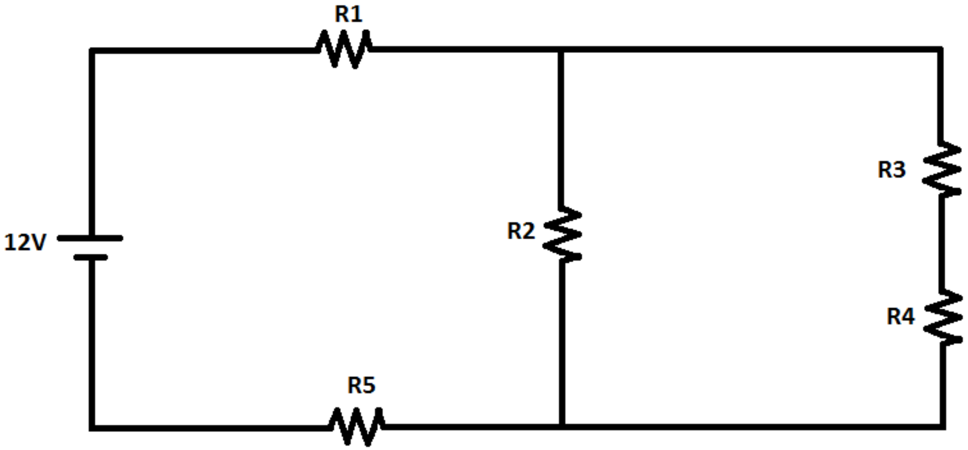
UIL Physics

2022-2023



Topics by Question:

- **Physics Questions P1 – P3** will be from "QED" by Richard Feynman.
- **Physics Question P4** will be from the field of **Astronomy**.
- **Physics Question P5** will be about **Measurement/Dimensional Analysis/Significant Figures/Order of Magnitude**.
- **Physics Question P6** will be about **Uniformly Accelerated Motion**.
- **Physics Question P7** will be about **Forces**.
- **Physics Question P8** will be about **Work/Energy/Power/Momentum**.

Topics by Question:

- **Physics Question P9** will be about **Circular and Rotational Motion/Equilibrium**.
- **Physics Question P10** will be about **Waves/Sound/ Harmonic Motion**.
- **Physics Question P11** will be about **Fluid Statics and Dynamics/ Thermodynamics.**
- **Physics Question P12** will be about **DC Circuits/Resistors/Capacitors**.
- **Physics Question P13** will be about **Electric Fields and Forces/Electric Potential/Gauss' Law**.
- **Physics Question P14** will be about **Magnetic Fields and Forces/Magnetic Materials/Ampere's Law**.

Topics by Question:

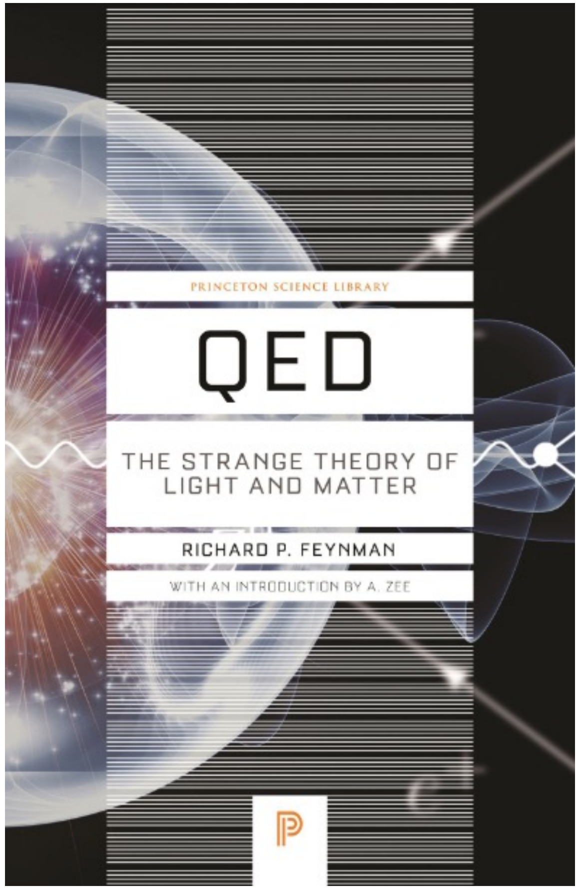
- **Physics Question P15** will be about **Faraday's Law/Induction/EM Oscillation and Waves/AC Circuits**.
- **Physics Question P16** will be about **Geometric Optics/Wave Optics**.
- **Physics Question P17** will be about **Modern Physics/Quantum Physics**.
- **Physics Question P18** will be about **Nuclear Physics/Particle Physics**.
- **Physics Question P19** will be a wildcard question from the topics traditionally covered in a Physics 1 course.
- **Physics Question P20** will be a wildcard question from the topics traditionally covered in a Physics 2 course.

Physics Directed Study Text

QED: The Strange Theory of Light and Matter

by

Richard Feynman



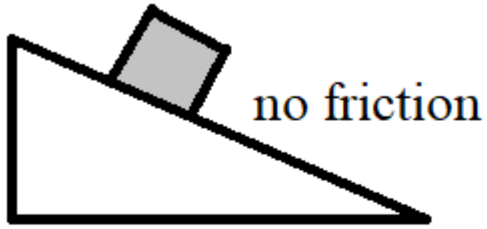
Directed Study Questions

- Invitational A – chapter 1
- Invitational B – chapter 1
- District – chapter 2
- Regional – chapter 3
- State – chapter 4

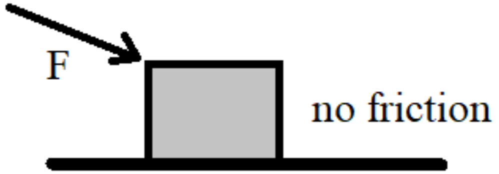
Each Test Increases in Difficulty

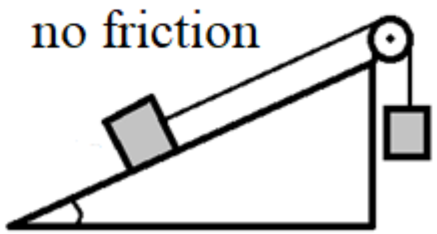
for example, consider questions from P07: Forces

Level 1: Invitational

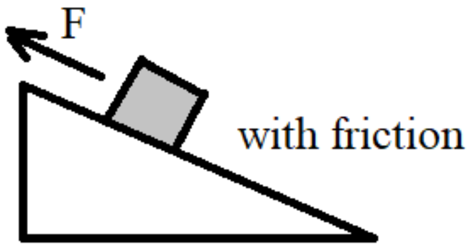


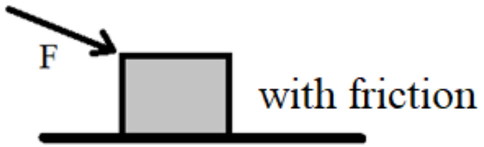
Level 2: District





Level 3: Region and State





The "Process"

Generate two-three potential questions

Choose question number

Topic is determined

Solve, decide if difficulty is correct

Decide form:
- for example P07:
  - inclined or not
  - static or dynamic friction?

Work incorrectly, making common mistakes

Finalize
- images
- constants
- etc…

Sample Physics Questions

When a main sequence star expands into a red giant star, how and where is the energy generated that causes the star to expand?

A) helium fusion in the central core
B) helium fusion in a shell around the core
C) hydrogen fusion in the central core
D) hydrogen fusion in a shell around the core
E) carbon/oxygen fusion in the central core

(D) When a main sequence star exhausts the hydrogen fuel in the central core, what remains in the core is helium. The helium core begins to contract, and, because of gravitational energy, it heats up. The helium in the core does not undergo fusion, but the excess energy does heat up a shell of hydrogen around the core sufficiently to start hydrogen fusion in the shell. The energy generated by the hydrogen fusion in the shell is significantly larger than when the star was on the main sequence. This excess energy from the shell flows to the upper layers of the star, causing the entire star to expand – creating a red giant.

A small car is moving at 30.0 mph when it gets on the entrance ramp for a highway. The car accelerates at a rate of 9500 mi/hr^2 for the entire 0.15-mile length of the ramp. What is the speed of the car as it enters the highway?

A) 36 mph
B) 48 mph
C) 53 mph
D) 61 mph
E) 73 mph

(D) The units are odd, but they are compatible, so we don't need to make any unit conversions to solve the problem. We have distance information but are not given any information about the time that the car is on the entrance ramp. Thus, we should use the kinematic equation: $v_f^2 = v_i^2 + 2a(x_f - x_i)$.

Plugging in the given values:

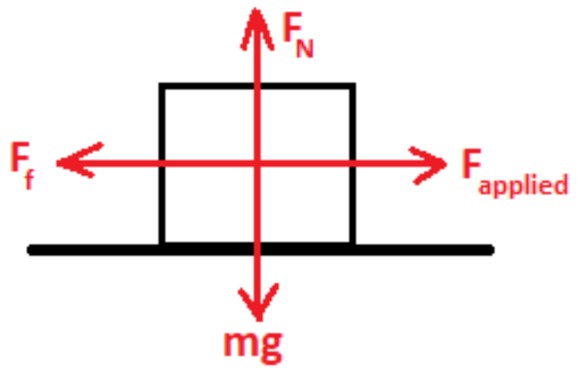
$v_f^2 = (30.0)^2 + 2(9500)(0.15) = 3750.$

So $v_f = \sqrt{3750} = 61$mph.

A tokoloshe is stealing an 11.4kg box of tools. The tokoloshe pulls with a horizontal force of 80.0N, and the coefficient of friction between the box of tools and the floor is 0.170. Assuming that it starts from rest, what is the horizontal velocity of the box of tools after being pulled for 2.50seconds.

A) 1.67 m/s
B) 5.35 m/s
C) 13.4 m/s
D) 15.6 m/s
E) 17.5 m/s

(C) The force diagram for the box of tools is shown. Since there is no motion in the y-direction, we know that the normal force (F_N) and the weight (mg) cancel one another.



Thus, $F_N - mg = 0 \quad \rightarrow \quad F_N = mg.$

So, the normal force is $F_N = (11.4)(9.8) = 111.7$ N.

From this we can determine the frictional force, $F_f = \mu F_N$.

Thus, $F_f = (0.170)(111.7) = 19.0$ N.

In the horizontal direction, there is a net acceleration to the right, so by the acceleration law: $F_{app} - F_f = ma$.

Putting in the values that we know: $80.0 - 19.0 = (11.4)a$, which gives an acceleration of $11.4a = 61.0 \quad \rightarrow \quad a = 5.35$ m/s².

Finally, we can get the velocity by using a kinematic equation:

$v_f = v_i + at = 0 + (5.35)(2.50) = 13.4$ m/s.

You stand near a long, straight, high power DC electric line. When you are 4.50m away from the power line, you measure the magnetic field strength to be 2600.0 Gauss. To produce this field, what must be the current flowing in the power line?

A) 5.85×10^{6} A

B) 9.31×10^{6} A

C) 1.17×10^{7} A

D) 3.68×10^{7} A

E) 7.35×10^{7} A

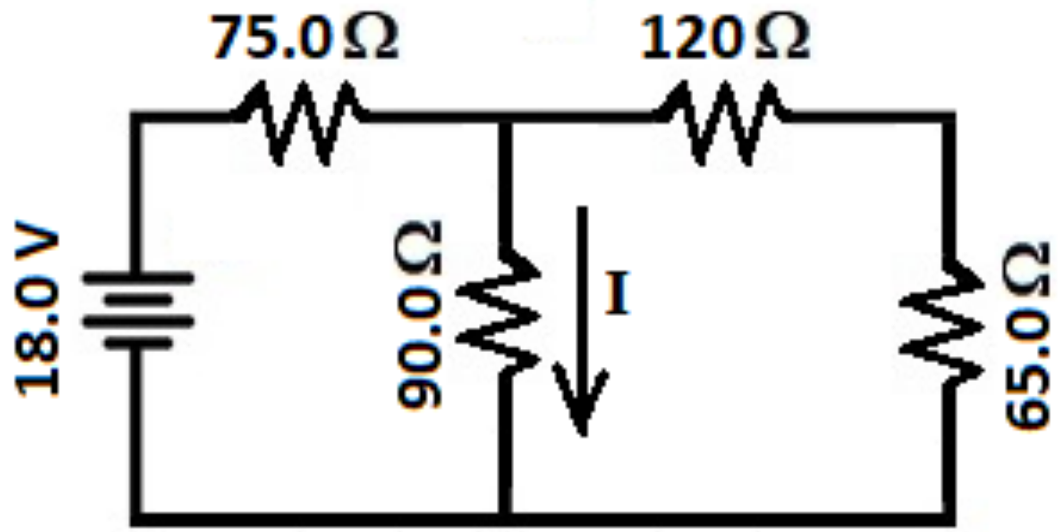
(A) The equation describing the magnetic field produced by a long, straight, current-carrying wire is $B = \frac{\mu_0 I}{2\pi r}$. Solving for the current, we get $I = \frac{2\pi r B}{\mu_0}$. Before using this equation, we must convert the magnetic field to Teslas: $B = 2600G = 2600\times10^{-4}T = 0.26T$.

Plugging this, and the distance, into the formula gives:

$$I = \frac{2\pi(4.50)(0.26)}{4\pi \times 10^{-7}} = 5.85\times10^{6}A$$

Determine the current, I, flowing through the 90.0 Ω resistor in this circuit.

A) 43.5 mA
B) 77.3 mA
C) 89.3 mA
D) 111 mA
E) 133 mA



(C) First, we will need to simplify the circuit by combining the resistances. The first pair to combine are the 120Ω and the 65.0Ω, which are in series.

That gives a combination of $R_s = 120 + 65 = 185\Omega$.

This combination is in parallel with the 90.0Ω resistor. Putting together that parallel group leads to an equivalent resistance of $\frac{1}{R_p} = \frac{1}{185} + \frac{1}{90.0} \quad \rightarrow \quad R_p = 60.55\Omega$.

Finally, this parallel group is in series with the 75.0Ω resistor, giving a total equivalent resistance for the circuit of $R_T = 60.55 + 75.0 = 135.5\Omega$. Using Ohm's Law, we can find the total current produced by the battery: $I_T = \frac{V_T}{R_T} = \frac{18.0\ V}{135.5\ \Omega} = 0.1328\text{A}$.

Because of the series combination, this same current flows through the 75.0Ω resistor and through the parallel combination R_p. In other words, $I_p = I_{75} = I_T = 0.1328\text{A}$.

Using this, we can calculate the voltage across the parallel group:

$V_p = I_p R_p = (0.1328)(60.55) = 8.04\text{V}$.

For resistances in parallel, the voltage across each branch is the same as the voltage across the group. In other words, $V_s = V_{90} = V_p = 8.04\text{V}$. Lastly, since we know the voltage across the 90.0Ω resistor, we can calculate the current through that branch using Ohm's Law.

This is the current we are seeking: $I_{90} = \frac{8.04\ V}{90.0\ \Omega} = 0.0893A = 89.3mA$.

A candle that is 13.0cm tall is placed 45.0cm to the left of a concave mirror. The mirror has a radius of curvature of 30.0cm. A real, inverted image of the candle is formed by the mirror. How tall is the image of the candle?

A) 3.25cm
B) 5.20cm
C) 6.50cm
D) 9.75cm
E) 26.0cm

(C) First, let's find the focal length of the mirror. It is concave, so the focal length is positive, and we know $f = \frac{R}{2} = \frac{30}{2} = 15.0\text{cm}$. Now we can find the location of the image using $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$. Plugging in the focal length and object distance: $\frac{1}{45} + \frac{1}{q} = \frac{1}{15}$ gives an image distance of $q = 22.5\text{cm}$.

Now we can calculate the magnification: $M = -\frac{q}{p} = -\frac{22.5}{45} = -0.5$. So, the image height is $h_i = Mh_o = (-0.5)(13) = -6.50\text{cm}$.

The negative sign just means it is inverted, which is given in the problem. Thus, the answer to the question of "how tall is the image" would be 6.50cm.

A particle you are seeking consists of an up quark and an anti-charm quark ($u\bar{c}$). What are the expected properties of this particle?

A) Meson, +1 charge, −1 charm, 0 strangeness

B) Meson, 0 charge, −1 charm, 0 strangeness

C) Meson, −1 charge, +1 charm, −1 strangeness

D) Baryon, +1 charge, −1 charm, 0 strangeness

E) Baryon, 0 charge, −1 charm, +1 strangeness

(B) First, we should notice that the particle contains a quark-antiquark pair. This means that the particle is a meson (baryons contain three quarks). Thus, the answer is neither D nor E.
Now, notice that there are no strange quarks/antiquarks in the particle, this means that the strangeness must be zero. Thus, C cannot be the correct answer
Finally, we know that an up quark has a charge of $+\frac{2}{3}e$, but a charm antiquark has a charge of $-\frac{2}{3}e$. Combined, these charges cancel – leaving the particle with a net charge of zero. Thus, A is not the correct answer. Only answer choice B correctly describes the properties of this particle.
By the way, this particle is cataloged as the $\overline{D}^0$ meson.

You measure the angular acceleration of a heavy door for different values of torque applied to the door. The data is plotted below. Based on this data, what is the approximate rotational inertia of the door?

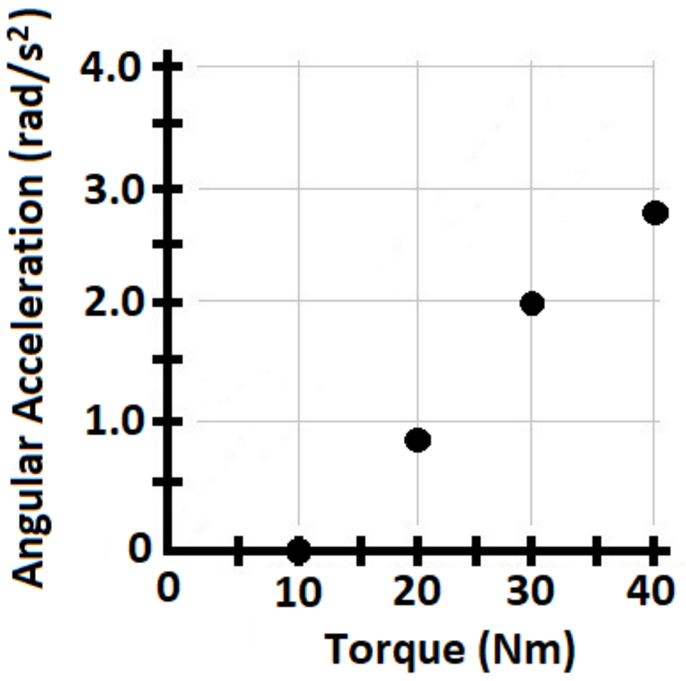
A) 5.0 kgm^2

B) 10 kgm^2

C) 15 kgm^2

D) 20 kgm^2

E) 25 kgm^2



(B) The equation relating torque to angular acceleration is $\tau = I\alpha$. This clarifies that the relationship is linear, and that we can obtain the rotational inertia from the slope of the best-fit line. The first thing you need to do is sketch in a best-fit line. This is shown to the right. Because the torque is plotted on the x-axis, and the angular acceleration is plotted on the y-axis, the slope of the best fit line will equal the inverse of the rotational inertia.

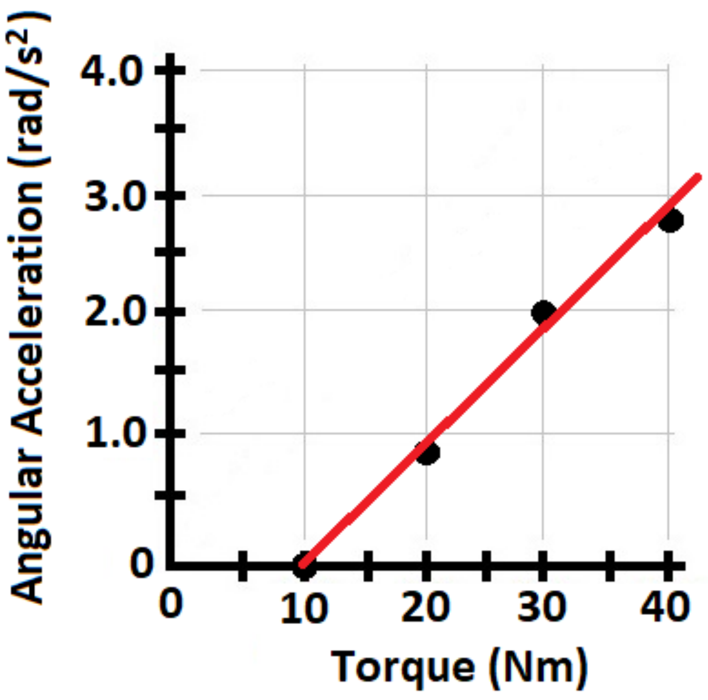
That is, $slope = \frac{1}{I}$, or $I = \frac{1}{slope}$.

To obtain the slope, I must choose two points on the best fit line. Specifically, I chose (20Nm, 0.95rad/s^2) and (40Nm, 2.95rad/s^2). This gives a slope of:

$slope = \frac{2.95-0.95}{40-20} = \frac{2.0}{20} = 0.1\ (\text{kgm}^2)^{-1}$.

Finally, this gives a rotational inertia of $I = \frac{1}{0.1} = 10\ \text{kgm}^2$.

Note: The non-zero intercept is likely due to static friction.



HINTS!!

- Watch units!
- Make diagrams with labels (free body diagrams!)
- Look for order of magnitude answers
- Work backwards
- Know your formulas
- If new to Physics: focus on a few easy topics, skip other questions.
- Easier question numbers are P05, P06, P08, P10, P12, P16
- Read the book! P01-P03 are essentially free points.
- P19-P20 are laboratory-based. These can often be figured out…