FEYNMAN SIMPLIFIED
1A: PROBLEM SET
ANSWERS

EVERYONE’S GUIDE TO THE
FEYNMAN LECTURES ON PHYSICS

BY
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This Book

This eBook contains problems to help readers of *Feynman Simplified: 1A* exercise their new-found expertise. It is divided into chapters matching those of *1A*. No problems are provided for Chapter 3 as that is a general overview of the relationship of physics to other sciences.

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Some Useful Physical Constants

Newton’s constant $G = 6.674 \times 10^{-11} \text{ m}^3/\text{s}^2 \text{ kg}$

Acceleration of gravity at Earth’s surface $g = 9.8 \text{ m/sec}^2$

mass of electron = $9.11 \times 10^{-31} \text{ kg}$

charge of electron = $-1.60 \times 10^{-19} \text{ coulombs}$

Moon: mass = $7.35 \times 10^{22} \text{ kg}$; radius $= 1.737 \times 10^6 \text{ m}$

Earth: mass = $5.97 \times 10^{24} \text{ kg}$; radius $= 6.37 \times 10^6 \text{ m}$
Answers — Chapter 1

1. Everything we see is made of atoms
2. Only nature votes
3. Observation, reason, imagination, and experiment
4. Protons, neutrons, and electrons.
5. Hydrogen, helium, oxygen, and carbon
6. Solid, liquid, gas
7. Ice melting, water freezing or boiling, gas condensing
8. The lowest possible temperature, at which heat energy is zero. -273°C / -460°F.
Answers — Chapter 2

1. (a) Repulsive, (b) 0, (c) attractive, (d) 0, (e) repulsive, (f) attractive

2. Strong, weak, electromagnetic, and gravity

3. Multiple choice:

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Answers — Chapter 4

1. In any closed system, the total amount of energy in all its forms never changes.

2. Mass, gravitational potential, electrical potential, nuclear potential, kinetic, heat, work, chemical, elastic, radiation, electric field, and magnetic field.

3. A reversible machine can complete a full cycle, in either direction, and return to its exact starting condition with zero energy input or output.

4. \( mgh; \) \( m=\text{mass}, \ g=\text{acceleration of gravity}, \ h=\text{height}. \)

5. The Total Sum of each of these quantities is conserved: energy, linear momentum, angular momentum, electric charge, baryon number, and lepton number.
Answers — Chapter 5

1. 62
2. 62
3. Time is what a clock measures.
Answers — Chapter 6

1. $gt^2/2 = 9.8\text{ms}^{-2} \times (1.5s)^2/2 = 11.025\text{m}$

2. $at^2/2 = 50\text{ms}^{-2} \times (9s)^2/2 = 450\text{m}$

3. Initial separation divided by closing speed = $80\text{m} / (8.0\text{m/s} - 0.8\text{m/s}) = 100/9$ sec. In $100/9$ sec, the tortoise runs $8.888\ldots$ meters while Achilles runs $88.888\ldots$ meters, catching him.

4. $100\text{ m/s at 45-degrees}$ is $70.7\text{m/s}$ horizontally and $70.7\text{m/s}$ vertically. Time to reach peak height: $t = \frac{70.7\text{ms}^{-1}}{9.8\text{ms}^{-2}} = 7.22\text{sec}$. Time in air = $14.44\text{sec}$; horizontal distance = $14.44\text{sec} \times 70.7\text{m/s} = 1020\text{m}$.

5. Dot product = $v_x^2 + v_y^2 + v_z^2$; Cross product of any vector with itself = 0

6. $df/dt$ is slope of the curve and $\int df dt$ is area under the curve

7. (a) $21t^6 + 2t$; (b) $-\omega\sin(\omega t)$; (c) $e^{t^2} / (2t)$

8. (a) $x^{(n+1)} / (n+1)$; (b) $e^{3x} / 3$; (c) $-\cos(x)$
Answers — Chapter 7

1. Newton’s three laws of motion.

   1. **Inertia**: object’s velocities do not change unless acted upon by external forces

   2. **Force**: \( F=ma \) or \( F=\frac{dp}{dt} \); an object’s momentum changes when acted upon by an external force

   3. **Action & Reaction**: when A exerts a force on B, B exerts an equal but opposite force on A

2. Force to hold = 9.8 newtons. Work to hold (no motion) = 0.

   Force to lift = 9.8 newtons. Work to lift = 9.8 newton-meters = 9.8 joules.

3. \( x(t) = (-10\text{cm}) \cos(t/\sqrt{k/m}) \)

4. Only relative velocities have physical significance in nature; absolute velocities do not. The laws of nature are the same in every reference frame moving at constant velocity.
1. Kepler’s laws of planetary motion:
   a. Planets orbit in ellipses with the Sun at one focal point.
   b. A planet’s radial line sweeps equal areas in equal times.
   c. The square of a planet period is proportional to the cube of its semi-major axis.

2. \[ F = \frac{GMm}{r^2}, \] where \( G \) is Newton’s gravitational constant, \( M \) and \( m \) are the masses of the bodies exerting a force on one another, and \( r \) is the distance between the bodies.

3. The locus of all points whose total distance to two foci equals the ellipses’ major axis.

4. Each minute, the Moon moves forward 61km and drops 4.8m toward Earth; the vector sum keeps the Moon in a stable orbit.

5. The Moon’s pull is stronger on the ocean on the nearest side than its average pull on Earth’s rock, which in turn is stronger than the Moon’s pull on the ocean on the far side.

6. In an infinitesimal time \( dt \), arc length traveled \( ds = vdt = r d\theta \).
   \[ d\theta = \frac{dv}{v} \]
   \[ vdt = r \frac{dv}{v} \]
   \[ \frac{dv}{dt} = a = \frac{v^2}{r} \]

7. \[ a = \frac{F}{m} = \frac{GM}{r^2} = \frac{v^2}{r} \]
   \[ GM = v^2 r = (2\pi r/T)^2 r = 4\pi^2 r^3 / T^2 \]
   \[ M = \frac{T^2}{r^3} \] with \( M \) in solar masses, \( T \) in years, \( r \) in AU

8. \[ GM = v^2 r, \] \( r = 4.19 \times 10^5 \) m + Earth’s radius \( 6.37 \times 10^6 \) m = \( 6.79 \times 10^6 \) m
   \( (6.674 \times 10^{-11} \) m\(^3\)/s\(^2\) kg)\(\times(5.97 \times 10^{24} \) kg) = \( v^2 \) \( (6.79 \times 10^6 \) m\)
   \[ v = 7658 \) m/s = 27,569 km/hr = 17,230 mph

9. \[ M \frac{T^2}{r^3} = r^3 \]
   \[ M = \frac{(1800)^3}{(38)^2} = 4.0 \) million solar masses
   This is the supermassive black hole named Sagittarius A*
Answers — Chapter 9

1. When the center of the electron’s negative charge is displaced from the nucleus’s positive charge, atoms can orient themselves so that each atom’s negative side is closer to the other’s positive side than to its negative side, and vice versa.

2. \( F = -\mu N \), where \( N \) is the force normal to the ramp, \( \mu \) is coefficient of friction, and \( F \) is anti-parallel to object’s velocity.

3. \( F=kq^2/r^2 \), with \( k=8.99 \times 10^9 \) coulombs, and \( r=1 \text{m} \), in mks units.
   \[ F=2.30 \times 10^{-28} \text{ newtons}. \]

4. \( F=Gm^2/r^2 \), with \( G=6.674 \times 10^{-11} \), \( m=9.11 \times 10^{-31} \text{kg} \), \( r=1 \text{m} \), in mks units.
   \[ F=5.54 \times 10^{-71} \text{ newtons}, \text{ smaller than the electrostatic force by } 4 \times 10^{42}. \]

5. Lorentz force. \( F = q(E + v \times B) \), force \( F \) is exerted on charge \( q \) with velocity \( v \) by electric field \( E \) and magnetic field \( B \).

6. Coriolis and centrifugal effects are observed in accelerating frames, not inertial frames.
Answers — Chapter 10

1. \( \frac{mv^2}{2} = 0.058 \text{kg} \times (2.63 \times 10^5 \text{m/hr} / 3600 \text{sec/hr})^2 / 2 = 155 \text{ joules.} \)

2. Work = 100\( \text{kg} \times 9.8 \text{ms}^{-2} \times 20\text{m} = 19,600 \text{ joules.} \) Power = Work / 5sec = 3920 watts.

3. \( U = -GMm/r, \ F = -dU/dr = -GMm/r^2 \)

4. Asteroid mass, \( m = 3000\text{kg.} \)

   \( U = \text{Potential energy} = GMm/r; \ M, \ r = \text{mass, radius of Moon or Earth} \)

   Potential energy released = \( GMm(1/r-1/\infty) \) is converted to kinetic energy

   Moon: \( U = 6.674 \times 10^{-11} \times 7.35 \times 10^{22} \text{kg} \times 3000 \text{kg} / 1.737 \times 10^6 \text{ m} = 8.47 \times 10^9 \text{ joules} \)

   Earth: \( U = 6.674 \times 10^{-11} \times 5.971 \times 10^{24} \text{kg} \times 3000 \text{kg} / 6.37 \times 10^6 \text{ m} = 1.88 \times 10^{11} \text{ joules} \)

   \( v = \text{velocity} = \sqrt{2U/m} \)

   Moon: \( v = 2377 \text{ m/s} = 8556 \text{ km/hr} = 5348 \text{ mph} \)

   Earth: \( v = 11,185 \text{ m/s} = 40265 \text{ km/hr} = 25166 \text{ mph} \)

5. By symmetry, all directions are equivalent, none is preferred. Therefore the force cannot point in any direction, so it must be zero.

   END