Physics for the Master Continuation Programmes

SAMPLE TEST with answers

Branches: Mathematical Physics, Nuclear and Particle Physics, Quantum Technologies

The entrance examination is regarded as successful, if the candidate has obtained at least 20 points (i.e. 50% of the maximum score).

1. A particle's movement is governed by parametric equations $x = at$, $y = bt$ with a, b constant. Determine the radial and transverse components of the velocity and acceleration vectors of the movement.

   (4 points)

   Answer: $v_r = \dot{r} = \sqrt{a^2 + b^2}$, $v_\varphi = r\dot{\varphi} = 0$, $a_r = \ddot{r} - r\dot{\varphi}^2$, $a_\varphi = 2\dot{r}\dot{\varphi} + r\ddot{\varphi} = 0$

2. A simple pendulum of mass m and length l is at time $t = 0$ displaced by angle φ_0 from the vertical and released. Determine the maximum tension in the string and velocity at the equilibrium position.

   (4 points)

   Answer: $F = mg(3 - 2\cos\varphi_0)$, $v = \sqrt{2gl(1 - \cos\varphi_0)}$

3. A cart loaded with sand moves along a horizontal road due to a constant horizontal force F. Sand spills through a hole in the bottom with a constant rate per time μ. At time $t = 0$ was the cart's velocity zero and the cart loaded with sand had the mass M. Determine the speed and acceleration of the cart.

   (5 points)

   Answer: $a = \frac{F}{M - \mu t}$, $v = \frac{F}{\mu} \ln \frac{M}{M - \mu t}$

4. A spaceship moves with speed $v_1 = 0.8c$ relative to Earth and fires a rocket in the forward direction at a speed $v_2 = 0.6c$ relative to the spaceship. The proper length of the rocket is $l_0 = 10m$. Determine the length of the rocket measured by the observer on the spaceship and by the observer on Earth.

   (4 points)

   Answer: $l_{v_1} = 8m$, $l_{v_2} = 3.24m$

5. Determine the magnitude of the electric field E at the centre of a hemispherical shell with radius R and uniform surface charge density σ.

   (5 points)

   Answer: $E = \frac{\sigma}{4\varepsilon_0}$

6. Determine the leakage resistance of a spherical capacitor with the radii of its metal shells $R_1 < R_2$. The space between the spherical shells is filled with oil of resistivity ϱ.

   (5 points)

   Answer: $R = \frac{\varrho}{4\pi} \frac{R_2 - R_1}{R_1 R_2}$

7. Determine the force on a charged particle that is moving with velocity $v = E/B$ in mutually perpendicular electric and magnetic fields. The vectors $\vec{E}$, $\vec{B}$, $\vec{v}$ form a right-handed orthogonal system.

   (4 points)

   Answer: $\vec{F} = \vec{0}$

8. Determine natural frequency of longitudinal vibrations of a mass point that is connected to fixed points by two springs with equal spring constants k.

   (4 points)

   Answer: $\omega = \sqrt{\frac{2k}{m}}$

9. Determine the Lagrangian $L(\varphi, \dot{\varphi}, t)$ and derive the equation of motion of a simple pendulum with extensible length l which increases as $l(t) = l_0(1 + kt)$, where l_0 and k are constant.

   (5 points)

   Answer: $L(\varphi, \dot{\varphi}, t) = \frac{1}{2} m \left(\dot{l}^2 + l^2 \dot{\varphi}^2 \right) + mgl \cos\varphi$, $(1 + kt)\ddot{\varphi} + 2k\dot{\varphi} + \frac{g}{l_0} \sin\varphi = 0$

Entrance Examination in Physics for the Master Continuation Programmes

SAMPLE TEST with answers

Branches: Physical Electronics, Nuclear Engineering, Solid State Engineering, Physical Engineering of Materials, Plasma Physics and Thermonuclear Fusion

The entrance examination is regarded as successful, if the candidate has obtained at least 20 points (i.e. 50% of the maximum score).

1. A particle's movement is governed by parametric equations $x = at$, $y = bt$ with a, b constant. Determine the radial and transverse components of the velocity and acceleration vectors of the movement.

   (4 points)

   Answer: $v_r = \dot{r} = \sqrt{a^2 + b^2}$, $v_\varphi = r\dot{\varphi} = 0$, $a_r = \ddot{r} - r\dot{\varphi}^2$, $a_\varphi = 2\dot{r}\dot{\varphi} + r\ddot{\varphi} = 0$

2. A simple pendulum of mass m and length l is at time $t = 0$ displaced by angle φ_0 from the vertical and released. Determine the maximum tension in the string and velocity at the equilibrium position.

   (4 points)

   Answer: $F = mg(3 - 2\cos\varphi_0)$, $v = \sqrt{2gl(1 - \cos\varphi_0)}$

3. A cart loaded with sand moves along a horizontal road due to a constant horizontal force F. Sand spills through a hole in the bottom with a constant rate per time μ. At time $t = 0$ was the cart's velocity zero and the cart loaded with sand had the mass M. Determine the speed and acceleration of the cart.

   (5 points)

   Answer: $a = \frac{F}{M - \mu t}$, $v = \frac{F}{\mu} \ln \frac{M}{M - \mu t}$

4. A spaceship moves with speed $v_1 = 0.8c$ relative to Earth and fires a rocket in the forward direction at a speed $v_2 = 0.6c$ relative to the spaceship. The proper length of the rocket is $l_0 = 10m$. Determine the length of the rocket measured by the observer on the spaceship and by the observer on Earth.

   (4 points)

   Answer: $l_{v_1} = 8m$, $l_{v_2} = 3.24m$

5. Determine the magnitude of the electric field E at the centre of a hemispherical shell with radius R and uniform surface charge density σ.

   (5 points)

   Answer: $E = \frac{\sigma}{4\varepsilon_0}$

6. Determine the leakage resistance of a spherical capacitor with the radii of its metal shells $R_1 < R_2$. The space between the spherical shells is filled with oil of resistivity ϱ.

   (5 points)

   Answer: $R = \frac{\varrho}{4\pi} \frac{R_2 - R_1}{R_1 R_2}$

7. Determine the force on a charged particle that is moving with velocity $v = E/B$ in mutually perpendicular electric and magnetic fields. The vectors $\vec{E}$, $\vec{B}$, $\vec{v}$ form a right-handed orthogonal system.

   (4 points)

   Answer: $\vec{F} = \vec{0}$

8. Determine natural frequency of longitudinal vibrations of a mass point that is connected to fixed points by two springs with equal spring constants k.

   (4 points)

   Answer: $\omega = \sqrt{\frac{2k}{m}}$

9. Determine the average speed $\langle v \rangle$ for the Maxwell–Boltzmann distribution of speeds.

   (5 points)

   Answer: $\langle v \rangle = \sqrt{\frac{8kT}{\pi m}}$

Entrance Examination in Physics for the Master Continuation Programmes

SAMPLE TEST with answers

Branch: Decommissioning of Nuclear Facilities

The entrance examination is regarded as successful, if the candidate has obtained at least 20 points (i.e. 50% of the maximum score).

1. A particle's movement is governed by parametric equations $x = at$, $y = bt$ with a, b constant. Determine the radial and transverse components of the velocity and acceleration vectors of the movement.

   (4 points)

   Answer: $v_r = \dot{r} = \sqrt{a^2 + b^2}$, $v_\varphi = r\dot{\varphi} = 0$, $a_r = \ddot{r} - r\dot{\varphi}^2$, $a_\varphi = 2\dot{r}\dot{\varphi} + r\ddot{\varphi} = 0$

2. A simple pendulum of mass m and length l is at time $t = 0$ displaced by angle φ_0 from the vertical and released. Determine the maximum tension in the string and velocity at the equilibrium position.

   (4 points)

   Answer: $F = mg(3 - 2\cos\varphi_0)$, $v = \sqrt{2gl(1 - \cos\varphi_0)}$

3. A cart loaded with sand moves along a horizontal road due to a constant horizontal force F. Sand spills through a hole in the bottom with a constant rate per time μ. At time $t = 0$ was the cart's velocity zero and the cart loaded with sand had the mass M. Determine the speed and acceleration of the cart.

   (5 points)

   Answer: $a = \frac{F}{M - \mu t}$, $v = \frac{F}{\mu} \ln \frac{M}{M - \mu t}$

4. A spaceship moves with speed $v_1 = 0.8c$ relative to Earth and fires a rocket in the forward direction at a speed $v_2 = 0.6c$ relative to the spaceship. The proper length of the rocket is $l_0 = 10m$. Determine the length of the rocket measured by the observer on the spaceship and by the observer on Earth.

   (4 points)

   Answer: $l_{v_1} = 8m$, $l_{v_2} = 3.24m$

5. Determine the magnitude of the electric field E at the centre of a hemispherical shell with radius R and uniform surface charge density σ.

   (5 points)

   Answer: $E = \frac{\sigma}{4\varepsilon_0}$

6. Determine the leakage resistance of a spherical capacitor with the radii of its metal shells $R_1 < R_2$. The space between the spherical shells is filled with oil of resistivity ϱ.

   (5 points)

   Answer: $R = \frac{\varrho}{4\pi} \frac{R_2 - R_1}{R_1 R_2}$

7. Determine the force on a charged particle that is moving with velocity $v = E/B$ in mutually perpendicular electric and magnetic fields. The vectors $\vec{E}$, $\vec{B}$, $\vec{v}$ form a right-handed orthogonal system.

   (4 points)

   Answer: $\vec{F} = \vec{0}$

8. A wire of constant resistivity is bent in the form of an equilateral triangle. Two vertices of the triangle are connected to a source of electromotive force $\mathcal{E}$. Determine the magnetic field in the centre of the triangle.

   (4 points)

   Answer: $\vec{B} = \vec{0}$

9. A square loop with side length a rotates in the uniform magnetic field $\vec{B}$ around axis parallel with the loop plane and perpendicular to the field with constant angular velocity ω. At time $t = 0$ is the loop in the plane perpendicular to the field. Determine the induced electromotive force $\mathcal{E}$ at time t.

   (5 points)

   Answer: $\mathcal{E} = Ba^2\omega \sin \omega t$