Engage Education Foundation

Units 3 and 4 Physics

Practice Exam Solutions

Stop!

Don't look at these solutions until you have attempted the exam.

Any questions?

Check the Engage website for updated solutions, then email practiceexams@ee.org.au.

Marks allocated are indicated by a number in square brackets, for example, [1] indicates that the line is worth one mark.

Section A – Core

Part 1: Motion in one and two dimensions

Question 1

Momentum=Mass × Velocity=$(B + 4B) \times 5 = 25B$ [2]

Question 2

Kinetic Energy=$\frac{mass \times (velocity)^2}{2}$

$\frac{31250 \times 2}{25} = 2500 = total\ mass$ [1]

Mass of barge = $\frac{4}{5}$ total mass = 2000 [1]

Question 3

Since there are no resisting forces, and there is no net force (constant speed implies no net force), the tugboat is applying no force on the barge and the barge is applying no force on the tugboat. [1 for answer, 1 for explanation]

Question 4

The time taken for the ball to bounce back up is the same as the time taken to fall down (i.e. 5 seconds). (Calculations are also fine here) [1]

The total time taken is hence 5+5=10 seconds [1]

Question 5

Since the ball is dropped from rest, $x = \frac{at^2}{2} = 125m$ [2]

Question 6

Find t=4.736s (either through solving $x = ut + \frac{1}{2}at^2$ or combining $v^2 = u^2 + 2ax$ and $v = u + at$) then sub in to horizontal $x = vt = 20.5$

[2 for time or 1 for writing the equation to be solved for time] [1 for finding distance (20.5m)]

Question 7

The correct answer is C [2].

B and D contradict conservation of momentum. A is an inelastic collision. C is potentially elastic.

Question 8

The correct answer is C [2].

B and D contradict conservation of momentum. In A, no kinetic energy remains in the system. C is potentially inelastic.

Question 9
He is not feeling weightlessness because the fans are pushing him onto the floor, resulting in a reaction force (commonly known as the normal reaction force), which is what we recognise as the weight force. Being in deep space there is no forces acting on him, he is in fact experiencing "apparent weight", while being actually weightless [1 for correct answer, 3 for explanation].

Question 10
Emma is still being affected by gravity and thus, is not truly weightless. She is experiencing "apparent weightlessness" due to the lack of a normal force [1 for correct answer, 2 for explanation].

Question 11
$v = \sqrt{ar} = 10ms^{-1}$

Question 12
$Fnet = \frac{mv^2}{r} = NormalForce + GravitationalForce,$ plus because they are acting in the same direction.

$$Normal = WeightForce = \frac{420 * 15^2}{10} - 10 * 450 = 5250N$$

Question 13
Energy is conserved. Let S be the velocity at the top, and m is the mass:

$$\frac{1}{2}mv^2 = \frac{1}{2}mS^2 + 20 * m * 10$$

Remove a factor $\frac{1}{2}m$ of from all terms.

$$v^2 = S^2 + 400$$

$$S = \sqrt{v^2 - 400}ms^{-1}$$

Question 14
Weight=$\frac{GM_1M_2}{r^2} = 167.267 = 167N$ [1]

Question 15
$a = \frac{GM_1}{r^2} = 2.22$m/s^2

$v = \sqrt{ar} = 5454.17 = 5450ms^{-1}$[1]

Momentum=$mv = 4.11x10^5$kgm/s [1]

Question 16
$T = \frac{\pi r^2}{v} = 154036.75\ seconds = 4.29\ hours$ [2]

Part 2: Electronics and photonics

Question 1
$240V \times 0.3A \times 0.2 = 14.4W$ [2]

Question 2
$240 * 0.3 * 24/1000 = 1.7$ kWh

Question 3
$14.4/V = 0.06$A

Question 4
The power not used to generate light is converted from electrical energy to heat energy [2]

Question 5
Since the diode uses 1V, and is connected in parallel, R1 uses 4V [1]

$I = \frac{V}{R} = \frac{4}{20} = 0.2A$ [1]

Question 6
$I = \frac{V}{R} = \frac{5}{20} = 0.25$A [2]

Question 7
0A [2]

No current can pass through a reverse biased diode.

Question 8
Since 0.1V>45mV, the signal is clipped. The amplifier inverts signals, so the output is hence $45mV \times -300 = -13.5V$ [2] ([1] if magnitude is correct, but sign is incorrect)

The reason for this is that the amplifier only works with its maximum voltage gain of 300 in its linear region. Input signals outside the linear region are clipped – the output is only as much as the maximum output within the linear region. When graphed, this results in a "clipped" appearance for large sinusoidal inputs [2 for explanation].

Question 9
20 degrees Celsius (from reading the graph) [1]

Question 10
R_1, the variable resistor [1]

The thermistor's resistance increases when the temperature decreases, hence its share of the voltage increases. Since we instead want the switch to receive **less** voltage at lower temperatures, it should instead be connected to the variable resistor [2].

Question 11
For the switch component in parallel across R_1, to receive 2V, the resistance of R_1 must be twice that of R_2 [1].

Across the range of temperatures (5 degrees to 20 degrees), the resistance of the thermistor varies from 500 to 2500 ohms [1].

Hence, the required resistance range of R_1 is twice this, or 1000 to 5000 ohms [2]

Part 3: Electric Power

Question 1

$V = IR$, and here voltage is the voltage loss in the wires. [1 mark if answer is wrong]

$$R = \frac{V}{I}$$

$$R = \frac{3000}{10}$$

$R = 300\Omega$ [2 marks]

Question 2

30kW ($P = IV$) [1 mark], The missing power is **converted** to **heat energy** [1].

Question 3

Either: Explain how having a much lower voltage would increase the current significantly [1] which increases the exposure to resistance ($V = IR$) [1], resulting in much power loss [1].

Or figure out the new power loss: Power generated is unaffected, hence $P = 138k * 10A = 20k * 69A,$ [1 mark if dodgy conclusion]

$V_{\text{loss}} = IR = 69 \times 300 = 20.7kV,$ [1] if dodgy conclusion.

$P_{\text{loss}} = 20.7 * 69 = 1428.3\ kW$, effectively increasing wasted power by more than a gigawatt [3]

Question 4

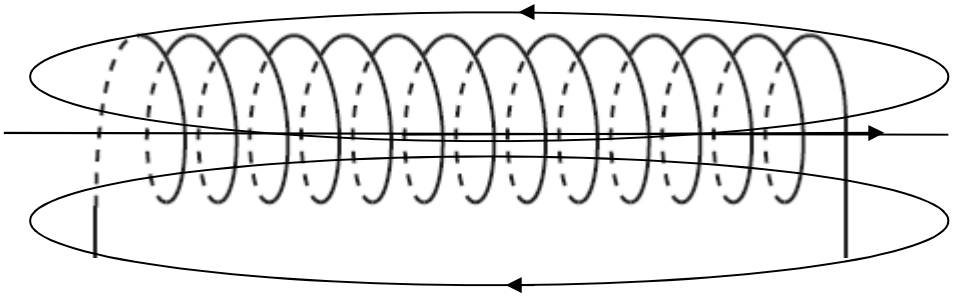
$$\frac{V_1}{N_1} = \frac{V_2}{N_2}$$

$$N_2 = N_1 \times \frac{V_1}{V_2} = 2000 \times \frac{135000}{250} = 1080000 = 1.08 \text{ million coils}$$

Question 5

AC power is easier to generate [1]. Also, only ac power is able to be converted from higher to lower voltage [1] and we need to increase voltage to reduce power loss and then reduce voltage to a more useable level to run devices [1].

Question 6

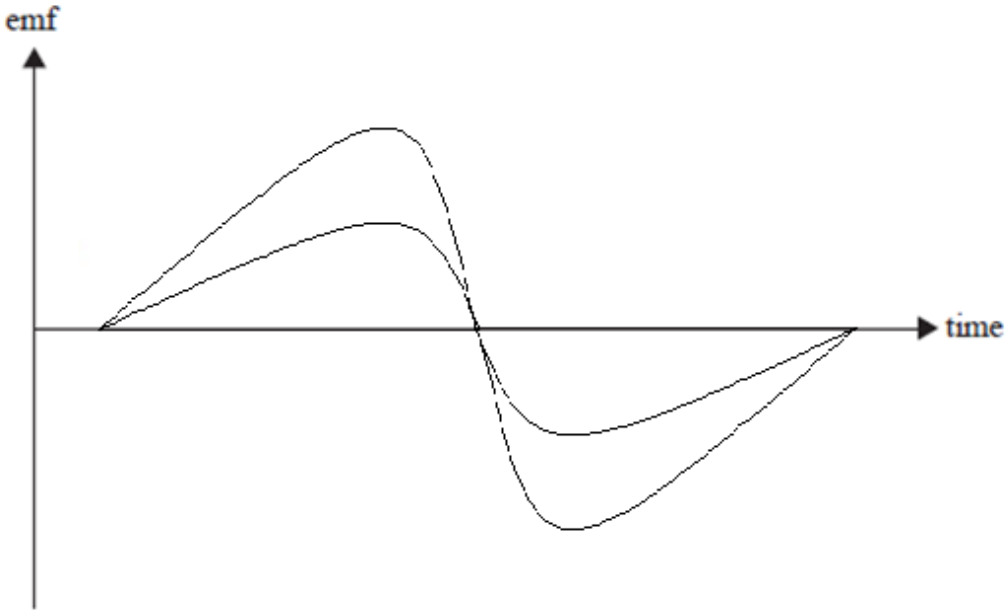


Minimum 3 non overlapping lines, 2 must be continuous circles and all must show the correct direction for the full 3 marks.

Question 7

Significantly strengthens the magnetic field, but also increases the heat generated [2].

Question 8



Two graphs changing direction at some point, one should have twice the magnitude of the other.

[2] if one graph is correct, [3] if both.

Question 9

Explain using Faraday's law: *The induced electromotive force (EMF) in any closed circuit is equal to the negative of the time rate of change of the magnetic flux through the circuit.* As the position of the magnet changes, the flux is changed and this changing flux creates an emf. [3] for both the rule and the explanation to the system.

[1] for each of the following:

Stating that the **flux** causes the **magnetic field** to change (it is the opposite).

Stating that a **current** induces an **emf** (it is the opposite).

Question 10

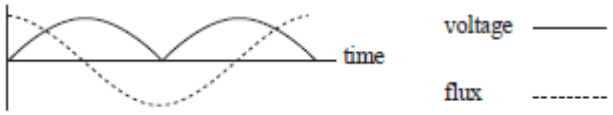
$\Phi = AB = 0.05^2 \times 0.005 = 1.25 \times 10^{-5} Wb$

Question 11

If it completes one rotation in 0.1s, it completes one quarter rotation in 0.025s. Note, as this is a split ring DC generator, the average is not zero (an AC generator would have an average of zero).

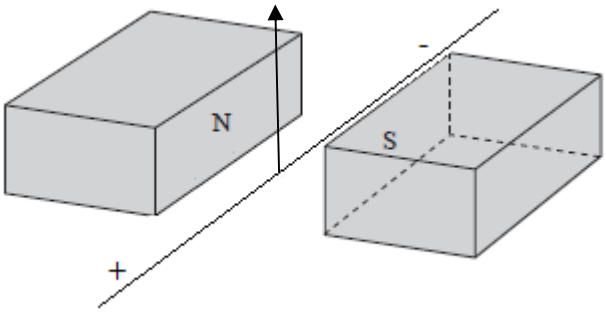
$$\frac{\Delta\Phi}{\Delta t} = 1.25 \times \frac{10^{-5}}{0.025} = 5 \times 10^{-4} Vs^{-1}$$

Question 12



Starting posistion is irrelevant, but it should show one full rotation of flux, that should be labled. Voltage should be the rate of change of flux (either negative rate of change or positive - it is a DC generator so voltage should always be positive or negative). Deduct marks for: incorrect flux, voltage changing sign.

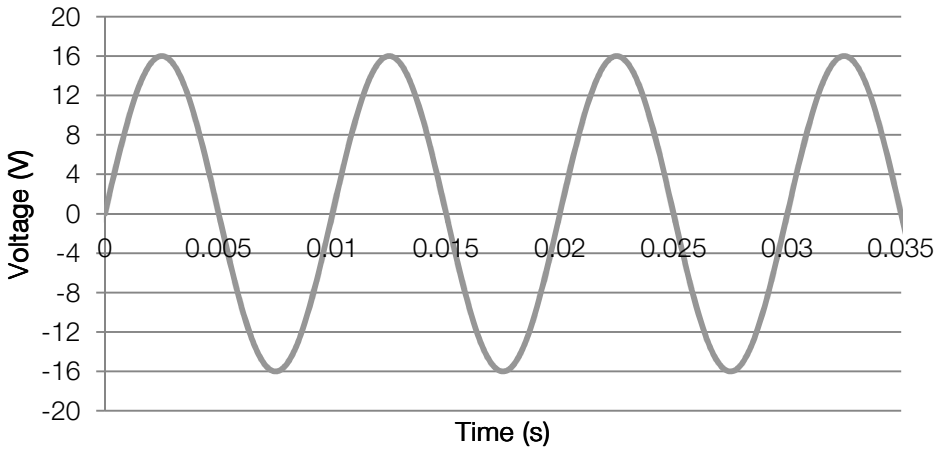
Question 13



Question 14

$F = IBL = 1.6 \times 0.15 \times .3 = 0.72N$

Question 15



At least 1 period required, double height and half the period.

Part 4: Interactions of light and matter

Question 1

The photoelectric effect *(Plank's effect or Plank's experiment are also acceptable)* supports the particle model of light, because of the observation where the energy of the emitted electrons only depends on the frequency of the photon, not the intensity of the source. This contradicts the wave model of light where the intensity should affect the energy of emitted electrons.

[1] for name, [1] for why it supports the particle model, [1] for why it opposes the wave model

Question 2

Young discovered that when shining light through slits, a pattern of light and dark bands appear and this is consistent with the wave model of light as waves tend to diffuse from any source. This contradicts the particle model because particles should travel in a straight line unless reflected.

[1] for the effect, [1] for why it supports the wave model, [1] for why it opposes the particle model.

Question 3

$E = \frac{hc}{\lambda} = 1.01\ \text{eV}$, which is a jump from the 3rd state to the 1st state. The arrow needs to be pointing down.

Question 4

The Energy of a violet photon is 3.1eV, and a red photon has 1.77eV, all transparent surfaces must not have energy states that are between 1.7-3.1eV apart thus any photon would merely pass through them and not be absorbed or reflected. *In reality the energy states of transparent surfaces such as glass have bands that are so wide that no photons in the visible spectrum have the appropriate energy to excite them.*

Question 5

There is an intercept at 5×10^{14} Hz, and at 9×10^{14} Hz, the stopping voltage is 2 V. This means the ionizing energy is 2.5eV. You could also extend the graph back to reach this conclusion.

Question 6

When $E_{k,\max} = 0, \frac{w}{f} = h, h = \frac{2.5}{5\times10^{14}} = 5 \times 10^{-15}$, so only the experimental data should be used, trying to match the actual 4.14×10^{-15} is irrelevant.

Question 7a

The current will decrease.

Question 7b

The stopping voltage will increase.

Question 8

For bright bands, the formula is $n\lambda, n = 0,1,2 \ldots$ The difference is $2\lambda = 2 \times 500 = 1000nm$. Some recognition of the formula or reasoning to get this value must be shown for full marks.

Question 9

Increasing the separation on the slits will cause the spacing on the fringes to decrease.

Question 10

For a double slit interference pattern to occur, the slit width $s, \ll \lambda$. If increasing the separation of the slits removes this property ($s = \lambda \; or \; s > \lambda$), then instead of two light sources, we effectively get two single slit diffraction patterns resulting in similar dark and light bands where each light band has smaller and less defined light and dark bands.

Question 11

$$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 * 10^{8}}{500 \times 10^{-9}} = 2.48 \text{ eV}$$

Question 12

The wavelength of macroscopic matter is in the order of $10^{-27}m$, so any pattern that is observed would be so smeared together that it would be indistinguishable from travelling straight. *Stating that the wavelength of macroscopic matter is very low and the effect on the pattern is enough.*

Section B – Detailed studies

Einstein's special relativity

Question 1

The correct answer is D. From Alice's perspective, light must travel an equal distance to reach the front and rear walls. As the speed of light is constant for all observers, the light pulse travels a shorter distance to reach the rear wall (which moves towards the pulse) than the front wall (which moves away from the pulse) in Bob's frame of reference.

Question 2

The correct answer is D. A and C are related to the result of the experiment, though not the purpose of it. B was an attempt to make the results of the Michelson-Morley experiment consistent with the existence of the ether.

Question 3

The correct answer is D. A and B are unrelated to the result of the experiment. C is true, though not immediate from the results of the experiment.

Question 4

The correct answer is A. Use $L = \frac{L_0}{\gamma}$

Question 5

The correct answer is C. Use $t = t_0\gamma$

Question 6

The correct answer is B. Total energy released is $5.49 + 5.49 + 12.86 = 23.84\ MeV$. $E = mc^2$ yields the desired result.

Question 7

The correct answer is A.

Question 8

The correct answer is C. The height of the tower is perpendicular to the swallow's direction of travel; it is not length contracted in the bird's frame of reference.

Question 9

The correct answer is C. Evaluate by comparing the change in kinetic energy in each case by using $E_k = (\gamma - 1)m_0c^2$.

Question 10

The correct answer is D. The ISS orbits the earth and the earth is rotating (and also orbiting the sun); circular motion requires acceleration, therefore the two are non-inertial frames. For the curious, look up the Foucault pendulum.

Question 11

The correct answer is A. Use $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ to show that $v = \frac{2\sqrt{6}}{5}c = 2.997 \times 10^8 m/s$ (Alternatively, make the approximation $v \approx c$). Hence, the proper decay time is $t_{decay} = \frac{87\times10^{-6}}{2.997\times10^8} = 2.90 \times 10^{-13}$. So the observed decay time is 25 times this.

Question 12

The correct answer is B. Use the fact that $E_k = \frac{\gamma-1}{\gamma} \times E_{total}$, so $E_k = \frac{24}{25} \times 7.11 \times 10^{-9} = 6.83 \times 10^{-9} J$

Materials and their use in structures

Question 1
The correct answer is B. This can be confirmed by reading the graph correctly.

Question 2
The correct answer is A. X's elastic limit is at 10, while X's fracture point is at 20. The difference is hence 10.

Question 3
The correct answer is D. The area under X's graph is greater than under Y's graph, hence it is tougher. It is not possible to determine the hardiness of a material from a stress-strain graph.

Question 4
The correct answer is C. Y's gradient in its elastic region is greater than X's gradient in its elastic region, hence it is stiffer. It is not possible to determine the roughness of materials from a stress-strain graph.

Question 5
The correct answer is C. The question asks for the higher Young's modulus, represented by the gradient of a stress-strain graph. Material Y has the highest gradient. It is possible to check this gradient by considering any point in the elastic region (except for the origin). A good candidate is at stress=5. Young's modulus=25 x 10^6 /5=5 x 10^6 Pa

Question 6
The correct answer is A. The length of a material is doubled when strain=1. This occurs for material X at 2 MPa.

Question 7
The correct answer is C. Strain=10N/$(0.002)^2$=2.5MPa. This results in a stress of 0.5, which, when applied to a length of 1m, stretches it to 1.5m.

Question 8
The correct answer is A. A tensile force of 125N results in a strain of 32.5MPa. This is still within the elastic region for Material Y, so it stretches and reverts to original length.

Question 9
The correct answer is C. Consider the torque about a wire when the cleaner stands on the edge furthest from that wire. The maximum weight that can be held is $\frac{3}{5} \times 1000 = 600N$, which converts to 60kg.

Question 10
The correct answer is D. Consider the torque about a wire when the cleaner stands on the opposite edge. The maximum weight that can be held is $1 \times 1000N = 1000N$.

Question 11
The correct answer is B. The bridge described in the question experiences both tensile and compressive forces.

Question 12
The correct answer is C. All of the components except the horizontal bar at the bottom are in tension.

Further electronics

Question 1

The correct answer is A. Use of the equation: $\frac{V_1}{V_2} = \frac{N_1}{N_2}$ so $\frac{240}{15} = \frac{720}{45} = 16$.

Question 2

The correct answer is C. Use of same equation as in question 1 gives output RMS voltage is 10.2V. To convert to peak to peak voltage, $V_{RMS} = \frac{1}{2\sqrt{2}} V_{P-P}$, which gives option C).

Question 3

The correct answer is B. After one time constant has elapsed, the potential difference across the capacitor will have decreased by 63%, so 14.8V is 37% of the original voltage. 14.8 is 37% of 40.

Question 4

The correct answer is A. Using the equation $\tau = RC$. Time constant is given, as 0.2s. The total resistance in the circuit is 400Ω, since the two resistors are connected in parallel. This gives the capacitance as $C = \frac{0.2}{400} = 5 \times 10^{-4} = 500\mu F$.

Question 5

The correct answer is D. The best estimate for the total current in the circuit immediately after the capacitor begins discharging in the circuit is given by $V_{TOTAL} = I_{TOTAL} \times R_{TOTAL}$

This gives the total current in the circuit as 0.1A. Since R_1 and the light bulb have the same resistance, this current is split evenly between the two of them so the light bulb receives 0.05A.

P=VI, its output power is 40x0.05 = 2W.

Question 6

The correct answer is C.

Question 7

The correct answer is C. A voltmeter is connected in series, and an ammeter is connected in parallel. This means that the resistance of an ideal voltmeter is infinite and the resistance of an ideal ammeter is zero. Option C gives the resistances as close as possible to this.

Question 8

The correct answer is B.

Question 9

The correct answer is B.

Question 10

The correct answer is A.

Question 11

The correct answer is B.

Question 12

The correct answer is A.

Synchrotron and its applications

Question 1
The correct answer is D.

Question 2
The correct answer is B.

Question 3
The correct answer is D.

Question 4
The correct answer is D.

Question 5
The correct answer is D.

Question 6
The correct answer is C.

Question 7
The correct answer is C. Force is proportionate to charge; acceleration is inversely proportionate to mass.

Question 8
The correct answer is B. Note the distinction between angle of incidence ϕ (the angle made by x-rays to the a line perpendicular to the crystal plane) and the angle θ used in Bragg's law.

Question 9
The correct answer is C.

Question 10
The correct answer is B.

Question 11
The correct answer is C.

Question 12
The correct answer is A.

Photonics

Question 1
The correct answer is C.

Question 2
The correct answer is D.

Question 3
The correct answer is C.

Question 4
The correct answer is A.

Question 5
The correct answer is B.

Question 6
The correct answer is C.

Question 7
The correct answer is D.

Question 8
The correct answer is B.

Question 9
The correct answer is C.

Question 10
The correct answer is A.

Question 11
The correct answer is C.

Question 12
The correct answer is B.

Sound

Question 1
The correct answer is C.

Question 2
The correct answer is D.

Question 3
The correct answer is B.

Question 4
The correct answer is C.

Question 5
The correct answer is D.

Question 6
The correct answer is D.

Question 7
The correct answer is A.

Question 8
The correct answer is B.

Question 9
The correct answer is C.

Question 10
The correct answer is A.

Question 11
The correct answer is D.

Question 12
The correct answer is B.